# FLUID INCLUSION RESEARCH

Edwin Roedder, *Editor*

Andrzej Kozłowski and Harvey E. Belkin,
*Associate Editors*

Volume 20
1987

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# Fluid Inclusion Research

Volume 20

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

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Fluid Inclusion Research
University of Michigan Press
P.O. Box 1104
Ann Arbor, MI 48106, USA

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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 above addresses. We are acutely aware of the inadequate coverage of the French literature, and would particularly welcome volunteers to make these items available to inclusion workers. 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.

# FLUID INCLUSION RESEARCH

VOLUME 20
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*ANN ARBOR*
*THE UNIVERSITY OF MICHIGAN PRESS*

ISBN 0-472-02020-X
Published in the United States of America by
The University of Michigan Press
Manufactured in the United States of America

# Preface

This publication started in 1968 as an offshoot of the Commission on Ore-Forming Fluids in Inclusions (COFFI) of the International Association on the Genesis of Ore Deposits (IAGOD). However, the publication of these volumes is independently arranged and separately financed, solely by subscriptions, on a nonprofit basis. It was started with a loan, now repaid, from the International Union of Geological Sciences.

Its purpose 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 judgements 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 1409 abstracts, citations, or annotated citations total, including 90 from the Russian, 58 from the Chinese, 83 from other languages, and 46 from theses. A major segment (137 pages) is devoted to a translation of the remainder of a Russian book by Kalyuzhnyi made by David A. Brown (Broulee, Australia) and Associate Editor Kozłowski. Other contributions of translations include R. Bodnar (Blacksburg, VA); C. Eastoe (Tucson, AZ); K. Fuzikawa (Belo Horizonte, Brazil); E. Horn (Göttingen, FRG); S. Jaireth (Canberra, Australia); I. Kulikov (Moscow, USSR); G. Landis (Denver, CO); P. Lattanzi (Firenze, Italy); Li Binglun (Beijing, PRC); H.-Z. Lu (Chicoutimi, Que.); and H.A. Stalder (Bern, Switzerland). These translations represent an enormous contribution toward achieving the aims of *Fluid Inclusion Research*. *Chemical Abstracts*, of Columbus, Ohio, has most graciously permitted the use of a few of their copyrighted abstracts, as indicated by a CA number at the end of the abstract. Other help has been received from: C.E. Barker (Denver, CO); L. Baumann (Freiberg, GDR); J. Dubessy (Nancy, France); M. Fleischer (Smithsonian Institution); A. Gize (Manchester, U.K.); J. Guha (Chicoutimi, Que.); J. Hedenquist (Taupo, N.Z.); M.J. Logsdon (Denver, CO); B.E. Nesbitt (Edmonton, Alb.); and R. Thomas (Freiberg, DDR). Many other individuals, too numerous to list here, have helped by sending books, reprints, references, and abstracts. I am deeply indebted to my coeditors Kozłowski and Belkin for their hard work, and to the U.S. Geological Survey and Harvard University for their cooperation. I also want to thank 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, 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 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 July 1 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, in exchange for partial or full translations for use in future issues. I would particularly like to receive abstracts from pertinent graduate theses and dissertations, as these are exceedingly difficult to locate.

July 30, 1988 Edwin Roedder, Editor

P.S. I have just learned that the University of Michigan Press has found it necessary to double the price of these volumes starting with this one. Although this change is unfortunate, it was made inevitable by rising costs; even so, these volumes are still inexpensive compared with other similar publications.

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# Editor's Special Request to Users

A lot of volunteers have put a lot of time into *Fluid Inclusion Research*. Now that volume 20 is done, and work on volume 21 is well underway, perhaps it is 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. *Fluid Inclusion Research* has gotten some nice compliments in the book review columns, but in these 20 years, I have gotten *almost no feedback from users as to how it is used, and in what way it might be made more useful*. 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 contemplating major revisions in both the entry selection process and 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.

July 30, 1988

Edwin Roedder, Editor, Fluid Inclusion Research
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# Notices of Meetings and Symposia

## Past Meetings

The initial conference of American Current Research on Fluid Inclusions (ACROFI) was held Jan. 5-7, 1987 at Socorro, N.M. This is the American counterpart of the European group (ECRFI), which was established some years ago (see below). ACROFI will meet every 2 years, approximately in alternation with those of ECRFI. The Socorro (first) meeting had 55 verbal papers, 20 posters, and 127 registrants, including 10 Canadians, 3 West Germans, and one each from Mexico, Sweden and Norway. In the notices section of vol. 19 it was incorrectly stated that the abstracts would be found in that volume; these are 1987 abstracts and hence are given here, in vol. 20. The name of the group has been changed, for future meetings, to PACROFI, to emphasize its Pan American nature (see Future meetings).

The Ninth European Current Research on Fluid Inclusions (ECRFI) Symposium was held 4-6 May, 1987, at University of Oporto, Portugal. The meeting had 65 verbal papers, 11 posters and 173 registrants from 23 countries. Abstracts will be found in this volume. Papers from the symposium will be published in Bull. Minéralogie.

A 3-day fluid inclusion user school, sponsored jointly by Imperial College and the Applied Mineralogy Group, was held in July, 1987, at Imperial College, London.

A meeting of Deutschen Mineralogischen Gessellschaft on Sept. 13-18, 1987 involved a special session on fluid inclusion studies. Abstracts of these presentations (mostly in German) were published in Fortschritte der Mineralogie and are given in English translation in this volume.

A meeting on "Granites and their surroundings" was held by the Societá Italiana di Mineralogia e Petrologia in Verbania, Sept. 28 - Oct. 3, 1987. A number of contributions dealt directly or indirectly with fluids associated with granites. The abstracts of all contributions to the meeting were published by Rendiconti Soc. Ital. Mineral. Petrol., vol. 42, p.316-365, and a number of full papers will appear in a forthcoming issue of the same journal.

The first national meeting on Fluid Inclusion Studies was held at the Bergakademie, Freiberg, G.D.R., 22-23 Oct. 1987, convened by Dr. O. Leeder, Dr. R. Thomas, + Dr. W. Klemn. The papers (21) from this meeting will be published in a special issue of Zeitschrift für Geologische Wissenschaften.

The Institut für Geol. und Dynamik der Lithosphäre, Univ. Göttingen, held a "Fluid Information Meeting" 29-30 Oct., 1987, at which many aspects of fluid inclusion study were covered in formal and informal discussions by over 70 participants.

The Second Chinese National Conference on Fluid Inclusion Studies and Experimental Geochemistry was held in Guiling, Guangxi Province, PRC from 16-22 Nov. 1987, with 219 scientists in attendance. There were 215 scientific papers, including 147 on fluid inclusion studies, larger than the First Nat'l Conf. (1977). The titles of these 147 papers have been translated by Dr. H.-Z. Lu and will be found under "Chinese Soc. of Min. Petr., and Geochem." in this volume.

An international symposium on petrogenesis and mineralization of granitoids was held December 7-10, 1987 in Guangzhou, PRC. Some papers will be published as a separate volume, by PRC.

The seventh annual Princeton Graduate Student Spring Workshop was held on April 8-9, 1988, on the subject "Fluids in the Earth's Crust", with 11 oral papers covering aspects of diagenesis, mid-ocean ridge fluids, metamorphic fluids, hydrolytic weakening, etc.

The V.M. Goldschmidt conference was held 11-13 May, 1988, in Baltimore. The abstracts of numerous papers of pertinence will be found in this issue.

Bicentennial Gold 88, on Gold and the Explorationist, was held 16-20 May, 1988, in Melbourne, Australia. Abstracts of the many papers involving fluid inclusions will be found in this volume.

## Future Meetings

The European Assoc. of Geochemistry will hold an Int'l Congress on Geochemistry and Cosmochemistry, Aug. 29-Sept. 2, 1988, in Paris. It will include symposia on fluid-rock interactions, new analytical techniques, isotopic tracers and ore deposits, paleothermometry, etc.

A Symposium Barite is scheduled for Kutna Hora, Czechoslovakia, Sept. 20-22, 1988, sponsored by the Geological Survey, UUG, Prague, ČSSR.

A conference on the Bohemian Massif will be held 26 Sept. - 3 Oct., 1988, in Prague, ČSSR, to include magmatic and metallogenic history of the massif up to the Mesozoic.

The Geothermal Resources Council will hold its Annual Meeting 9-12 Oct., 1988, in San Diego, CA.

The Soc. of Economic Geologists will offer a short course on Ore Deposition Associated with Magmas, Oct. 28-30, 1988, in connection with the GSA Annual Meeting in Denver, Colorado.

An international symposium on geothermal energy will be held at Kumamoto and Beppu, Japan, Nov. 10-14, 1988. For details, contact the Geothermal Research Society of Japan, c/o Geological Survey of Japan, 1-1-3 Higashi, Yatabe, Tsukuba, 305 Japan.

The 2nd Biennial Pan American Conference on Research on Fluid Inclusions (PACROFI) will be held in Blacksburg, Virginia, 4-7 Jan., 1989. Abstracts (one page) are due by Nov. 1, 1988, to Dr. Phil Brown, Dept. of Geol. and Geophy., Univ. Wisconsin-Madison, Madison, WI 53706. For other details contact Dr. R.J. Bodnar, Dept. Geol. Sci., VPI&SU, Blacksburg, VA 24061.

ECROFI X, the 10th meeting on European Current Research on Fluid Inclusions, will meet at Imperial College, London April 6-8, 1989. All inquiries should be sent to Dr. A.H. Rankin, Dept. Geol., Royal School Mines, Imperial College, London SW7 2BP, UK. Provisional booking is requested by Sept. 1, 1988.

Gold 89 in Europe, an international symposium on gold metallogeny, exploration and beneficiation will be held in Toulouse, France, May 23-25, 1989.

The International Association of Volcanology and Chemistry of the Earth's Interior will hold a General Assembly on Continental Magmatism in Santa Fe, New Mexico, June 25 - July 1, 1989. For details, contact IAVCEI/1989, Protocol Office, Los Alamos National Lab., MS P-366, Los Alamos, New Mexico 87545, USA. There will be symposia coverning many aspects of magmatic and volcanic processes.

The 6th International Symposium on Water-Rock Interaction will be held Aug. 3-12, 1989, in Malvern, UK. For details, contact Dr. W.M. Edmunds, Scty.-Gen., British Geological Survey, Wallingford, Oxon, OX10 8BB, UK.

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

The 13th Int'l Geochemical Exploration Symposium will be held in Rio de Janeiro, Brazil, Oct. 1-6, 1989.

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

The 15th General Meeting of the International Mineralogical Association will be held 12-17 July 1990, in Beijing, China. A symposium on fluid inclusions in planned.

The next meeting of the Int'l. Assoc. Genesis of Ore Deposits (IAGOD) will be held in Ottawa, Canada, in August 1990. For details contact Dr. R.W. Boyle, Geol. Survey Canada, 601 Booth St., Ottawa Ont. Canada.

# 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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# 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* |
| G | gas | Te | temperature of eutectic melting* |
| L | liquid | Th | temperature of homogenization* |
| V | vapor | Tm | temperature of melting* |
| P | primary | Tn | temperature of nucleation* |
| PS | pseudosecondary | Tt | temperature of trapping* |
| S | secondary | (...) | part of author's abstract omitted. |

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

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

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

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

# Microthermometry Abbreviations

A concensus of fluid inclusion workers on usage of microthermometric terms was reached and first printed in Vol. 10 of COFFI (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, I suggest not using subscripts.)

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

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.

# Abstracts and Citations, 1987

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. 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); all names starting with "Mc" or "St" are alphabetized as though spelled "Mac" or Saint. 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.

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ABRAJANO, T.A., STURCHIO, N., STEVENS, C. and POREDA, R.J., 1987, Methane-hydrogen gas seeps, Zambales ophiolite, Philippines: Carbon and helium isotope ratios (abst.): EOS, v. 68, p. 443.

AGAR, J.N. and LIN, J.-L., 1987, Thermal diffusion in solutions containing two or more solute species in equilibrium: The Wagner effect: J. Solution Chem., v. 16, no. 12, p. 973-983.

AHARON, Paul, 1987, On the nature and origin of strata-bound massive magnesites: A neglected problem of sedimentary geology (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 568. Author at Dept. Geol. & Geophys., Louisiana State Univ., Baton Rouge, LA 70803.

Magnesite beds up to 700 m thick from the Early Proterozoic rocks of the Rum Jungle Uranium Field, Northern Territory of Australia, offer attractive circumstances for studying the isotope systematics of magnesites and coexisting dolomites. Magnesites yield $\delta$O-18 and $\delta$C-13 compositions of 11.2 to 14.6‰ (SMOW) and 1.0 to 5.8‰ (PDB), respectively. Dolomites yield $\delta$O-18 and $\delta$C-13 values of 11.7 to 21.9‰ and -4.0 to 2.9‰ respectively, and show an O-18 enrichment gradient away from the magnesite. The oxygen isotopic fractionation in the system magnesite-water has not yet been experimentally determined but has been estimated here based on crystal chemistry arguments for the temperature range 0 to 200°C ($10^3 \ln \alpha + 2.95 (10^6 T^{-2}) - 2.16$). Fluid inclusion Th (Bone, 1983) ,used in conjunction with the isotope determinations and the magnesite-water equation above, indicate that magnesites were formed in the temperature range 100 to 200°C from fluids that became progressively enriched in O-18. The results support an epigenetic-metasomatic replacement model of dolomite by magnesite under the influence of invasive hot, Mg-rich fluids. (From the author's abstract)

AHMAD, M., SOLOMON, M. and WALSHE, J.L., 1987a Mineralogical and geochemical studies of the Emperor gold telluride deposit, Fiji: Econ. Geol., v. 82,

p. 345-370. First author at Northern Territory Geol. Survey, Dept. Mines & Energy, G.P.O. Box 2901, Darwin, Queensland, 5794, Australia.

The Emperor gold telluride deposit consists of a system of quartz-filled fractures lying on the margin of a caldera in Fiji. Textures establish five stages of quartz, two of ore minerals without quartz, and late carbonate.

Fluid inclusions in quartz indicate that the early stages formed at 300° and 250°C and later stages, from 250° to 160°C. The presence of co-existing vapor and liquid-vapor inclusions in much of the vein system indicates that the solutions were boiling. Leachate analyses and Tm ice of fluid inclusions yield an average fluid composition of $m(Na^+) = 0.32$, $m(K^+) = 0.25$, $m(Mg^{=2}) = 0.005$, $m(Cl^-) = 1.0$, and I (ionic strength) = 1.0.

The five quartz stages (except possibly the first) appear to have crystallized in isothermal conditions during periods of shallow sealing of the hydrothermal system and low mass fluid flux. Sulfide, telluride, and gold precipitation probably resulted largely from boiling and cooling along the boiling point depth curve. Changes in the fluid as a direct result of boiling include loss of $H_2$, $H_2S$, $CO_2$, and $H_2Te$, with loss of $H_2S$ the main cause of gold deposition. Assuming only partial equilibrium in the fluid indicates a more reduced fluid with a higher tellurium content.

Carbon isotope ratios of carbonates and sulfur isotope ratios of sulfides indicate a dominantly sedimentary source for carbon and sulfur, believed to be carbonate-bearing sediments underlying the host basalts. The $\delta^{18}O$ and $\delta D$ analyses indicate that the ore fluid was mainly composed of magmatic water and seawater with a possible meteoric component. (From the authors' abstract)

AHMAD, Masood, SOLOMON, Mike and WALSHE, J.L., 1987b, The formation of the quartz-gold-telluride veins of the Emperor mine, Fiji: Pacific Rim Congress 87, 26-29 August, 1987, Australasian Inst. Mining & Metallurgy, Victoria, Australia, p. 1-4. First author at Northern Territory Geol. Survey, G.P.O. Box 2901, Darwin, Northern Territory 5794.

See previous paper. (E.R.)

AI, Y., WOLFSON, I. and ZENTILLI, M., 1986, Geological and fluid inclusion study of tin mineralization associated with the Wedgeport Pluton, Yarmouth County, Nova Scotia (abst.): Marine Sediments and Atlantic Geol., v. 22, no. 2, p. 175. First author at Inst. Mineral Deposits, Acad. Geol. Sci., Beijing, China.

Cassiterite and base metal sulphides occur in veinlets in the margin of the Wedgeport monzogranite, and in vein and stratiform concentrations in calcareous meta-sediments. The sulphide cassiterite veinlets exhibit a mineralogical zonation away from the pluton: Mo and W rich within 2 km of the pluton, Sn rich about 3 to 4 km away, to Pb and Zn rich about 4 to 7 km distant.

P fluid inclusions in fluorite and quartz in greisenized veinlets within the pluton have moderate salinities and Th ~295°C and those in quartz veinlets associated with base metals as far as 5 km from the pluton have slightly lower Th. Different populations of S fluid inclusions throughout the area have Th <200°C. This is compatible with emplacement of the cassiterite mineralization following emplacement of the pluton and contact metamorphism, at P of 1000-2000 bars and 400-500°C. The S inclusions have developed during a protracted and complex post-mineralization structural history which involves shearing events, and the intrusion of dikes in Triassic-Jurassic times. (From the authors' abstract)

AÏSSA, M., MARIGNAC, Ch. and WEISBROD, A., 1987, Thermobarometric evolution of hydrothermal and magmatic processes at Echassières (Massif Central, France) from fluid inclusion data (abst.): Terra Cognita, v. 7, no. 2-3, p. 321. Authors at CRPG, Vandoeuvre-lès-Nancy, France.

At Echassières, a quartz-ferberite stockwork is crosscut by a succession (in chronological order) of granitic intrusions: 1) the Li-bearing Colette granite and 2) the lithium-fluorine-albite Beauvoir granite.

Fluid inclusions show evidences of two major hydrothermal events: First, in the stockwork, fluids associated with W are mainly nitrogen-bearing aquo-carbonic fluids. These fluids are progressively diluted by water. This dilution is associated with ore deposition. As the inclusions are not decrepitated during the subsequent intrusion of granite, the lithostatic P at that time must have been ~1500 bars (for 525°C) in the stockwork.

Composition of [later] equilibrium vapor and brines involved in the boiling process indicates a fluid P of about 840 bars at ~580°C. (From the authors' abstract)

AÏSSA, Mohammed, WEISBROD, Alain and MARIGNAC, Christian, 1987, Chemistry and thermodynamics of the hydrothermal circulations in the Échassières district: Mémoire Géol. profonde de la France, v. 1, no. 2/3, p. 335-350 (in French; English abstract). First author at Centre de Rech. Pétr. et Géoch. (C.N.R.S.), P.B. 20, 54501 Vandoeuvre Cedex, France.

Three stages [of hydrothermal evolution] have been recognized.

1. - Formation of the Bosse stockwork (wolframite-bearing quartz veins) and associated aplitic veins. The earliest aqueous fluids in the quartz veins ("COHN fluids") contain significant amounts (up to 5 mol. %) of $CO_2$, $CH_4$ and $N_2$ in various proportions. Their density is low to moderate (0.15 to 0.70). However, the lower densities (0.15 to 0.40) result from partial decrepitation of inclusions, the initial density of which was >0.70. The dilution of these early hot (450-600°C) volatile-bearing fluids by colder aqueous ones resulted in wolframite (ferberite) precipitation between 300 and 400°C.

2. - Intrusion of the Colettes granite. This granite crosscuts the Bosse stockwork and is responsible for the decrepitation of a part of the stockwork COHN inclusions. Combining the maximum T reached at that time in the stockwork sampling area (~600°C) and the limiting density (0.70) of the nondecrepitated COHN inclusions in the quartz-wolframite veins, permits an estimate of Pt of these volatile-bearing fluids (1000-1200 bars).

3. - Intrusions of the successive sheets of the Beauvoir granite. Most of the associated hydrothermal events are related to the first (B1) facies. The P of emplacement of the Beauvoir granite (~800 bars) was estimated by combining the solidus T of this granite (560-580°C) and the density of the earliest brines. These brines (25-30 wt % eq. NaCl), enriched in alkalis (Na, Li, K), Al, F, Nb, etc., unmixed from the B1 magma. An over-P built up yielding hydraulic fracturing and changing the fluid regime from lithostatic to hydrostatic. During this process, the fluid P dropped quasi-adiabatically from 700-800 bars, 500°C to 100-200 bars, 350-400°C. Consequently, the early magmatic brines unmixed into low-density aqueous vapors and high density-very high salinity brines.

These early fluids reacted with the quartz-wolframite veins of the Bosse stockwork: the quartz was partly dissolved and replaced with topaz and Li-rich micas. During this operation, a small part of the COHN fluid inclusions of the stockwork were re-entrapped into a few new-formed topaz.

Low salinity (2-6 wt % eq. NaCl) fluids of likely outer origin circulated from the bottom to the top of the Beauvoir granite at 350 to 410°C. This convective circulation is related to the presence of a source of heat that was still remaining in the center of the Beauvoir granite. Indeed these aqueous fluids mixed with the early brines, yielding in the B1 granite, fluids of salinities ranging from 10 to 60 wt % eq. NaCl. However, some of these brines, circulating in expanding fractures, were still unmixing and soon reached the saturation with respect to halite and, in some cases, sylvite. These boiling fluids probably reached the surface at that time. (From the authors' abstract)

AKANDE, S.O. and ABIMBOLA, A.F., 1987, Aspects of the genesis of the lead-zinc-fluorite-barite mineralization in the Nigerian Benue Trough, in G. Matheis and H. Schandelmeier, eds., Current Research in African Earth Sciences: Rotterdam, A.A. Balkema Inc., p. 365-369. Authors at Dept. Geol. & Min. Sci., Univ. Ilorin, Nigeria.

Microthermometric determinations were carried out on inclusions in sphalerite, quartz, calcite and fluorite in two districts. Sphalerite and quartz inclusions in the Abakaliki district have Th 117°C - 199°C (avg. 154°C). P inclusions in fluorite, calcite and quartz of Arufu-Akwana district have Th 95°C - 188°C while S hydrocarbon inclusions in calcite cluster at 83°C. There is no evidence of boiling. Assuming a cover of 600 m during ore formation a P correction of ~10°C may be required. Tm ice equal -17 to -24°C for the Abakaliki inclusions and -11 to -23°C for the Arufu-Akawana inclusions. Te average equal -60°C in both districts. Our investigation suggests that the ore solution is of basinal origin, probably from an evaporitic environment. Metals, sulfur and fluorine are likely to be of basinal source with a possible contribution of the metals and also silica from the basement. (From the authors' text)

AKANDE, S.O. and FAKOREDE, O., 1987, Geologic and fluid inclusion characteristics of the Bini Yauri and Okolom gold bearing quartz veins, Nigeria (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 1-2. First author at Dept. Geol. & Min. Sci., Univ. Ilorin, Ilorin, Nigeria.

The Bini Yauri and Okolom primary gold occurrences are localized within the Precambrian to Lower Paleozoic schist belt of Western Nigeria. This belt consists of ensialic suites of metasedimentary, metavolcanic, and intrusive sequences that are infolded into the Precambrian basement migmatite complex. Gold bearing veins in the Bini Yauri lode occur as lenticular bodies within altered mica schists at the contact zone with a granite porphyry. The Okolom veins are hosted in sheared zones within a sequence of silicified biotite gneiss, amphibolite and schist. Vein constituents in the two lodes are essentially quartz, sericite, biotite, chlorite, albite, tourmaline and calcite. These are commonly intergrown with pyrite, pyrrhotite, hematite, arsenopyrite, galena, sphalerite and argentite which altogether may constitute up to 3% of the vein system. Fluid inclusion studies in quartz reveal a bimodal distribution of Th centered on 170°C and 240°C up to a maximum of 320°C during mineral deposition. Salinity estimates for the ore fluid averages 1.5 eq. wt. % NaCl and ore precipitation appears to have taking place at a minimum estimated depth of 1.4 km.

Our study of the contacts, shape, petrology and fluid inclusion characteristics of the Bini Yauri and Okolom vein systems suggest that gold mineralization in the two lodes and in the Nigerian schist belt in general, may have evolved as a result of the metamorphic dewatering of thick sequences of sedimentary clastics, shales, and their associated volcanic rocks within the Precambrian to Lower Paleozoic basement complex. At least two stages of remobilization and reconcentration of vein constituents may have taken place during succeeding thermotectonic events. (Authors' abstract)

ALBINSON, Tawn, 1987, Thermal structure and its relation to ore body distribution in some epithermal systems in Mexico (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Author at Grupo Catorce, Paseo de la Reforma No. 51 Piso 16, 06030 Mexico, D.F.

Detailed and reconnaissance fluid inclusion T and salinity analysis has been carried out on a number of Mexican Ag-Au and Ag-Pb-Zn bonanza type vein systems. These include Sombrerete and Colorada (Zacatecas), Real de Catorce (San Luis Potosi) and Tayoltita (Durango). Within these deposits, ore body distribution is generally characterized by a combination of significant lateral extent (several kilometers) and limited vertical intervals of mineralization (200-700 meters), leading to ribbon like "ore horizons" within the host structures. The structural and stratigraphic characteristics of the deposits do not explain adequately the general morphology of mineral distribution in these systems.

Fluid inclusion Th for the various ore zones investigated fall between 150°C and 330°C. However, ranges within individual deposits are more restricted; Sombrerete (150°C - 260°C), Colorada (210°C - 315°C), Catorce (225°C - 330°C) and Tayoltita (190°C - 320°C). Salinities of the inclusion fluids are generally below 6 eq. wt% NaCl but may reach values as high as 14 eq. wt% NaCl.

The occurrence and intensity of boiling in the ore fluids, as recorded by the presence of vapor-dominated inclusions, appears to be a critical control for the deposition and distribution of ore in most systems. Significant evidence of boiling appears to correlate with marked vertical thermal gradients (7.5°C to 12°C/100 meters), and more restricted ore intervals (200-450 meters). Absence of boiling coincides with low vertical thermal gradients (less than 1°C/100 meters) and greater vertical extent of ore grade mineralization (+600 meters). Furthermore, it appears that boiling systems are characterized by more abrupt and better defined downward termination of ore whereas non-boiling systems exhibit gradual downward impoverishment of mineralization. (Author's abstract)

ALDERTON, D.H.M. and SUDHARTO, R.T., 1987, Mineralization at Gunung Limbung, West Java: A fluid inclusion and geochemical study: Pacific Rim Congress 87, 26-29 August, 1987, Australasian Inst. Mining & Metallurgy, Victoria, Australia, p. 5-8. First author at Geol. Dept., Royal Holloway & Bedford New College (London Univ.), Egham, Surrey TW20 OEX, UK.

Sulphides of Cu, Pb, and Zn occur in quartz veins associated with a quartz monzodiorite stock at Gunung Limbung, West Java. The mineralization was polyphase and occurred at depths of less than 1 km. Wall-rock alteration is extensive and typically consists of an outer zone of propylitization and an inner zone of potassic (K-feldspar-rich) alteration. Sporadic argillic alteration is probably of supergene origin. A variety of elements were mobilized during hydrothermal alteration and Ba in particular shows marked enrichments in the potassic zone. Fluid inclusions in the vein quartz indicate that T of mineralization were within the range 250-390°C and that two fluids with differing chemistry were involved. One fluid had high Ca/Na ratios and a low overall salinity, the other had low Ca/Na ratios and a moderate salinity. The former is probably of meteoric derivation, whilst the latter had a magmatic origin. Precipitation of the sulphides was probably brought about by mixing of these fluids. (Authors' abstract)

ALLARD, Patrick, DELIBRIAS, Georgette and LABEYRIE, Jaques, 1987, Carbon isotopes in volcanic gases from La Soufriere of Guadaloupe, Lesser Antilles: A contribution to volcano geochemical monitoring (abst.): Hawaii Symp.

on How Volcanoes Work, Abst. Volume, Hilo, Hawaii, Hawaiian Volcano Observatory, p. 11. Authors at Centre des faibles Radioactivites, CNRS, 91190 Gif/Yvette, France.

A now famous seismo-volcanic crisis occurred in 1975-1977 at La Soufriere of Guadaloupe, leading to the evacuation of 45,000 people for 4 months. Although the eruptive events remained of strictly phreatic nature, their source mechanism may have included the upward migration of new magma and hot gases from below. In order to detect a possible change in the source of the Sourfriere gases with time, we carried out isotopic analysis of carbon dioxide in 30 gas samples collected between 1975 and 1981, before, during and after the crisis. Carbon dioxide was the major anhydrous gas species and, because of its low solubility in magma at moderate depth, it can be reliable tracer of underground degassing.

Apart from short-term and limited variations, no long-term evolution was observed in the $^{13}C/^{12}C$ ratio of the $CO_2$, which thus indicates that the eruptive events were not linked with the participation of different $CO_2$ sources. The average $\delta^{13}C$ value, -3.6 + 0.3‰ vs PDB, is compatible with magmatic origin, although higher than typical mantle values (≃ -6‰). Surprisingly, however, both the eruptive and post-eruptive $CO_2$ were found to contain a significant and similar amount of $^{14}C$ (≃ 10% of a modern activity). An atmospheric $^{14}C$-source being excluded by the low air content of the samples ($CO_2/N_2 > 100$), only an organic contribution, from either ancient vegetal matter buried by former eruptions or/and modern organic carbon dissolved in groundwaters, can explain the results. Depending on the actual age of this organic and from its $\delta^{13}C$ (≃ -25‰), the inorganic $CO_2$ complement should amount to at least 90% of the total, with a $\delta^{13}C$ of -1.2‰. This is not far from $\delta^{13}C$ for carbonates. However, the presence of mantle helium ($R/R_A = 8$) in the post-eruptive gases suggests that mantle $CO_2$ could make a part of the inorganic fraction (between 15 and 45% of the total). (Authors' abstract)

ALMEIDA, A. and NORONHA, F., 1987, Fluid associated with W and Au-Ag deposits of the Mirandela area, NE Portugal: An example of peri-batholitic zonation (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 3-4. Authors at Centro de Geol. da Univ. do Porto, 4000 Porto, Portugal.

W and Au-Ag ore deposits in Mirandela (Northern Portugal) are spatially associated with leucogranites belonging to a syn- to late-tectonic composite batholith. The leucogranite outcrops exclusively at the western extremity of the batholith and in a small apex at Pedra-Luz to which the quartz veins exploited for W (Pedra-Luz and Lombo da Veiga) and Au-Ag (Freixeda) are spatially related. The ore-bearing quartz veins have similar strikes ranging from N 40°E to N 60°E and occur enclosed in Lower Silurian metasedimentary terrains made up of quartzose phyllitic rocks frequently accompanied by black shales. The metasedimentary formations have undergone the effect of at least two folding episodes responsible for a N 120°E, 25°E schistosity (S1) and a N 130°E sub-vertical fracture cleavage, respectively (Ribeiro, 1974) [references given in original].

A zonal arrangement around the batholith is marked by the relative abundance of certain minerals (viz.: scheelite, molybdenite, stannite, galena and sulphosalts) as well as by arsenopyrite nonstoichiometry indicating a temperature gradient (Maurel-Palacin, 1985 and Maurel-Palacin et al., in press).

Microthermometry and Raman spectrometry analysis of fluid inclusions in the ore-bearing quartz veins show that in Pedra-Luz and Lombo da Veiga scheelite-bearing veins the fluids are rich in almost pure $CO_2$ ($ZCO_2$, 95-100%; $XCO_2$, 13-28 mole%) but no $CO_2$ has been detected at Freixeda. However, small amounts of $CH_4$ and $N_2$ have been detected in the latter deposit ($ZCH_4$ = 62%; $XCH_4$ = 0.42 mole%; $ZN_2$ = 38%; $XN_2$ = 0.26 mole%).

The fluids of the three ore deposits have low density and salinity: Pedra Luz, d = 0.64; 4 wt% eq. NaCl; Lombo da Veiga, d = 0.69; 3.5 wt% eq. NaCl; Freixeda, d = 0.71; 38 wt% eq. NaCl. The corresponding fluid P are close to 1000,600 and 200 bar. The probable trapping T range 375-400°C at Pedra-Luz and Lombo da Veiga (Th = 340°C and 300°C respectively) and 330-375°C at Freixeda (Th = 280°C).

Assuming that the fluid phase was in equilibrium with the graphitic material of the metasedimentary rocks, $fO_2$ was estimated between $10^{-20}$ and $10^{-21}$ bar close to the Ni-NiO buffer, on the basis of the equilibrium $C + O_2 \rightleftharpoons CO_2$. At Freixeda a lower $fO_2$ is seen, closer to the QFM buffer, characterizing a more reducing environment.

It was then possible to complete a model of mainly lateral zonation around the Pedra-Luz apex, revealed by decreasing $CO_2$, $fO_2$ and fluid pressure, a small increase of the bulk density and the presence of $CH_4$ instead of $CO_2$ probably controlled by the occurrence of graphite. (Authors' abstract)

AMUNDSEN, H.E.F., 1987, Evidence for liquid immiscibility in the upper mantle: Nature, v. 327, p. 692-695. Author at Mineral.-Geol. Museum, Sars gt. 1, 0562 Oslo 5, Norway.

Liquid immiscibility, the separation of magmas into two or more immiscible liquid phases, has been shown to occur both experimentally and in nature, but this phenomenon has received only limited attention in modelling magmatic processes, as known cases of liquid immiscibility are generally restricted to magma compositions encountered during late stages of crystal fractionation, and relatively shallow crustal levels. Here I report the results of a study of trapped quenched liquids in spinel lherzolite xenoliths; these are fragments of upper mantle material carried to the surface in volcanic rocks. These xenoliths carry quenched coexisting basaltic, carbonatitic and volatile-rich ultramafic liquids, showing the existence of a previously unknown field of three-liquid immiscibility. This type of immiscibility occurs in primitive volatile-rich magma compositions at upper mantle to crustal levels. Furthermore, metasomatic growth of amphibole ± apatite ± phlogopite in the lherzolites is associated with introduction of carbonatitic and volatile-rich ultramafic liquids, indicating that such liquids may play an important role in mantle metasomatism. (Author's abstract)

ANDERSEN, T., AUSTRHEIM, H. and BRIDGWATER, D., 1987, P-T and fluid evolution of the Angmagssalik "charnockite" complex, SE Greenland (abst.): Abstracts, NATO Advanced Research Workshop, Fluid movements, element transport, and the composition of the deep crust, Lindås, Norway, 18-24 May, 1987 (unpaginated). First author at Min. Geol. Mus., Oslo, Norway.

The fluid evolution of the Angmagssalik "charnockite" complex can be outlined from a study of fluid inclusions in minerals. All rock types studied contain one or more phases containing abundant inclusions of carbonic fluids. Quartz in the melagabbro contains primary inclusions of pure $CO_2$, with abundant silicate and carbonate crystals (probably accidentally trapped inclusions). These inclusions do not show melting point depressions, and have liquid Th in the range 0 to -20°C. $CO_2$ melting at the triple point is also characteristic for inclusions in plagioclase in the melagabbro and in the anorthosite veins. The inclusions in plagioclase are distinctly S, and have higher densities than the P inclusions in quartz (Th ranging down to -30°C). S carbonic fluid inclusions in the country rock gneisses melt at -57 to -60°C, and range in Th from +10°C (garnet) to -10°C (quartz, plagioclase).

Our observations suggest an interpretation of the evolution of the fluid regime in the complex: Primary magmatic rocks crystallized in the middle-lower crust (P: 6-8 kbar, T: 1000-1100°C). The higher density, S inclusions reflect isobaric cooling to ca. 700°C. During this cooling process, $CO_2$ existed as a free fluid phase in the intrusive rock and in the anorthosite veins. This fluid phase migrated into the country-rock gneisses, where they mixed with $CH_4$ and/or $N_2$-bearing fluids to give inclusions with melting point depressions. (From the authors' abstract)

ANDERSEN, T., GRIFFIN, W.L. and O'REILLY, S.Y., 1987, Primary sulphide melt inclusions in mantle-derived megacrysts and pyroxenites: Lithos, v. 20, p. 279-294. First author at Mineral.-Geol. Museum, Sars Gate 1, 0562 Oslo 5, Norway.

Inclusions of sulphide are common in clinopyroxene megacrysts and Al-augite pyroxenite xenoliths in undersaturated continental basalts. The sulphides are typically FeS with 2-4 wt.% Ni and minor Co and Cu. The morphology of the inclusions and their relations to growth planes in the pyroxenes show that the sulphides were trapped as drops of immiscible sulphide melt. These nucleated on the surfaces of crystals growing from magmas, and are thus primary inclusions. Compound $CO_2$-sulphide inclusions are evidence for the coexistence of three immiscible fluids-silicate melt, sulphide melt and supercritical $CO_2$. Hollow tubular to spherical sulphide inclusions result from the trapping of sulphide melts with up to 10 wt.% $CO_2$ in solution. Primary $CO_2$ inclusions have densities of 1.07-1.189 g $cm^{-3}$; this corresponds to trapping pressures of 10-15 kbar at 1000-1200°C and confirms the origin of the megacrysts in the uppermost mantle. A wide variety of secondary inclusions formed by the decrepitation of the sulphide-$CO_2$ inclusions during entrainment and transport by the host basalt. Clinopyroxene megacrysts containing sulphide inclusions show a very narrow compositional range, compared to the worldwide population of Al-augite megacrysts. This suggests that S-saturation was reached at a similar stage of mantle fractionation in similar magmas. Dumping of S (and Ni, Co, Cu) in the uppermost mantle is an important part of the overall process of mantle metasomatism. (Authors' abstract)

ANDERSON, A.J., CLARK, A.H., MA, X.-P, PALMER, G.R., MACARTHUR, J.D., BODNAR, R.J. and ROEDDER, E., 1987, In situ elemental analysis of fluid inclusions using PIXE and PIGME (abst.): GAC/MAC Program with Abstracts, v. 12, p. 21. First author at Dept. Geol. Sci., Queen's Univ., Ontario.

A proton microprobe using the Queen's University Van de Graaff accelerator has been applied to the analysis of synthetic and natural fluid inclusions. Proton-induced X-ray and gamma-ray emission (PIXE and PIGME, respectively) provides a non-destructive means of analyzing selected fluid inclusions within a polished section. Detection limits, for a given operating condition, vary with the composition of the host mineral, the depth of the inclusion beneath the surface, the dimension of the fluid inclusion traversed by the proton beam, and the yield of X-rays and gamma-rays from the elemental constituents of the inclusions.

Using a 4 MeV proton beam of less than 0.5 nA intensity to minimize sample heating, and a spot size of 15 μm, we have detected gamma- and X-rays produced from compositionally-diverse fluids and solids within quartz capillaries with a 10 μm wall thickness, as well as within synthetic and natural fluid inclusions in quartz. Gamma-ray emissions allow analysis of light elments such as Li, Be, B, F, Na and Mg, whereas PIXE can be used to analyze the heavier elements. Determination of the inclusion composition requires analysis of the host mineral overlying the inclusion, and in the inclusion-free surroundings. (Authors' abstract)

ANDERSON, A.T., Jr., 1987, Eruption durations inferred from hourglass inclusions (abst.): Int'l. Union of Geodesy & Geophys., XIX Gen. Assembly, Vancouver, Canada; Aug. 9-22, 1987; Abstracts, v. 2, p. 400. Author at Univ. Chicago, Chicago, IL 60637, USA.

Hourglass inclusions are reentrants of glass connected to the rim of a crystal by a narrow passage. The passage acts as a constriction through which melt must flow if vesicles within the inclusion are to grow. Flux of melt through the passage may be estimated according to pipe flow if the melt viscosity and P drop are known. The vesicles record the amount of flow and allow estimation of both the amount of decompression and the duration of flow.

About 1% of the phenocrysts of quartz from the Bishop Tuff, Calif., contain hourglass inclusions. The glass in the hourglass inclusions is less devitrified and poorer in Cl and $H_2O$ than the glass in enclosed inclusions. The hourglass inclusions are round to subround whereas the enclosed inclusions are subangular to angular (negative crystals). The volume fraction of vapor in the hourglass inclusions ranges from 0.015 to 0.6, compared to less than 0.005 in the enclosed inclusions. The range in volume fraction of vapor suggests that the hourglass inclusions did not attain equilibrium at the time of quenching. Four of six crystals with hourglass inclusions from a single block of pumice from the late-extruded Mono Lobe yield minimum durations of decompression on the order of a few days. The calculations assume a viscosity of $10^8$ poise and an instantaneous P drop of 500 atm consistent with the vesicularity of the hourglass inclusions and analyses of $H_2O$ in the hourglass glass. Because P drop likely was gradual and because melt at the orifice will be more viscous owing to larger loss of $H_2O$, the duration of evacuation probably was longer. However, consistent results for inclusions with 1 to 30 vol. % of vapor suggest that the total duration probably did not exceed about 10 times the best fit value of about 5 days. The removal of about 2 km of overlying magma is implied by the decompression and is consistent with Bailey's field data constraining the amount of caldera subsidence. Thus it seems plausible to associate the duration of emptying of the hour-glass inclusions with the duration of the eruption which produced the Bishop Tuff and Long Valley Caldera. Extrusion of the Bishop Tuff in a matter of days is consistent with what is known and inferred about other major ash-flow tuff producing eruptions. (Author's abstract)

ANDES, J.P., Jr. and McKIBBEN, M.A., 1987, Thermal and chemical history of mineralized fractures in cores from the Salton Sea Scientific Drilling Project (abst.): EOS, v. 68, p. 439. Authors at Dept. Earth Sci. & Inst. Geophys. & Planet. Physics, Univ. California, Riverside, CA 92521.

Eight distinct zones of vertical to sub-vertical ore-bearing fractures were intersected in the State 2-14 drill hole at depths (ft) of 1984-1989 (FZ-1), 2997-3024 (FZ-2), 4243-4249 (FZ-3), 4643-4718 (FZ-4), 5575-5576 (FZ-5), 8133-8136 (FZ-6), 9095-9096 (FZ-7), and 9426-9428 (FZ-8). Fluid inclusion data yield mean trapping temperatures (°C) of 274 (FZ-1), 250 (FZ-2), 307 (FZ-3), 295 (FZ-4), and 326 (FZ-7). NaCl equivalent salinities (wt. %) are 12, 16, 19, 22 and 27, respectively. FZs 1, 3 and 6 are completely sealed and contain the paragenesis epidote + adularia ± ankerite, calcite, sphalerite + pyrite + chalcopyrite ± galena ± galena ± pyrrhotite. They represent an early vein set formed under a relatively high geothermal gradient. Sphalerite compositions and the presence of pyrrhotite imply relatively reducing conditions. Wall rock alteration is minimal. FZs 2, 4, 5 and 7 are open and contain the paragenesis epidote + quartz ± chlorite, calcite, chalcopyrite + pyrite ± sphalerite ± galena, hematite. They represent a later vein set formed under a relatively lower geothermal gradient. The presence of hematite implies relatively oxidizing conditions. Wall rock alteration is pervasive.

The bimodal paleo-geothermal gradients defined by both vein sets are higher than the maximum temperatures yet measured down hole. If they are representative of paleo-reservoir temperatures, then the upper 1 km of this portion of the geothermal system has cooled by 40-100°C. Fluids in this portion of the system have become significantly more oxidized through time. Likely causes of these changes include migration of heat sources and influx of cool, oxygenated brines formed during stages of lake formation. (Authors' abstract)

ANDREW, A.S. and BAKER, E.M., 1987, The nature and origin of the ore-forming fluid in the Kidston gold deposit, North Queensland: Pacific Rim Congress 87, 26-29 August, 1987, Australasian Inst. Mining & Metallurgy, Victoria, Australia, p. 13-16. First author at CSIRO Div. Mineral Physics & Mineral., PO Box 136, North Ryde, NSW, 2113, Australia.

The Kidston orebody is a kilometer diameter breccia pipe of Permo-Carboniferous age associated with rhyolitic dikes.

Fluid inclusion and stable isotope results show the importance of moderate-high T, saline, magmatic fluids in the early stage mineralization and in the brecciation of the pipe. Later periods of alteration, accompanied by Au deposition, are associated with fluids only slightly depleted in $^{18}O$ relative to magmatic waters, unlike the strongly $^{18}O$-depleted meteoric water typically found in hydrothermal Permian and Carboniferous deposits of eastern Australia. The $\delta^{18}O$ values and low salinities in fluid inclusions suggest the fluid may have formed from vapor condensation from a magmatic fluid.

Fluid inclusion data and alteration assemblages define the prevailing chemical conditions. Au transport under these conditions would have been primarily as a bisulfide complex. (From the authors' abstract)

See also Baker, this volume. (E.R.)

ANIL, Mesut and YAMAN, Servet, 1985, Fluid inclusion studies on the Arapucandere (Yenice-Canakkale) Pb-Zn mineralization: Yerbilimleri Bull. Earth Sci. Application & Res. Centre of Hacettepe Univ. [Turkey], v. 12, p. 81-91 (in Turkish; English abstract). Authors at Cukurova Univ., Muhendislik-Mimarlik Fak., Jeoloji Muhendisligi Bol., Balcah-ADANA.

The mineralization in arkoses and diabases is seen as veins and pockets. In vein-type ores galena is the dominant mineral. Paragenesis consists of galena, sphalerite, chalcopyrite, pyrite, quartz and calcite. Quartz is rich in two-phase fluid inclusions, and show Th of about 250°C. Cryoscopic data show that the liquid contains 1-2% NaCl. These values suggest that meteoric water has taken an active part during mineralization. Th/Tm relations show that similarities exist between some vein type hypothermal or mesothermal Pb-Zn deposits and the mineralization in this area. (From the authors' abstract)

ANOVITZ, L.M., HEMINGWAY, B.S., WESTRUM, E.F., Jr., METZ, G.W. and ESSENE, E.J., 1987, Heat capacity measurements for cryolite ($Na_3AlF_6$) and reactions in the system Na-Fe-Al-Si-O-F: Geochimica Cosmo. Acta, v. 51, p. 3087-3103. First author at Dept. Geosci., Univ. Arizona, Tucson, AZ 85721, USA.

SEM studies of abundant fluid inclusions in Ivigtut, Greenland, cryolite show some crystals of chiolite ($Na_5Al_3F_{14}$). (E.R.)

ANSDEL, K.M., 1985, Fluid inclusion and stable isotope study of the Tom Ba-Pb-Zn deposit, Yukon Territory: MS thesis, The University of Alberta, 134 pp. (Continued)

The Tom Ba-Pb-Zn deposit is a typical, sediment-hosted, stratiform, exhalative, massive sulfide deposit, hosted by carbonaceous mudstones, turbiditic sand-banded mudstones, and debris flow chert pebble conglomerates of the Upper Devonian Earn Group. The deposit consists of a lens of massive sulfides (pyrrhotite-galena-Fe-rich sphalerite-ankerite-chalcopyrite) which passes vertically and laterally into laminated sulfides (Fe-poor sphalerite-galena-pyrite-barite-chert). In the footwall units below the massive sulfides is an area of ankerite, and quartz veining, interpreted by Carne (1979) to represent the feeder zone for the mineralizing fluids. Ankerite veins are related to mineralization, whereas fluid inclusion and stable isotope data suggest that the quartz veins formed during one of the post-mineralization, deformation events.

Th of ankerite and quartz range from 125° to 335°C, due to variable leakage from all inclusions during deformation. Leakage increases the measured Th and so the average ankerite Th (258°C) represents an upper limit for the T of the mineralizing fluid. However, fluid inclusion analysis allows distinction of the mineralizing fluid from the deformation fluid on the basis of inclusion type and salinity. Ankerite was deposited from an aqueous solution of salinity 9.1 ± 1.3 wt.% NaCl eq. The $CO_2$ content of inclusions within a given quartz grain are usually similar, but there are distinctive inter-grain, and inter-sample variations. This is a function of local variations in the proportion of secondary ankerite cement in the adjacent rocks.

The lack of variation in the oxygen isotopic compositions of mudstones, and <2 µm mineral fractions, plus the absence of an alteration halo around the mineralization, implies that the extent of interaction between the mineralizing fluid and the country rock was small. This may be due to a low water/rock ratio, a high fluid flow rate and/or a low T (~150°C) for the mineralizing fluid. Pure clay samples were not obtained, but a depletion in $^{18}O$ in kaolinite-rich samples does suggest that the isotopic composition of the kaolinite is a result of interaction with the hydrothermal fluid.

The isotopic compositions of the ankerite- and quartz-forming fluids were calculated for T from 100° to 250°C, by assuming equilibrium fractionation between the minerals and water. At a given T, the isotopic composition of the quartz-forming fluid is enriched in $^{18}O$ relative to the ankerite-forming fluid. Both fluids were probably formation waters.

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

APODACA, L.E., BROWER, K. and NORMAN, D.I., 1987, Hydrocarbon species in fluid inclusions from epithermal districts (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 5. Authors at New Mexico Inst. Mining & Tech., Socorro, NM 87801, USA.

Gaseous species in fluid inclusions analyzed by a mass spectrometer from epithermal districts indicate bulk composition consisting of $CO_2$, $H_2S$, $H_2$, $N_2$, $CH_4$, CO, minor amounts of Ar and He with $C_2$ through $C_7$ organic compounds. Typically the total amount of the gaseous species is about 1 mole % with the remaining constituent being water.

The organic species occurring in these inclusions are measured by the use of a gas chromatograph-mass spectrometer. The organic species are ethylene, propylene, butane, three isomers of $C_4H_8$, six isomers of $C_5H_{10}$, cyclopentane, cyclopentene, six isomers of $C_6H_{12}$, methylcyclopentene and

$C_7H_{14}$. Predominance of alkenes over alkanes occurs in these fluid inclusions.

The gas sample analyzed for organics was obtained by thermal decrepitation of rock at 500°C in vacuum. Decrepitation at 350, 400 and 450°C as well as crushing showed the same hydrocarbon components indicating little chemical alteration of the organic compounds by thermal decrepitation.

The source of the organic constituents in these epithermal deposits is not known with certainty. Comparison with hydrocarbons from petroleum or natural gas show straight chain saturated character unlike the unsaturated organic species in the fluid inclusions. The pyrolysis of oil shale seems more promising, containing 35% olefins and naphthenes, but the alkanes are more abundant than the alkenes. Pyrolysis of sucrose in water and beer concentrate both produced $C_3H_6$ and $C_4H_8$. The possibility that hydrocarbons in fluid inclusions formed by pyrolysis of carbohydrate material or "humic acid" exists. (Authors' abstract)

APOLLONOV, V.N., 1986, Br and Rb in sylvite of the Verkhne-Kama deposit and some problems of genesis: Vestnik Moskovskogo Univ. Geologiya, v. 41, no. 2, p. 42-48 (in Russian; translated in Moscow Univ. Geol. Bull., p. 41-47).

APPLIN, K.R. and HICKS, B.D., 1987, Fibers of dumortierite in quartz: Am. Mineral., v. 72, p. 170-172. Authors at Dept. Geol., Univ. Missouri-Columbia, Columbia, MO 65211, USA.

Etching occurred along fiber contacts with quartz; similar natural etching might lead to some fluid inclusions along other fibrous inclusions in quartz? (E.R.)

ARAI, Shoji and TAKAHASHI, Natsuko, 1987, A kaersutite-bearing dunite xenolith from Ichinomegata, northeastern Japan: The J. of Japanese Assoc. Mineral., Petrol. Econ. Geol., v. 82, no. 2, p. 85-89 (in Japanese; English abstract).

The dunite has suffered from metasomatic alteration which led to the subsolidus crystallization of titanian pargasite and kaersutite and the entrapment of fluid inclusions into olivine and spinel. Amphiboles in this rock are far more enriched in Ti than those in any ultramafic xenoliths ever documented from Ichinomegata. The metasomatizing fluid may have been enriched in Ti and Na over K, implying the consequence of some intra-plate magmatism. (From the authors' abstract)

ARCULUS, R.J. and DELANO, J.W., 1987, Oxidation state of the upper mantle: Present conditions, evolution, and controls, in Mantle Xenoliths, P.H. Nixon, ed.: John Wiley & Sons, p. 589-598. Authors at Dept. Geol. & Mineral., Univ. Michigan, 1007 C.C. Little Bldg., Ann Arbor, MI 48109, USA.

Mineral parageneses in mantle-derived peridotites, thermodynamic calculations of heterogeneous phase equilibria, fluid inclusions, developments with oxygen-specific solid electrolytes, and modelling of siderophile element abundances all suggest that there is at present a heterogeneous distribution of redox states in the Earth's upper mantle. Values of oxygen fugacity seem to range between levels equivalent to the iron-wüstite buffer and somewhat more oxidized than the fayalite-magnetite-quartz buffer. Appropriate redox mechanisms have been proposed for both reduction and oxidation of the upper mantle including disparate diffusivities of potentially mobile volatile components and the introduction of oxidized subducted lithosphere. (From the authors' abstract)

Reviews the evidence concerning the composition of $CO_2$ inclusions (p. 592) and the depth ranges involved. (E.R.)

ARCULUS, R.J. and KUSHIRO, I., 1987, Mt. Fuji - a big, basaltic, explosive and fast-growing stratovolcano in Honshu, Japan (abst.): EOS, v. 68, p. 1521. First author at Dept. Geol. Sci., Univ. Michigan, MI 48109, USA.

Mt. Fuji is the tallest mountain in Japan (3776 m) and one of the largest stratovolcanoes in the world with a basal diameter of about 50 km. Fluids trapped in glasses inside phenocrysts and cumulate blocks are abundant and appear to be both $CO_2$ and $H_2O$. The high supply rate may account for the dominance of basalt, but the underlying cause of this feature together with the early opx saturation, vapor separation and violent eruptive history remain unclear. (From the authors' abstract)

ARNE, D.C., 1985, A study of zonation at the Nanisivik Zn-Pb-Ag mine, Baffin Island, Canada: MS thesis; Lakehead Univ., Thunder Bay, Ontario, Canada, 194 pp.

See Arne et al., Fluid Inclusion Research, v. 19, p. 13, and following item. (E.R.)

ARNE, D.C., KISSIN, S.A. and CURTIS, L.W., 1987, A fluid inclusion study of sphalerite and dolomite from the Nanisivik lead-zinc deposit, Baffin Island, Northwest Territories, Canada - A discussion: Econ. Geol., v. 82, p. 1968-1971. First author at Dept. Geol., Univ. Melbourne, Parkville, Victoria 3052, Australia.

A discussion of the interpretation of fluid inclusion data on the Nanisivik deposit by McNaughton and Smith (Fluid Inclusion Research, v. 19, p. 276). (E.R.)

ARNOLD, M. and GONZALEZ PARTIDA, E., 1987a, The present hydrothermal system of Los Humeros (Mexico): Study of the system $SO_4^{--}$ - $SH_2$ at 300°C, origin of sulfur, and oxidation phenomena associated with boiling of the ascending fluid: Mineral. Deposita, v. 22, p. 90-98 (in French; English abstract). First author at C.R.P.G., B.P. 20, 54501 Vandoeuvre Cédex, France.

In the geothermal system of Los Humeros, hydrothermal fluids are low in sulfur (7.7 mM/kg) and are slightly alkaline (pH of ca. 8.5) at depth. Based on fluid inclusion study the boiling of hydrothermal fluid before the geothermal area was opened by drilling is proven in neoformed minerals sampled at different levels of the volcanic sequence. In this way, the pervasive oxidation of the primary reduced paragenesis (pyrite + pyrrhotite + magnetite) can be explained. The boiling of the ascending water does induce a $H_2$ loss from the liquid and creates more oxidizing conditions in the ascending liquid. (From the authors' abstract)

ARNOLD, M. and GONZALEZ PARTIDA, E., 1987b, The Fresnillo mine (Mexico): Conditions of deposition; origin of sulfur and metals (abst.): Terra Cognita, v. 7, no. 2-3, p. 226. Authors at CRPG, Vandoeuvre-lès-Nancy, France.

In the deeper levels, a low (1.7% wt NaCl) and constant salinity prevailed during thermal event from 350 to 200°C. In Lode vein, the increase of salinity (from 1.7 to 10% wt NaCl) is clearly related with a decrease of T (300° to 160°C) and of the depths. This is consistent with deposition by a boiling hydrothermal fluid and calcite precipitation in the veins. Fresnillo mineralizations are not the product of a late magmatic hydothermal activity. Indeed, strongly reduced properties of hydrothermal fluid can be attained only by a slow percolation across the intensively fractured bituminous shaly unit. (From the authors' abstract)

ATKINSON, B.K. and MEREDITH, P.G., 1987, The theory of subcritical crack growth with applications to minerals and rocks, in Fracture Mechanics of Rock, B.K. Atkinson, ed.: New York, Academic Press, p. 111-166. Authors at Dept. Geol. Sci., Univ. Coll. London, UK.

Discusses theory useful for the study of the origin of secondary fluid inclusions. (H.E.B.)

AULSTEAD, K.L. and SPENCER, R.J., 1987a Diagenesis of the Manetoe facies, Northwest Territories, Canada: Fluid inclusions and isotopes (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Authors at Dept. Geol. & Geophys., Univ. Calgary, Calgary, Albera, Canada T2N 1N4.

The Manetoe facies is a diagenetic feature which cross-cuts Lower and Middle Devonian carbonate strata. The Manetoe is of economic importance as the reservoir rock for three gas fields. The paragenetic sequence of diagenetic cement phases in the Manetoe is: white sparry dolomite, calcite, mega-quartz, fluorite, anhydrite, barite, sphalerite and galena. Diagenetic fluids originated as residual evaporite brines. These brines were heated during deep circulation through basement rocks prior to cement formation in the Devonian.

Th and final melt temperatures from aqueous fluid inclusions were compared with $\delta^{18}O$ isotope data from dolomite cements. Fluid inclusion data indicate dolomite cements formed from hot (150-210°C), hypersaline (20-29 equiv. wt. % NaCl) brines. Values of $\delta^{18}O$ for the Manetoe dolomite range from -8‰ to -15‰ PDB. The light isotopic values and high T indicate the $\delta^{18}O$ of the waters responsible for dolomitization were near +2‰ to +8‰ SMOW. This suggests an evaporitic input to the diagenetic fluids. Further evidence for diagenesis at high T is provided by fluid inclusions in calcite and quartz. Calcite cements formed from hot (110-180°C), saline (15-21 wt. % NaCl) brines. Quartz cements formed later at high T (Th = 170-215°C) from fluids of lower salinity (3-6 wt. % NaCl).

In addition to the fluid inclusion and $\delta^{18}O$ data, Sr and S isotopes and mass balance calculations are used to interpret the origin of the Manetoe. Ratios of 87Sr/86Sr from dolomite cements are more radiogenic than the host limestone. This suggests circulation of dolomitizing fluids through granitic basement rocks. Similarities between $\delta^{34}S$ of Manetoe cements and Devonian seawater as well as the stratigraphic position of the Manetoe imply diagenesis occurred prior to the end of the Devonian. (Authors' abstract)

AULSTEAD, K.L. and SPENCER, R.J., 1987b Diagenesis of the Manetoe Facies, Yukon and Northwest Territories, Canada (abst.): Abstracts, SEPM annual midyear meeting 20-23, Aug. 1987, v. 4, p. 5. Authors at Dept. Geol. & Geophys., Univ. Calgary, Calgary, Alberta, Canada T2N 1N4.

The Manetoe Facies is a diagenetic feature which cross-cuts Lower and Middle Devonian carbonate strata of the Mackenzie Shelf. The Manetoe is of economic importance in that it forms the reservoir rock for three gas fields and contains Pb-Zn mineralization similar in nature to MVT deposits. The paragenetic sequence of cements is: white sparry dolomite, bitumen, fluorite, anhydrite, barite, calcite, quartz, sphalerite and galena. Fluid inclusion data indicate dolomite cements formed from hot (150-210°C), hypersaline (20-20 eq. wt. % NaCl) brines. This agrees well with $\delta^{18}O$ of the dolomite cements, yielding an initial water composition of +2 to +8‰. Thus, diagenetic fluids originated as residual evaporite brines. Dolomite and calcite cements are more radiogenic in $^{87}Sr/^{86}Sr$ than the host limestone. This implies that the brines were heated during deep circulation through clastic or basement rocks prior to dolomitization in the Devonian. Increasing burial depth from north to south across the study area in the Mesozoic accounts for the systematic increase in fluid inclusion Th of about 80°C in quartz and calcite cements. Fluid inclusions in calcite and quartz contain hydrocarbons implying hydrocarbon migration occurred at this time. (Authors' abstract)

AUSTRHEIM, Håkon and JAMTVEIT, Bjørn, 1987, Fluid control on formation of eclogites from granulite facies anorthosites, Bergen Arcs, western Norway (abst.): Abstracts, NATO Advanced Research Workshop, Fluid movements, element transport, and the composition of the deep crust, Lindås, Norway, 18-24 May, 1987 (unpaginated). Authors at Min.-Geol. Museum, Sars gate 1, N-0562 Oslo 5, Norway.

Estimation of fluid composition from mineral equilibria suggests an $H_2O$-dominated fluid ($X(H_2O) = 0.9$). This is in agreement with textural indications of partial melting within the shear zones. (From the authors' abstract)

AVDONIN, V.V., DOROGOVIN, B.A. and LAPTEV, V.A., 1987, Liquation during the melting of effusive rocks: Dokl. Akad. Nauk SSSR, v. 297, no. 5, p. 1185-1188 (in Russian).

AWAKURA, Yasuhiro, KAWASAKI, Yukio, UNO, Akito, SATO, Koji and MAJIMA, Hiroshi, 1987, Activities of water and HCl in aqueous solution systems of $HCl$-$MCl_n$ including $CuCl_2$, $NiCl_2$ and $FeCl_3$: Hydrometallurgy, v. 19, p. 137-157.

AYORA, Carlos, GUILHAUMOU, Nicole, TOURAY, J.-C. and MELGAREJO, J.C., 1987, Scheelite-bearing quartz veins from Poblet (Catalonian Coastal Range): Characterization of fluid inclusions and genetic model: Bull. Minéral., v. 110, p. 603-611. First author at Dépt. Min. & Cristallogr., Univ. Barcelone, Spain.

Scheelite-bearing quartz veins from Poblet, trending in a NE-SW direction, are hosted by calcic granitoids of Late Hercynian age in the southern part of the Catalonian Coast Range. Fluid inclusions from quartz and scheelite have been characterized using microthermometry, Raman microspectrometry and Scanning Electron Microscopy. Except for type I inclusions (not observed in scheelite), similar inclusions have been observed in both minerals. One recognizes, in order of formation:

Type I inclusions containing brine, daughter phases (halite, sylvite and sometimes iron chloride) and incidentally trapped minerals (ankerite, siderite, muscovite, K-feldspar and unidentified species). Type II(L) inclusions have a low salinity (1 to 6% eq. NaCl) and homogenize in the liquid phase in the range of 300-400°C or under critical conditions near 400°C. Type II(V) are low density, $CO_2$-poor aqueous inclusions, homogenizing in the gas phase in the range of 350-420°C. Type II(V') have higher $CO_2$ contents. Type II inclusions appear as samples of an initially hypercritical fluid, trapped at different stages of its evolutions towards two subcritical fluids. Type III inclusions indicate later circulation of a colder, low-salinity solution (Th: 150 to 300°C; salinity: 0 to 3.5% NaCl wt %).

Abundant iron contents in type I inclusions suggest some interaction at elevated T (400 to 600°C) with a biotite granite (Whitney et al., 1985). P-T conditions compatible with measurements performed on type II inclusions are about 400°C and 0.8 kbar, in a range similar to that determined for the Djbel Aouam occurrence in Hercynian Morocco (Cheilletz, 1984). Equivalent conditions have been postulated for scheelite precipitation at Poblet. (Authors' abstract)

AYUSO, R.A., FOLEY, N.K. and BROWN, C.E., 1987, Source of lead and mineralizing brines for Rossie-type Pb-Zn veins in the Frontenac axis area, New York: Econ. Geol., v. 82, p. 489-496. First author at U.S. Geol. Survey, National Center, Mail Stop 963, Reston, VA 22091.

Th values in fluorite, calcite, and sphalerite range from 90 to 152°C and contain halite dms, suggesting salinities of 26-31 eq. wt. % NaCl. Te ranged from -30 to -50°C. These data, plus oil inclusions and lead isotopic data, suggest a Paleozoic basinal environment containing evaporites for the fluids, at rather high thermal gradients. (E.R.)

BACON, C.R., 1987, Granitoid blocks in climactic ejecta of Mount Mazama, Oregon: Quenched samples of a magma chamber's partially fused walls (abst.): Geol. Soc. Am. Abstracts wtih Programs, v. 19, p. 577. Author at USGS, 345 Middlefield Rd., Menlo Park, CA 94025.

Medium-grained tonalite blocks to 4 m and minor fine-grained granite and gabbro clasts are common in the climactic ejecta of Mount Mazama (Crater Lake). Many have been partially melted, but very few have adhering climactic magma. Unlike most partially fused xenoliths in lava, these rocks had remained in a conductive thermal regime for sufficient time to form equilibrated partial melts and mineral phases. Primary crystallization of the tonalites produced phenocrystic pl + hyp + aug + mt + il + ap + zircon, followed by qz + hb + bt + alkali feldspar(af). Presence of fluid inclusions in all samples suggests complete crystallization before melting. The exceptionally violent climactic eruption apparently regurgitated the deep walls of its magma chamber as joint blocks that are remarkable natural examples of equilibrated partial melting experiments. (From the author's abstract)

BAGDASAROV, Kh.S., ARZUMANYAN, G.A., RYADNOV, S.N. and BELYKH, I.G., 1987, Influence of crystallization conditions on the content of gaseous impurities in crystals of leucosapphire: Kristallografiya, v. 32, p. 467-472 (in Russian; translated in Sov. Phys. Crystallogr., v. 32, no. 2, p. 272-275).

BAILEY, D.K. and MACDONALD, R., 1987, Dry peralkaline felsic liquids and carbon dioxide flux through the Kenya rift zone, in B.O. Mysen, ed., Magmatic Processes: Physicochemical Principles: Geochem. Soc. Spec. Pub. 1, p. 91-105.

BAIN, John, 1987, New data for north Queensland gold deposits (abst.): BMR Res. Newsletter, no. 6, p. 14 [Bureau of Mineral Resources, Canberra, Australia].

New K-Ar isotopic ages and inclusion data are reported on the Etheridge goldfield in the Georgetown region. Deposits in the northern part of the goldfield have simple two-phase fluid inclusions with relatively low Th (170 to 250°C), salinities of about 10 wt% NaCl eq., and $\delta^{18}O$ values of about 2 to 5 per mil, indicative of meteoric fluid. The Mount Hogan deposit in the south has $CO_2$-rich three-phase fluid inclusions with higher Th (about 350°C), salinities of about 10 wt% NaCl eq., and $\delta^{18}O$ fluid values of about 9.5 per mil; such characteristics may be evidence of a magmatic fluid component, or of more highly modified meteoric water. (From the author's abstract)

BAIN, J.H.C., 1987, Structural setting and origin of the Woodlawn and Captains Flat massive sulphide deposits: Bur. Mineral Resources, Geology, and Geophysics [Australia] Yearbook, 1987, p. 86-89.

May involve fluid inclusion studies. (E.R.)

BAKER, D.R. and EGGLER, D.H., 1987, Compositions of anhydrous and hydrous melts coexisting with plagioclase, augite, and olivine or low-Ca pyroxene from 1 atm to 8 kbar: Application to the Aleutian volcanic center of Atka: Am. Mineral., v. 72, p. 12-28.

BAKER, E.M., 1987, Brecciation, mineralization and alteration of the Kidston gold deposit: Pacific Rim Congress 87, 26-29 August, 1987, Australasian Inst. Mining & Metallurgy, Victoria, Australia, p. 29-33.

Fluid inclusion and isotope studies on the pre-breccia quartz indicate that the mineralizing fluid had a salinity between 30 and 50 eq. wt. % NaCl, and T >500°C and is of magmatic origin. The late stage post-breccia fluid associated with the economic Au mineralization had a salinity range of 1 to 10 eq. wt. % NaCl and T between 250 and 400°C, and is of predominantly magmatic origin with a minor meteoric component. (From the author's abstract)

See also Andrew and Baker, this volume. (E.R.)

BAKUMENKO, I.T., 1986, Processes of magmatic petrogenesis according to data from studying inclusions of mineralizing media: Geologiya i Geofizika, v. 27, no. 7, p. 125-133 (in Russian; translated in Sov. Geol. & Geophys., p. 27, no. 7, p. 109-115).

Abstract in Fluid Inclusion Research, v. 19, p. 19-20. (E.R.)

BANNON, M., KELLEY, S. and TURNER, G., 1987, Argon isotopes in fluid inclusions from tin-tungsten deposits (abst.): Terra Cognita, v. 7, no. 2-3, p. 129-130. Authors at Physics Dept., Univ. Sheffield, Sheffield, UK.

See next item. (E.R.)

BANNON, M.P., TURNER, G. and KELLEY, S.P., 1987, $^{40}$Ar-$^{39}$Ar and thermometric analysis of fluid inclusions in quartz from mineralization associated with the Cornubian Batholith, SW England (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 7-8. Authors at Dept. Physics, Univ. Sheffield, Sheffield S3 7RH, UK.

Fluid inclusions within quartz from mineral veins associated with the Cornubian Batholith, SW England have been analyzed by the $^{40}$Ar-$^{39}$Ar stepped heating technique in addition to conventional thermometric analysis. This new area of application of the $^{40}$Ar-$^{39}$Ar method has allowed substantive inferences concerning the geochemistry and mixing of the hydrothermal fluids, as well as the first reliable K-Ar age determinations of fluid inclusions.

Stepped heating analysis shows that a mixture of radiogenic, atmospheric and parentless, or excess, $^{40}$Ar is dissolved within the brines contained within the fluid inclusions, as well as held within the lattices of the dms and host quartz. By combining the stepped heating and thermometric data, the separation and identification of several components is possible using correlations between $^{39}$Ar, $^{38}$Ar and $^{37}$Ar isotopes induced by neutron bombardment of K, Cl and Ca. So far, three major components have been identified. A K-correlated component arises from in situ decay of potassium and is associated with daughter/captive minerals within the inclusions. A Cl-correlated component is dissolved within the brines and trapped in the lattice of the host quartz. This component represents a mixture of excess argon leached from the country rocks and ancient atmospheric argon.

An analysis of argon released from the fluids by crushing the sample prior to step-heating has allowed this Cl-correlated component to be further distinguished from components associated with the solids. A knowledge of the salinity of the inclusions from thermometric analysis and of the $^{36}$Ar/Cl ratio from the isotopic analysis allows the absolute concentration of both the K and Cl correlated components to be deduced. Concentrations of the excess component can be used as a qualitative measure of the interaction of the fluids with the country rocks.

The results from a number of samples representative of various phases of mineralization associated with the Cornubian Batholith indicate significant systematic variations of the leached excess $^{40}$Ar component between early and late fluids. The concentration of the atmospheric component is that expected for ancient meteoric waters.

It is hoped that a future extension of this research combining thermometric techniques and mass-spectrometry will involve the analysis of single inclusions by the use of a laser probe allowing much tighter constraints concerning the chemistry of the fluids to be applied. (Authors' abstract)

BARABOSHKIN, D.A., FROLOV, A.A. and BUNKIN, A.Yu., 1987, Motion of plane liquid inclusions in crystals of $Fe_{1-x}Co_xGe_2$ grown by the Czochralski method: Kristallografiya, v. 32, p. 478-481 (in Russian; translated in Sov. Phys. Crystallogr., v. 32, no. 2, p. 279-281). Authors at Polytech. Inst. Urals, Sverdlovsk.

In growing crystals of $Fe_{1-x}Co_xGe_2$ the authors experimentally investigate the motion of liquid inclusions entrained with loss of stability of the plane crystallization front. On the basis of Tiller's theory they describe the motion of plane liquid zones in the growing crystal. Comparison of the experimental results with the theory revealed that the captured liquid inclusions are plane layers of melt moving in the growing crystal in the field of the temperature gradient in diffusion conditions. (Authors' abstract)

BARANOVA, N.N. and KOL'TSOV, A.B., 1987, The influence of metals and volatiles in hydrothermal solutions on gold transport and deposition based on fluid-inclusion studies: Geochem. Int'l., v. 24, no. 1, p. 1-12. English translation of Geokhimiya, no. 6, p. 739-750 (1986); abstract in Fluid Inclusion Research, v. 19, p. 26. (H.E.B.)

BARKAN, Ye.S., 1986, The solubility of argon in water from mixtures with methane at high temperatures and pressures: Geokhimiya, no. 4, p. 562-565 (in Russian; translated in Geochem. Int'l., v., 23, no. 8, p. 144-147, 1987).

BARKER, C.E., 1987, Bibliography of cathodoluminescence petrography, in Process Mineralogy VI: Applications to precious metals deposits, industrial minerals, coal, liberation, mineral processing, agglomeration, metallurgical products, and refractories, with special emphasis on cathodoluminescence microscopy, R.D. Hagni, ed., p. 159-190. Author at U.S. Geol. Survey, Box 25046, Denver, CO 80225.

This paper contains a bibliography comprised of 424 references that deal with the applications of cathodoluminescence microscopy to carbonate sedimentary rocks, siliciclastic sedimentary rocks, fossils, igneous rocks, metamorphic rocks, ore deposits, mineralogy and chemistry, together with references on methods of cathodoluminescence microscopy, fluorescence petrography, and general references on cathodoluminescence microscopy. (From the author's abstract)

BARKER, C.E., CRYSDALE, B.L. and PAWLEWICZ, M.J., 1986, The relationship between vitrinite reflectance, metamorphic grade, and temperature in the Cerro Prieto, Salton Sea, and East Mesa geothermal systems, Salton Trough, United States and Mexico, in F.A. Mumpton, ed., Studies in Diagenesis: U.S. Geol. Survey Bull. 1578, p. 83-95. Authors at U.S. Geol. Survey, Box 25046, MS 921, Denver, CO 80225.

The degree of inaccuracy possible in estimating T(max) using metamorphic grade is illustrated by a short-term thermal event at a depth of 1,300 m in a borehole in the Cerro Prieto field, Mexico. This thermal event induced a reequilibration of oxygen isotopes and formed high-T fluid inclusions in veins and host rock. Vitrinite reflectance increased in the rock, and fission tracks in detrital apatite were completely annealed, indicating a T(max) of 250°-300°C. Metamorphic grade, as estimated by an assemblage change of smectite + kaolinite to illite + chlorite, suggests a T(max) of only 150°-180°C.

The wide T range over which certain mineral assemblages can form and (or) persist indicates that metamorphic grade is less accurate than vitrinite reflectance in estimating T(max). (From the authors' abstract)

BARKER, C.E. and HALLEY, R.B., 1987, Two-phase fluid inclusions in vadose cement of the Pleistocene Miami Limestone, southeast Florida (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Authors at U.S. Geol. Survey, Box 25046, MS-971, Denver, CO 80225.

The Late Pleistocene Miami Limestone has not been heated by burial, yet contains two-phase aqueous fluid inclusions. The inclusions occur in some vadose cements as irregular spindle-shaped vacuoles, arranged in bands crossing bundles of columnar crystals, or as isolated individuals within single crystals. These seemingly primary fluid inclusions homogenize to liquid between 75° and 130°C and have Tm [ice?] between -0.3° and 0.0°C. These are relatively narrow T ranges for vadose cements, considering that the range of Th may have been increased by inclusion stretching during measurement.

The $\delta^{18}O$ composition of these cements (-4 to -5.5 per mil, PDB) and the near-fresh water in the fluid inclusions are consistent with precipitation from low-T meteoric water. The carbon-isotope composition of vadose cements that contain only rare two-phase fluid inclusions are comparable to the host-rock matrix ($\delta^{13}C$ between 0 and +4 per mil, PDB). Cements that contain common two-phase fluid-inclusions have a distinctly lighter carbon isotopic compostions of -3 to -5 per mil.

The properties of the two-phase inclusions and the host calcite suggest several possible origins involving a uniform trapping mechanism, or volume changes (stretching) from overheating single phase inclusions. One possibility is that these inclusions trapped gas and water in a somewhat uniform ratio along surface irregularities and crystal defects. Another hypothesis is that natural overheating, caused by peat fires that have locally affected the Miami Limestone, has stretched some single-phase inclusions and produced two-phase inclusions upon cooling. Finally, the carbon isotopes of cements that contain two-phase fluid inclusions are on the average 6 per mil lighter than those of other vadose cements, perhaps the result of precipitation from water that has been supersaturated in $CO_2$ by biotic respiration. Trapping of $CO_2$-charged water in the vadose cement may result in later phase-separation and two-phase inclusions.

Regardless of the explanation, a mean Th of 100°C is surprising because these 130,000 yr old sediments have never been buried, and the vadose cement precipitated from meteoric waters that should not have exceeded 20-25°C, based on present-day ground-water T. Also, other studies have shown that two-phase fluid inclusions in the vadose zone usually have highly variable liquid/vapor ratios, resulting in Th spreading over a range up to 200°C. Yet the fluid-inclusions of the Miami Limestone have fairly uniform liquid/vapor ratios as shown by the relatively narrow Th range of 55°C. (Authors' abstract)

BARKER, C.E. and KOPP, O.C., 1987, New light shed on old rocks: Geotimes, v. 32, no. 10, p. 21-22. First author at U.S. Geol. Survey, Mail Stop 971, Denver, CO 80225.

A short review of cathodoluminescence. (E.R.)

BARKER, C.E. and WOOD, Teresa, 1987, A review of the Technosyn and Nuclide cathodoluminescence stages and their application to sedimentary geology, in Process Mineralogy VI: Applications to precious metals deposits, industrial minerals, coal, liberation, mineral processing, agglomeration, metallurgical products, and refractories, with special emphasis on cathodoluminescence microscopy, R.D. Hagni, ed., p. 137-158. First author at U.S. Geol. Survey, Box 25046, Denver, CO 80225, USA.

Much of the technique is applicable to studies of fluid inclusions in cathodoluminescent minerals. (E.R.)

BARKER, Colin and SULLIVAN, G.E., 1987, Analysis of gases in fluid inclusions in calcite cements from the deep Smackover formation, Mississippi (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Authors at Dept. Geosci., Univ. Tulsa, Tulsa, OK 74104.

A recently-developed mass spectrometric method for analyzing gases in individual fluid inclusions has been used to study the composition of gases in cements from deep parts of the Smackover formation, south Mississippi. In this area commercial gas fields appear to have been generated from the thermal breakdown of oil and show all the characteristics expected for so-called "thermal gas" including high methane (but low $C_{2+}$), high carbon dioxide, and high hydrogen sulfide accompanied by a graphitic residue in an abnormally pressured reservoir. Fluid inclusions in calcite cements from 19,366 ft, 19,384 ft, 19,576 ft and 19,750 ft in the Josephine A-1 well (Blackcreek Field, 35-1S-10W) were analyzed and showed variable mixtures of water, methane, hydrogen sulfide and carbon dioxide. There was no systemmatic trend over the depth range and the sample from 19,384 ft had considerably more carbon dioxide than the other samples. There were often wide ranges in methane/hydrogen sulfide ratios within samples (which weighed ~10 mg) and these were attributed to varying amounts of elemental sulfur trapped within the inclusions (and identified independently by laser Raman spectroscopy). In addition supporting thermodynamic calculations showed that in carbonate systems such as the Smackover the relative amount of sulfur compounds and available iron-bearing species controls the quantity of hydrogen sulfide. By plotting $H_2{}^{32}S$ (34 amu) and $H_2{}^{34}S$ (36 amu) on a ternary diagram with methane (at 15 amu) for samples with variable methane/hydrogen sulfide ratios it was possible to extrapolate to zero methane and estimate sulfur isotope ratios for the hydrogen sulfide in the inclusions. (Authors' abstract)

BARKER, Colin, UNDERWOOD, W.D. and SULLIVAN, G.E., 1987, Mass spectrometric analysis of gases in individual fluid inclusions (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Authors at Geosci. Dept., Univ. Tulsa, Tulsa, OK 74104.

A mass spectrometric method has been developed for analyzing the gases released as individual fluid inclusions decrepitate when their host mineral is heated in a vacuum (Anal. Chem., 58 (1986) 1330). Each burst lasts approximately 25 msec. The rapid pressure rise is recognized by the computer program which then triggers the mass spectrometer to retain the previous spectra as background and sample the following spectra for analytical data. The rise time and burst shape are important in designing an optimum computer program and we have measured many individual burst shapes for the release of water, methane, hydrogen sulfide and carbon dioxide from quartz, calcite, pyroxene and halite. For calcite and silicates rise time is generally fast and there is no significant difference between water and methane, suggesting that water is not being preferentially absorbed and that it can be treated like any other volatile component. Also, there is no evidence for adsorption of hydrogen sulfide. For some bursts rise time was slower (for reasons that are not yet clear) but are still within the capabilities of the program. Occasionally multiple bursts were observed with each successive burst coming before the previous one had pumped down. Presumably planes of secondaries or cleavage surfaces were "unzipping." Inclusions in halite lead to bursts with much slower rise time, often slow enough that the program in its present form will not recognize the increase as a burst.

Improved capabilities for recording the sizes of inclusions (in terms of total volatile content) has shown that the rupture sequence with increase T is independent of size, i.e., there is no preferential early breaking of large inclusions. In addition the ability to eliminate from the data set small inclusions where background correction is substantial reduces the scatter in the analytical data.

The mass spectrometer is being calibrated using exactly the same operating conditions as for data acquisition. For example, some deep quartz cements have large methane contents, no higher hydrocarbons, and minor water. For these methane 14-15-16 amu cracking patterns can be obtained from ternary diagrams displaying a large number of inclusion bursts (so that spurious data stands out). (Authors' abstract)

BARNES, R.O., 1987, Fluid and chemical fluxes between seawater and basement rocks during "active" and "passive" hydrothermal circulation in the oceanic crust (abst.): Int'l. Union of Geodesy & Geophys., XIX Gen. Assembly, Vancouver, Canada; Aug. 9-22, 1987; Abstracts, v. 3, p. 1095. Author at Rosario Geoscience Assoc., 104 Harbor Lane, Anacortes, WA 98221, USA.

Estimates of the helium content of upper basement pore fluids at Deep Sea Drilling Project sites are used to develop a first approximation curve for the average fluid residence time versus crustal age for the whole oceanic crust. These fluid residence times are converted into seawater to basement fluid exchange fluxes for various age provinces of the deep-sea floor. The total low temperature (passive) exchange flux is about 3 to 6 x $10^{10}$ g/yr, sufficient to cycle all the oceans through the crust in 2.4 to 4.7 x $10^{3}$ yr. More than 90% of this fluid exchange occurs on the mid-ocean ridge flanks where average measured conductive heat flow is significantly lower than theoretical values.

A ridge crest hydrothermal model is used to calculate the "active" water flux associated with the initial hydrothermal front at the spreading center. This high temperature water flux, exiting the sea floor primarily in discrete thermal vents, is about 4.4 x $10^{16}$ g/yr, about 1% of the "passive" exchange flux.

"Active" and "passive" hydrothermal chemical fluxes are calculated from concentration measurements in ridge crest vent waters and low temperature basement of sedimentary fluids. The low temperature fluxes dominate the basement to sea water chemical exchange for Ca, Mg and probably silica; the ratios of ridge flank to "active" ridge crest fluxes are >4.7, >1.4 and <3.6 respectively. The total hydrothermal exchange fluxes of Ca and Mg on crust younger than 35 Myr will alter the bulk oceanic basement chemical composition by -0.2 to -0.8 wt% for Ca and +0.25 to 0.8 wt% for Mg. To 35 Myr, the total hydrothermal silica flux may be 30-50% of the river input, the Ca flux may be 20-90% of the river input and the hydrothermal Mg sink may be 100-300% of the river input. Thus, variations in ocean crust generation rates and low temperature hydrothermal fluid exchange rates could have a significant effect on the oceanic balance of these species as reflected in deposition rates in marine sediments. (Author's abstract)

BARNOLA, J.M., RAYNAUD, D., KOROTKEVICH, Y.S. and LORIUS, C., 1987, Vostok ice core provides 160,000-year record of atmospheric $CO_2$: Nature, v. 329, p. 408-414. First author at Lab. Glaciologie & Géophys. de l'Environ., BP 96, 38402 Saint Martin de'Hères Cedex, France.

Direct evidence of past atmospheric $CO_2$ changes has been extended to the past 160,000 years from the Vostok ice core. These changes are most notably an inherent phenomenon of change between glacial and interglacial periods. Besides this major 100,000-year cycle, the $CO_2$ record seems to exhibit a cyclic change with a period of some 21,000 years. (Authors' abstract)

Analyses based on crushing in vacuum to release air bubbles in ice. (E.R.)

BAR-NUN, A., DROR, J., KOCHAVI, E. LAUFER, D., KOVETZ, D. and OWEN, T., 1986, Trapping and release of gases by water ice and implications for icy bodies (abst.): Origins of Life, v. 16, nos. 3/4, p. 220. First author at Dept. Geophys. & Planet. Sci., Tel-Aviv Univ., Tel-Aviv 69978, Israel.

The trapping and release of: $H_2$, $D_2$, Ne, Ar, CO, $N_2$, $CH_4$, $CO_2$, $C_2H_2$ and HCN by amorphous water ice was studied experimentally under dynamic conditions, at low temperatures, starting at 15 K with gas pressures of $5 \times 10^{-8} - 10^{-2}$ Torr. Up to 60% of $H_2$, $D_2$ and Ne could be trapped in the ice at 15-19 K and are released from it at 20 K. Ar, CO, $N_2$ and $CH_4$ are released from the ice at six different temperature ranges, starting at: (a) 23 K where the gas frozen on the ice evaporates; (b) 35 K where the annealing of the ice opens gas-filled holes; (c) 44 K where the monolayer of adsorbed gas evaporates; (d) 136.8 K where the transformation of amorphous into cubic ice liberates part of the trapped gas; (e) 160.0 K where the transformation of cubic to hexagonal ice liberates some additional gas; and (f) 180 K where gas and water are released simultaneously during the evaporation of a clathrate-hydrate. $C_2H_2$ behaves similarly, while $CO_2$ and HCN are released in one peak only.

The single process which traps the gas in the ice is the temperature dependent annealing of the ice. The gas release is accompanied by massive ejection of ice grains and by argon jets, which propel them.

The implications of these experimental findings to comets, icy satellites, icy ring particles and icy grain mantles around grains in dense interstellar clouds will be discussed, as well as the possible contribution of icy bodies to the inventory of volatiles on the primitive earth. (Authors' abstract)

Pertinent also to the problems of cryopumping during vacuum analysis of fluid inclusion gases. (E.R.)

BARRES, O., BURNEAU, A., DUBESSY, J. and PAGEL, M., 1987a Application of micro/FT-IR spectroscopy to individual hydrocarbon fluid inclusion analysis (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 9-10 (also in Terra cognita, v. 7, no. 2-3, p. 343). First author at Lab. Spectrométrie de Vibrations, Univ. Nancy I, BP 239, 54506 Vandoeuvre les Nancy Cedex, France.

IR spectra of fluid inclusions are obtained with a Fourier Transform IR microspectrometer. The experimental conditions and the analytical use are discussed. Interferograms are recorded in the transmission mode. The quality of spectra is good for fluid inclusions >20 μm, the spectral resolution being $4 cm^{-1}$ and the recording time 200 s. The limit of 20 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, the thickness of which should never exceed 1 mm. This fact limits their interpretation all the more as 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. This shows that it is necessary to use a detector which is as sensitive as possible towards high frequencies. A comparison of the current performances of IR and Raman spectroscopies as analytical methods of fluid inclusions is presented. The important improvement of the spatial resolution and the correlative possibility of characterizing heterogeneities is discussed in comparison to classical dispersive infrared spectrometry. Methane, carbon dioxide, liquid water, aromatic ester and linear or branched alkanes are identified in several samples. It is also possible to estimate the mean ratio of alkanes $CH_2/CH_3$ groups. In some cases, the intensity of the absorptions indicates the inclusion effective thickness and the mole fraction ratio. (Authors' abstract)

BARRES, O., BURNEAU, A., DUBESSY, J. and PAGEL, M., 1987, Application of micro-FT-IR spectroscopy to individual hydrocarbon fluid inclusion analysis: Appl. Spectrosc., v. 41, no. 6, p. 1000-1008.

This is the full paper for the previous item. (E.R.)

BARSUKOV, V.L., DURASOVA, N.A., KOVALENKO, N.I. and RYABCHIKOV, I.D., 1987, The conditions of tin dispersion and concentration in acid magmatic systems and supercritical fluids (abst.): Abstracts, Inter. Symp. on Petrogenesis and Mineralization of Granitoids, Dec. 7-10, 1987, Guangzhou, China, p. 8-9.

See Durasova et al., 1986, this volume. (E.R.)

BARSUKOV, V.L., DURASOVA, N.A., KOVALENKO, N.I., RYABCHIKOV, I.D. and RYZHENKO, B.N., 1987, Oxygen fugacity and tin behavior in metals and fluids: Geol. Zbornik-Geol. Carpathica, v. 38, no. 6, p. 723-733. First author at USSR Acad. Sci., Moscow, USSR.

The paper presents experimental data on Sn valence in magmatic phases and postmagmatic fluids at varied oxygen fugacities, as well as on tin behavior during formation. (From the authors' abstract)

BARTON, M.D., 1987, Petrological constraints on the development of fluorine-rich magmas and ore deposits (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 582.

BARTON, P.B., Jr., 1987, The role of archetypes in understanding ore genesis: Lessons from Creede, Colorado (abst.): Geol. Soc. Am. Abst. with Programs, v. 19, p. 259. Author at U.S. Geol. Survey, Reston, VA 22092.

In the field of mineral deposits a few well-studied examples set the course for the investigation of all the rest and provide opportunities for intellectual and technical innovation. Examples are: El Salvador Climax/Henderson, Butte and the Hokuroku district. A key factor in the recognition of these deposits as archetypes is intensive study, either by a strong team from the operating company, or by a wide group of scholars. Creede has followed the latter pattern, and, thanks to the foresight and generosity of all the operators, has become an archetype for epithermal base- and precious-metal deposits.

Economic geology has always been long on ideas but all too short on proofs. Tom Steven recognized in the mid-50's that Creede might provide some proofs, and intensive study began in 1959. Indeed, despite its small size ($<5 \times 10^4$ tons of ore worth $<\$10^9$ today) Creede has yielded disproportionately large scientific contributions. Some examples are: the first clear demonstration of boiling during mineral deposition (by E. Roedder, in 1960); development and application of stage-by-stage mineral stratigraphy (Bethke et al., 1960); discovery that individual growth bands in sphalerite correspond to "quantitized" temperature/salinity packets of solution (Roedder, 1977), and use of fluid inclusions in the stratigraphy to prove the mixing of brines and dilute meteoric waters (Hayba, 1984); the proof of sulfur redox disequilibrium in epithermal ores (Bethke et al., 1973); proof that fluid inclusions that differ drastically in salinity and isotopic signature can constitute spatially overlapping populations in quartz crystals (Foley et al., 1982); and identification of the buffer systems that control the chemical evolution of the ore fluid (Barton et al., 1977). The detailed characterization of the deposit, plus the excellent geologic framework, have resulted in Creede being given the highest priority by DOSECC for scientific deep drilling that will expose the roots of an ore-forming system to fully document the processes operating in the entire system. (Author's abstract)

BAZRAFSHAN, Khosrow and NORMAN, D.I., 1987a Fluid inclusion study of Hermosa mining district (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Authors at Geosci. Dept., New Mexico Inst. Mining & Tech., Socorro, NM 87801, USA.

A district-wide (30 km$^2$) fluid inclusion study of Hermosa mining district in Sierra County, New Mexico, was carried out in order to determine the T of mineralization and ore-forming fluid composition and any possible correlation(s) of T and fluid composition with mineralogy, mineral zonation, and local and regional structures.

Four hundred and fifty samples (quartz, calcite, sphalerite and barite) were analyzed for this study. About 150 samples are directly associated with ore mineralizations in the district and a total of 7500 fluid inclusions were analyzed. The results of this 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.

Preliminary analysis of the data reveals a T zonation in the district. Based on this information, T distribution maps of the region were developed. These maps indicate a higher T zone in the northern part of the district and the T decreases southward. Three bull's eyes with the hottest one in the north and the lowest one in the south, depict this T distribution in the district. At the very southern end of the study area, it seems another high T zone is present.

Further analyses of the data reveals a general correlation between mineralogy and T zonation. Gold occurrences are associated with the higher T zones, and silver and base metal occurrences are associated with medium to lower T zones. This correlation is true even with respect to gangue minerals in the district. 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. High ore grades are also associated with high and medium T zones in the district. This T and mineral zonation is inconsistent with fossil and present day hydrothermal systems.

It seems the T zonation is controlled by regional and local faults and intrusive bodies. The hottest zone is associated with major regional faults and their intersections and rhyolite domes in the region. The rhyolite domes are possibly related to the Emory Caldera, which is located 3-5 miles west of the district. Medium and lower T zones are also related to major regional and local faults and their intersections in the region. From preliminary analyses of fluid inclusion data and geology of the district, it could be 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. (Authors' abstract)

BAZRAFSHAN, Khosrow and NORMAN, D.I., 1987b, Fluid inclusion study of the northern Amethyst vein system [Creede, Colorado] (abst.): Geol. Soc. Am. Abst. with Programs, v. 19, p. 259. Authors at Geosci. Dept., New Mexico Inst. Mining & Tech., Socorro, NM 87801.

Fluid inclusions in more than 200 drill core samples have been studied by microthermometric analysis. On the basis of Th, salinity, and occurrence, the inclusions have been divided into three types. Type 1 inclusions are from an early phase of mineralization and have Th values from 320 to 200°C and salinities of 2.0 to 0.2 eq. wt. % NaCl. Inclusions are two-phase L-V types; both liquid and vapor dominant types occur, indicating the mineralizing solutions were boiling.

Type 2 inclusions have Th from 310 to 170°C and salinities of 11 to 3 eq. wt. % NaCl. Vapor-rich types indicate fluid boiling and some inclusions have an immiscible hydrocarbon phase.

Type R inclusions have Th of about 150°C and salinities of 3 to 2 eq. wt. % NaCl. They occur in late minerals and in minor veins.

These inclusions are interpreted to represent three types of hydrothermal fluids. Type R fluids are thought to be residual fluids. Similarity of temperatures and salinities between Type 2 fluids and fluids described from inclusion studies of the southern section of the vein system suggest they are the same. Th-salinity plots indicate the range in salinities of Type 2 fluids resulted from them mixing with a fluid like Type R. Type 1 fluids appear to be unique to the north part of the vein system.

Trend analysis of the data indicate different upwelling centers for Type 1 and Type 2 fluids and that both were mixing as they moved upwards. Trend analysis further indicates Type 1 fluids at depth had salinities <0.7% and mixed with more saline fluids like Type R, thereby increasing their salinity as they ascended. (Authors' abstract)

BEA, F., de FIGUEROLA, L.G., LOPEZ-PLAZA, M. and SANCHEZ, J., 1987, Chemistry of alkali elements in quartz-veins: Studies in central western Spain (abst.): Terra Cognita, v. 7, no. 2-3, p. 322. Authors at Dpto de Petrol. y Geoqu., Univ. Salamanca, Spain.

Alkaline elements (qualitative results only) in quartz concentrates are assumed to come from fluid inclusions, thus providing genetic information. (E.R.)

BEANE, R.E. and HAYNES, F.M., 1987, Analysis of fluid inclusion data from hydrothermal mineral deposits using cumulative frequency plots (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 583. First author at St. Joe American Corp., 2002 N. Forbes Blvd., Tucson, AZ 85745.

Hydrothermal mineral deposits have usually undergone more than one stage of fluid flow during their development. Each of the stages may have produced a distinctive alteration and mineralization assemblage, and only one of these may have been economic. Correct interpretation of alteration and mineralization conditions requires identification of each of the multiple hydrothermal stages, and determination of their attendant temperatures and salinities using fluid inclusion homogenization and melting temperatures. Failure to recognize multiple stages of hydrothermal fluids can lead, for example, to calculated means and ranges of temperature which are not truly representative of conditions of mineralization. Multiple stages of hydrothermal fluids can sometimes be distinguished using histograms of fluid inclusion data. In other cases, significant overlap or "nesting" of data makes interpretation from histograms difficult. Fluid inclusion Th and Tm for individual populations from mesothermal and epithermal base and precious metal deposits are often normally distributed. In such cases, cumulative frequency (probability) plots of fluid inclusion thermal data may be used to separate individual inclusion populations. Several examples from porphyry copper, Mississippi Valley-type, and epithermal precious metal deposits will be cited to demonstrate the use of probability plots to identify multi-stage hydrothermal systems from fluid inclusion data. Also, a pattern will be suggested as diagnostic of a population which has undergone boiling. (Authors' abstract)

BEATY, D.W., 1987, The use of $^{18}O/^{16}O$ data to discriminate between gold-rich and barren epithermal systems (UT, NV) (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 260. Author at Cerro Assoc., 13939 W. Cedar Place, Golden, CO 80401.

Many fossil hydrothermal systems in the Great Basin show similar products: jasperoid, qtz veins, calcite veins, and altered host rocks. Some systems are gold-rich, others are not. This study suggests that the gold content and $^{18}O/^{16}O$ ratios of these systems are correlated, reflecting the early water/rock exchange histories of the hydrothermal fluids. Thus oxygen isotope geochemistry may have important application in distinguishing gold-bearing from barren systems.

The data suggest that there may be fundamental isotopic differences between gold-rich and gold-poor epithermal systems. In two barren cases, jasperoid and quartz veins are distinctly lower in $^{18}O$ than that associated with ore bodies. This difference has clear application to gold exploration. (From the author's abstract)

BEATY, D.W. and LYNCH, W.C., 1987, Metallogenesis of Precambrian-hosted vein ores, Sugarloaf and St. Kevin districts, Colorado (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 260. First author at Canyon Resources Corp., 14142 Denver West Pkwy., Suite 250, Golden, CO 80401.

Average O isotope ratios in veins and altered wall rock at Sugarloaf ($\delta^{18}O$ = +12 and +9) and St. Kevin (+11 and +9), indicate high-$^{18}O$ ore-forming fluids ($\delta^{18}O$ = +4 to +6, assuming T = 300-350°C).

The Sugarloaf and St. Kevin veins geochemically and petrologically resemble the ore in the nearby manto districts at Leadville, Gilman and Tennessee Pass, and all are interpreted to have mesothermal, igneous-related origins. Preliminary data from the veins in the Granite district (table 1; $\delta^{18}O$ = +15) suggest a similar origin. The veins in the Holy Cross City district (high-Au, low-Ag, Pb, Zn), however, may have had a quite different origin (epithermal?, metamorphic?, syngenetic?). (From the authors' abstract)

BEATY, D.W., NAESER, C.W. and LYNCH, W.C., 1987, The origin and significance of the strata-bound, carbonate-hosted gold deposits at Tennessee Pass, Colorado: Econ. Geol., v. 82, p. 2158-2178. First author at Canyon Resources Corp., 14142 Denver West Pkwy., Suite 250, Golden, CO 80401.

Numerous small manto deposits in the Leadville Dolomite consist of semimassive pyrite, fine-grained quartz, zeolite, and native gold. Most P fluid inclusions in quartz have Th of 200° to 220°C, suggesting deposition T of about 250°C. Sulfur isotopes ($\delta^{34}S$(pyrite) = 1-4‰) suggest an igneous sulfur source. The trace element geochemistry (high As, Sb, Hg) is similar to that in many other low-T hydrothermal systems. Oxygen isotope ratios in quartz ($\delta_{18}O$ = 14-17‰) indicate that the ore fluid was relatively heavy ($\delta^{18}O$(fluid) = 4-8‰). Alteration and fission-track geochronology in apatite and zircon indicates that the alteration centers are part of a large (5-7 km diam) paleothermal anomaly which has reset ages of 38 to 42 m.y. This suggests the presence of a large, unexposed stock. (From the authors' abstract)

BECKER, P. and BILAL, B.A., 1987, Association constant of acetic acid in 1.02 m NaCl aqueous medium at elevated temperatures and pressures: Z. Naturforsch, v. 42a, p. 849-852.

BEDDOE-STEPHENS, B., SHEPHERD, T.J., BOWLES, J.F.W. and BROOK, M., 1987, Gold mineralization and skarn development near Muara Sipongi, West Sumatra, Indonesia: Econ. Geol., v. 82, p. 1732-1749. First author at British Geol. Survey, Murchison House, W. Mains Rd., Edinburgh EH9 3LA, Scotland.

The skarns range from andradite-diopside rocks to grossular-idocrase-wollastonite-diopside rocks which formed at about 450° to 650°C. Later retrogressive alteration caused the formation of epidote, prehnite, pumpellyite, actinolite, chlorite, calcite, and quartz. These phases record T to <200°C. Fluid during skarnification probably contained <5 mole % $CO_2$. During retrogressive hydration the skarns were mineralized locally with chalcopyrite, pyrite, magnetite, hematite, bornite, and Au, followed by sphalerite, arsenopyrite, marcasite, tetrahedrite, Co-Ni sulfarsenides, and Au-Ag tellurides.

Chlorite-calcite retrogressive alteration of the skarns is related to quartz veining which is hosted by the volcanic members of the country rocks. These veins are enriched in Pb + Zn compared to the skarns. Au occurs as inclusions within arsenopyrite. Fluid inclusion data indicate the vein-forming fluids to be weakly saline and to contain minor $CO_2$ but also to contain significant amounts of $CH_4$ and $N_2$. Th fall in the range 180° to 240°C, which together with the low $CO_2$ correlate with the conditions inferred for chlorite-calcite skarn alteration.

The Au was most probably transported by thio and/or carbonyl complexes. (From the authors' abstract)

BEHR, C.B., APODACA, L.E. and NORMAN, D.I., 1987, Gaseous species in epithermal ore fluids (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Authors at New Mexico Inst. Mining & Tech., Socorro, NM 87801.

Volatiles in fluid inclusions from nine epithermal deposits have been quantitatively analyzed in bulk by mass spectrometry. Principal gaseous species are $CO_2$, $H_2S$, $C_2$-$C_6$ organic compounds, $H_2$, $N_2$, and $CH_4$. Gaseous species comprise on average 0.0861 mol % of the volatiles with a range of 0.0005 to 2.1830 mole %. Proportionately higher amounts of $H_2S$ and $C_2$-$C_6$ organic species are measured in inclusions from areas of high-grade Ag-Au ores. Inclusions from Mn-Fe oxide deposits have no $H_2S$ or organic species. The average ratios of $H_2S$ to $CO_2$ for Au deposits is 3:1; for base-metal/silver deposits this ratio is 1:24. Sampling of an epithermal system over a vertical interval of several hundred meters shows increased levels of gaseous species at high elevations. Gas geothermometers give T in general agreement to fluid inclusion Th measurements from ore deposits. The $f(O_2)$ calculated from gas contents of ore fluids agrees with the $f(O_2)$ determined by mineral equilibria.

The reported gaseous species in geothermal systems and their average concentrations are generally similar to those measured in inclusions from epithermal deposits, which are assumed to be paleo-geothermal systems. However, there are some significant differences: in geothermal systems, average $H_2S$:$CO_2$ is 1:46, only small amounts of $C_2$-$C_6$ are reported and the range in concentration of gaseous species is 0.0002 to 0.0206 mole %.

Inclusion assemblages for which >1 mole % gaseous components were measured, have a high percentage of vapor-filled inclusions. The high levels of gaseous species is attributed to analysis of a mixture of volatiles that strongly partition into the vapor phase, such as $N_2$ and $CO_2$, and the gas geothermometer of D'Amore and Panichi developed for steam-dominant geothermal systems gives T close to Th values for the samples.

The high levels of $H_2S$ in inclusions from Au-deposits is consistent with transportation of Au as a bisulfide, ion-paired complex. This strong correlation may be of use in mineral exploration.

The gross similarity between inclusion volatiles and those reported in modern geothermal systems, as well as the reasonable calculated $f(O_2)$ and T from the analyses, indicate that the analyses represent the volatiles in the paleo-geothermal systems. These analyses differ in some respects from those reported in modern systems because only paleo-systems which deposited ores have been studied. (Authors' abstract)

BEHR, H.J., 1987a Results of the pre-site investigation and aims of fluid research in the continental deep drilling program of the Federal Republic of Germany (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 11-12. Author at Inst. Geol. & Dyanmik der Lithosphäre, Goldschmidtstr. 3, D-3400 Gottingen, FRG.

Cores of 12 shallow drillings from the two suggested drilling sites Schwarzwald and Oberpfalz as well as metamorphites, mineralizations and deposits of both regions were analyzed by different fluid inclusion investigation methods in order to find out which of the two drilling sites is most suitable for investigation in the field of crustal fluids and crustal deformation.

These studies on paleopermeability, paleoporosity and fluid inclusions yielded remarkable differences between the two regions.

In the central Schwarzwald, all metamorphites are characterized by high, but mostly healed paleopermeability and paleoporosity originating in the middle crust. The preserved open residual porosity amounting to 1-5 vol% is very striking. According to the author, the crystalline rocks have to be interpreted in terms of a paleo-low-velocity zone connected with anatexis in the middle crust. Due to the subsequent uplift processes, hydraulic fracturing and associated fluid impulses are of substantial importance. Pre-anatectic fluids and gases were released which is the reason why the Schwarzwald is poor in $CO_2/CH_4/N_2$ in contrast to other basement regions in central Europe. In the Mesozoic, a deep-reaching microcrack permeability developed in the Schwarzwald through which highly saline basinal brines penetrated, causing hydrothermal mineralization.

Separate geologic units with different paleopermeabilities and fluid generations as well as high gas contents of $CO_2/CH_4/N_2$ can be distinguished in the Oberpfalz but not in the Schwarzwald. Fluid systems and permeability structures prove a relation to the tectonic structure and crustal development in this region, which is described by a tectonic thrust and detachment model. In contrast to the Schwarzwald, in the Oberpfalz saturation of the crystalline rock by highly saline basinal brines in the Upper Permian is much more extensive along a marked system of strike-slip faults.

The results from both regions complement each other and provide further information on crustal development and for interpretation of geophysical data. Based on the findings of the pre-site investigations a strategy for the methods and aims of the crustal fluid investigation at the planned deep drilling site becomes possible. (Author's abstract)

BEHR, H.J., 1987b The interaction of crustal fluids, metamorphism and mineralization in the Hercynian basement - Preliminary results of the German deep drilling project (abst.): Abstracts, NATO Advanced Research Workshop, Fluid movements, element transport, and the composition of the deep crust, Lindås, Norway, 18-24 May, 1987 (unpaginated). Author at Niedersächsisches Landesamt für Bodenforschung, Stilleweg 2, Postfach 51 01 53, D-3000 Hannover 51.

During LP-HT overprinting all gases ($CO_2/CH_4/N_2$) were released and the preanatectic fluid history was extinguished quantitatively.

Cathodoluminescence methods evidenced that this process was related to a long-term pervasive crustal permeability at depths of 8-12 km. The applied cathodoluminescence techniques provide positive evidence for the palaeoporosities and palaeopermeabilities and by the PT data of the related fluid inclusion systems provide information on fluid movements during metamorphism and tectonics in the crystalline rock.

According to Raman microprobe/NAA leaching techniques and other methods, post-Variscan fluid Ca-Na-Cl systems extensively penetrated the crystalline rock in channelway porosities. This system originated in basinal brines of the post-Variscan molasse and developed according to the NaCl dissolution model; its chemical characteristics developed in the diagenetic albitization window. These solutions are of essential importance for the Pb/Zn and fluorite-barite vein mineralizations of Schwarzwald, Oberpfalz, Harz, and Rheinisches Schiefergebrige. (From the author's abstract)

BEHR, H.J. and FRENTZEL-BEYME, R., 1987, Scanning electron microscopy-cathodoluminescence studies of microstructures in silicate rocks (abst.): Fortschritte der Mineralogie, Bd. 65, Bhf. 1, p. 18 (in German). Authors at Inst. Geol. & Dynamics of Lithosphere, Univ. Göttingen, FRG.

Cathodoluminescence offers new possibilities to contrast the fine structures in grain junctions of the silicate rocks and to make them visible, which is otherwise impossible. It concerns especially quartz and feldspars, in which healed paleoporosity, grain boundaries or cracks of various origins may be recognized, even when the healed material has grown in perfect structural concordance with the parent grain. Thus it is possible to recognize and to distinguish "channel-like" or "pervasive" permeability from the various stages of the rock existence. (...) This method is especially valuable for studies of multistage processes connected with the fluid activity. Cathodoluminescence is also appropriate for recognition and contrasting of the products of changes in grain boundaries, recrystallization and neoformation of minerals, as well as the effects of paleo-stress. (Authors' abstract, translated by A.K.)

This method is useful especially in recognition of the sequence of healing processes in a fractured grain, i.e., for establishing the relative age of the secondary inclusion generations. (A.K.)

BEHR, H.-J. and GERLER, J., 1987, Inclusions of sedimentary brines in post-Variscan mineralizations in the Federal Republic of Germany - A study by neutron activation analysis: Chem. Geol., v. 61, no. 1/4, p. 65-77.

Full paper for abstract in Fluid Inclusion Research, v. 18, p. 132-133, 1985. (E.R.)

BEHR, H.J., GERLER, J., HORN, E.E. and REUTEL, Chr., 1987, Importance of studies of fluid inclusions for vein tectonics and hydrothermal mineralization in the Middle and Upper Harz (abst.): Fortschritte der Mineralogie, Bd. 65, Bhf. 1, p. 19 (in German). Authors at Inst. Geol. & Geodynamics of Lithosphere, Univ. Göttingen, FRG.

Quartz, barite, sphalerite, fluorite, calcite and anhydrite from the hydrothermal mineralized zones of the Middle and Upper Harz gave the following microthermometric results: - pre-barite quartz-carbonate-sulfide mineralization, Th 100 to 150°C, Tm ice -30 to -10°C, Te -70 to -55°C;

- post-sulfide main barite mineralization, Th <70°C, Tm ice -21 to -18°C, Te about -60°C; - post-barite quartz-fluorite generation, Th 100 to 150°C, Tm ice -40 to 0°C, Te -75 to -35°C; - final anhydrite formation, Th >200°C, Tm ice about -20°C, Te about -60°C; - gases $CO_2$, $CH_4$, $N_2$ were not found. The development of the mineral-forming solution system is explainable only by mixing from two sources. The Th values indicate the mixing T but not the primary T of the original solution systems. From the sequence of chevron structures with alternating fluid groups one may recognize two separate primary solution systems. One is of low salinity and low T, and the other of high salinity of the Ca-(K-Mg)-Cl type, with high Sr and Br contents and T >180°C. The system of high salinity (>2500 mg/l* of total salts dissolved) can be related to the dissolution of Zechstein halite rocks and the enrichment in Ca would come from the plagioclase dissolution at 100-180°C during diagenesis. The vein quartz from Harz is enriched in the specific trace element association Ga-Ge-As-Sb, typical of the post-Variscan hydrothermal quartz bodies. From the vein tectonics and a comparison of the fluid systems with other ore deposit regions of the Variscan age (Siegerland, Ruhr, Schwarzwald), which were studied by the same methods, establishes a post-Variscan age for the studied mineralization. A genetic model of the mineralization is presented; especially complicated relations were found in the deposit Bad Grund. (Authors' abstract, translated by A.K.) (See also adjacent abstracts)

*Sic; this is a typo for 250 g/l (personal communication, Prof. Dr. Horn)

BEHR, H.-J., HORN, E.E., FRENTZEL-BEYME, K. and REUTEL, Chr., 1987, Fluid inclusion characteristics of the Variscan and post-Variscan mineralizing fluids in the Federal Republic of Germany: Chem. Geol., v. 61, no. 1/4, p. 273-285.

Full paper for abstract in Fluid Inclusion Research, v. 18, p. 35, 1985. (E.R.)

BEHR, H.J., HORN, E.E. and REUTEL, Chr., 1987, Fluid inclusion studies (KTB, FRG): Program and preliminary results (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 133. (Also in Terra cognita, v. 7, no. 2-3, p. 126, 1987, and American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and abstracts (unpaginated). Authors at Inst. Geol. & Dynamik der Lithosphäre, Goldschmidtstr. 3, D-3400, Göttingen.

The German continental deep drilling program will sink a 14-km-deep well on the western margin of the Bohemian Massif. This well will penetrate crystalline rocks and tectonic complexes of the internal zone of the central European Hercynian. This region is extremely rich in polymetallic mineralizations and in various protore complexes. High paleofluid activity and very good circulation of deep groundwater containing volcanic $CO_2$ and much Rn and $^3$He have developed. Structurally, the well is located on one of the most important suture zones of the Variscan. This zone is traversed by the largest system of hydrothermal quartz veins in Europe, the Bavarian Pfahl, and is intersected by the Eger graben rich in hot springs. The aim of these studies are the problems of mantle degassing, rock fluids during Hercynian metamorphism, and hydrothermal mineralizations. Based on the results of preliminary studies including drilling an initial model and a program for crustal fluids have been developed.

The principle of polygenetic fluid generations is supported by the preliminary studies. (Authors' abstract)

BEHR, H.J. and NEUSER, R., 1987, Studies of cathodoluminescence of silicate rocks and hydrothermal mineralizations (abst.): Fortschritte der Mineralogie, Bd. 65, Bhf. 1, p. 20 (in German). Authors at Inst. Geol. & Geodynamics of Lithosphere, Univ. Göttingen, FRG.

In hydrothermal minerals, especially in vein quartz, cathodoluminescence reveals the fine structure of the mineral aggregates. This investigation, combined with the microthermometric data, gives a possibility of an exact analysis of the conditions of mineral growth, retrograde dissolution processes and possible pulsation of solutions. (From the authors' abstract, translated by A.K.)

BEHR, H-J. and SCHMIDT-MUMM, A., 1987, The role of sedimentary and tectonic brines in the Damara Orogen, Namibia: Applied Geochem., v. 2, p. 535-542.

See Schmidt-Mumm et al., 1987a,b, this volume. (E.R.)

BELKIN, H.E. and DE VIVO, Benedetto, 1987, The Phlegraean Fields (Italy) water-dominated geothermal system: Fluid inclusions and Sr isotopes (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). First author at U.S. Geol. Survey, MS 959, Reston, VA 22092.

The Phlegraean Fields, located west of Naples in southern Italy, have been known for their thermal manifestations since before the Roman Empire. An extensive geothermal exploration and drilling program began in 1978 by an ENEL and AGIP Joint Venture. Shallow and deep (~3 km) wells were drilled in areas of high thermal gradient (>100°C/km). At shallow depth, partly hydrothermally altered volcanic (mostly trachytic), volcanoclastic, and sedimentary rocks are encountered, whereas at greater depth, their thermometamorphic equivalents are found. The deep wells penetrated saline water-dominated zones with multiple reservoirs; a shallow, moderately saline fluid (~30,000 ppm TDS) and a deep hypersaline fluid (~200,000 ppm TDS). A fluid inclusion (FI) and reconnaissance Sr isotope study on cores from 5 wells (Mofete (MF) 1, 2, and 5; San Vito (SV) 1 and 3) was conducted in order to better understand the evolution of the fluid composition and the geothermal field regime.

P, PS, and S FI amenable to freezing and heating microthermometry occur in calcite, quartz, K-feldspar, and epidote. The FI are classified into three types (all aqueous): A -- two-phase [L(liquid) + V(vapor)], L-rich; B -- two-phase (L+V), V-rich; and C -- multiphase (L+V+crystals), L-rich with NaCl daughter crystals. Type A and B coexist in most samples; the results indicate that boiling has occurred during some stages of FI formation. The determination of first melting suggests the presence of other cations ($Ca^{2+}$) in addition to $Na^+$. 667 Th were measured and range as follows: MF1 = 238° to 354°C, MF2 = 249° to 367°C, MF5 = 356° to 415°C, SV1 = 238° to 354°C, and SV3 = 279° to 335°C. The data are not corrected for pressure; we assume boiling conditions. The correspondence of Th at each investigated level of the 5 wells with present downhole T suggests that the geothermal regime has remained essentially constant for MF1, MF1, SV1, and SV3 whereas cooling is suggested for MF5 (~30°C).

Salinity (wt% NaCl eq.) based on Tm ice (type A) or Tm NaCl (type C) ranges from: SV3 and MF2 = 0.3 to 39.0, MF1 = 0.1 to 6.0, SV1 = 2.2 to >23.0 and MF5 = >23 to 49.0. The salinity systematics, in general, are consistent with the multiple reservoirs found by drilling. Crushing studies reveal the presence of gas (P >1 atm.); the high $pCO_2$ measured in the wells suggests that the FI also contain $CO_2$.

The $^{87}Sr/^{86}Sr$ ratio was measured on carbonate fractions and the leached residue from all 5 wells. For most samples the carbonate fraction is generally higher than the leached residue and suggests the interaction with radiogenically enriched Sr-fluids (e.g., sea water).

FI and Sr isotope data support a model where an influx of sea water at depth (either direct or in buried marine sediments) remains localized in aquifers mainly controlled by rock fracturing. The origin of the hypersaline fluids is equivocal. Simple adiabatic boiling of sea water could not produce these brines. Perhaps a long history of boiling close to the magma chamber and/or the addition of magmatic fluids has produced these brines. (Authors' abstract)

BELKIN, H.E., DeVIVO, Benedetto, MAIORANI, Armando and TRIGILA, Raffaello, 1987a Fluid inclusion study of xenolith and lava cordierites, Lipari (Italy) (abst.): Hawaii Symp. on How Volcanoes Work, Abst. Volume, Hilo, Hawaii, Hawaiian Volcano Observatory, p. 18. First author at U.S.G.S., MS 959, Reston, VA 22092.

We classify the cordierites from Monte S. Angelo (c) and their trapped silicate melt inclusions (MI) into three types. Type A occur in the xenoliths, type B occur as rounded aggregates in the lava, and type C occur as eu- to subhedral, isolated crystals (phenocrysts) in the lava. The compositional range of c of all three types in terms of F(mol) = (FeT + Mn)/(FeT + Mn + Mg) is .40 to .50.

Studied type C MI are primary, whereas type A and B MI are complex and (to date) could not be classified. MI Th studies of type A show no change at 1000°; at >1000°C oxidation of the MI and/or host limit attempts at vapor-liquid homogenization. Preliminary microprobe analyses of the MI give compositions always in the fields of rhyolites and trachytes. Consistent low totals (96-98%) suggest the presence of appreciable dissolved volatiles. Rare $CO_2$ inclusions in type A c and associated K-feldspar yield triple point ~-56.3°C and density >0.46 g/cc.

The presence of P MI in type C c indicates crystallization from a melt and the abundance of MI in type A and B suggest, at least, an intimate association with a melt-rich environment. Thus, it appears that the occurrence of c in Mt. S. Angelo xenoliths and lavas is not just the simple incorporation and disaggregation of metamorphic cordierite-bearing xenoliths but that c was stable on the liquidus and that the xenoliths, are, perhaps, the residue from a zone of melt production. (From the authors' abstract)

BELKIN, H.E., DE VIVO, B., MAIORANI, A. and TRIGILA, R., 1987b Fluid inclusion study of xenolith and lava cordierites from the Monte S. Angelo rhyodacite, Lipari (Italy) (abstr.): Internat'l. Symp. Petrogen. & Mineraliz. Granitoids, Guangzhou (P.R. China), Dec. 1987, p. 12-13.

See previous item. (E.R.)

BELKIN, H.E. and LIBELO, E.L., 1987, Fibers and cylinders of cryptomelane-hollandite in Permian bedded salt, Palo Duro Basin, Texas: Am. Mineral., v. 72, p. 1211-1224. First author at 959 National Center, U.S. Geol. Survey, Reston, VA 22092, USA.

Fibers and thin-walled, hollow cylinders of cryptomelane-hollandite have been found [in and out of fluid inclusions] in both the chevron and the clear salt from various drill cores in Permian bedded salt from the Palo Duro Basin, Texas. Although our observations do not provide a definitive explanation for fiber origin, we suggest that the fibers grew in situ by a solid-state diffusional process at low temperatures.

The cylinders also appear to be single crystals of cryptomelane-hollandite, but these are found almost entirely in fluid inclusions in the chevron and clear salt. Their presence in the primary halite suggests that they were formed contemporaneously with the chevron structure and were accidentally trapped in the fluid inclusions. The cylinders found in the recrystallized salt are perhaps a residue from dissolved chevron salt. The observation of cylinders partially or completely enclosed by salt stratigraphically above large fluid inclusions suggests that natural downward fluid-inclusion migration has occurred, in response to the geothermal gradient. (From the authors' abstract)

BELLANCA, Adriana, DE VIVO, B., LATTANZI, P., MAIORANI, A. and NERI, R., 1987, Fluid inclusions in fluorite mineralizations of northeastern Sicily, Italy: Chem. Geol., v. 61, no. 1/4, p. 209-216.

Full paper for abstract in Fluid Inclusion Research, v. 18, p. 40-41, 1985. (E.R.)

BELVISO, S., JEAN-BAPTISTE, P., NGUYEN, B.C., MERLIVAT, L. and LABEYRIE, L., 1987, Deep methane maxima and $^3$He anomalies across the Pacific entrance to the Celebes Basin: Geochimica Cosmo. Acta, v. 51, p. 2673-2680.

BENNANI, M., MARIGNAC, C. and WEISBROD, A., 1987, Thermal and chemical evolution of the hydrothermal fluids in the tin-tungsten deposit at Tarmilet (Walmes district, central Morocco) (abst.): Terra Cognita, v. 7, no. 2-3, p. 322. Authors at CRPG, Vandoeuvre-lès-Nancy, France.

Fluids associated with Sn are $N_2$-$CO_2$-$CH_4$-bearing waters of low salinity. Th 320-270°C decrease from the early to late cassiterite. The beginning of wolframite deposition is marked by a significant rise in Th. (From the authors' abstract)

BENNETT, P. and SIEGEL, D.I., 1987, Increased solubility of quartz in water due to complexing by organic compounds: Nature, v. 326, p. 684-686.

BENOSMAN, A., VERGOTEN, G., MOSCHETTO, Y. and FLEURY, G., 1987, Computer program for molecular identification based on the use of Raman spectra. Examples of fluid inclusions in minerals: J. Raman Spectrosc., v. 18, no. 5, p. 317-322 (in French).

BENVENUTI, M., BORSELLI, G., CORTECCI, G., LATTANZI, P. and TANELLI, G., 1987, The barite-pyrite deposit of Pollone, Alpi Apuane. (abstr.): Rendiconti Soc. Ital. Mineral. Petrol., v. 42, p. 299 (in Italian).

Reports also microthermometric data on fluid inclusions. (P. Lattanzi)

BENY, C., TOURAY, J.C. and DARDENNE, M., 1987, Raman characterization of carbonates: Application to the determination of rhodochrosite as a daughter-phase in fluid inclusions (abst.): Terra Cognita, v. 7, p. 13. First author at GIS (BRGM-CNRS), 45071 Orleans, France.

See same authors, Fluid Inclusion Research, v. 19, 1986. (E.R.)

BERDNIKOV, N.V., 1986, Comparative study of fluid inclusions in amphibolite and granulitic facies rocks: Geol. Zbornik - Geol. Carpathica, v. 37, p. 719-727 (in Russian; English abstract). Author at Far Eastern Sci. Center of USSR Acad. Sci., Khabarovsk, USSR.

This paper provides the data on fluid inclusions in minerals of high-grade metamorphic rocks of pre-Cambrian basement in the Soviet Far East. It is shown that granulites are characterized by carbon dioxide fluid inclusions. Liquid nitrogen and methane inclusions are observed in pre-Cambrian charnokites. The amphibolite and epidote-amphibolite facies rocks are characterized by carbon dioxide fluid inclusion compositions with minor saline water mixtures. The appearance of carbon dioxide-methane fluid inclusions is related to tectonic evolution of pre-Cambrian blocks in young fold belts. (Author's abstract)

BERDNIKOV, N.V., KARSAKOV, L.P. and KOSYGIN, Yu.A., 1986, Thermobarogeochemical aspects of granulite facies metamorphism, in Thermobarogeokhimiya Endog. Protsessov, Vladivostok, 1986, p. 20-24 (in Russian).

BERNDT, M.E. and SEYFRIED, W.E., Jr., 1987, The chemistry of ridge crest hydrothermal fluids: Cation buffering by plagioclase and epidote solid solutions (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 587.

BERNER, R.A. and LANDIS, G.P., 1987a Chemical analysis of gaseous bubble inclusions in amber: The composition of ancient air? (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 587. See following items. (E.R.)

BERNER, R.A. and LANDIS, G.P., 1987b Chemical analysis of gaseous bubble inclusions in amber: The composition of ancient air?: Am. J. Sci., v. 287, p. 757-962. First author at Dept. Geol. & Geophys., Yale Univ., New Haven, CT 06511.

It has been suggested that gas bubbles enclosed in fossil amber may represent ancient air trapped at the time the original resin was exuded from its host tree. Through the use of quadrupole mass spectrometry, we have analyzed gaseous inclusions in two separate samples of amber from the Dominican Republic whose age is thought to be Oligocene or Miocene. The resulting data are compared with results for Baltic amber (Eocene) taken from the Russian literature, with published analyses of gases in shallowly-buried sediments, and with the composition of modern air. After consideration of a number of possible explanations, it is concluded that the gaseous inclusions represent ancient air modified by (1) the partial reaction of $O_2$ with amber to produce $CO_2$, (2) the addition of small amounts of hydrogen gas and hydrocarbons from amber decomposition, and, in the case of the Dominican amber, (3) the addition of excess argon during burial of the amber in sediments. The data suggest that the Eocene and Oligocene atmospheres, in terms of the principal gases $N_2$, $O_2$, and Ar, were not appreciably different in composition from that of today. (Authors' abstract) See also next item. (E.R.)

BERNER, R.A. and LANDIS, G.P., 1987c, 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. & Geophys., 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 primary bubbles (gas released during initial breakage) these gases represent mainly original 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) (See previous item.)

BETHKE, P.M., 1987, The Creede, Colorado, ore-forming system: A summary model (abst.): Geol. Soc. Am. Abst. with Programs, v. 19, p. 260-261. Author at U.S. Geol. Survey, Reston, VA 22092.

This paper summarizes the results of detailed and comprehensive studies of the ore-petrology, fluid-inclusions, stable isotopes, gas chemistry, Pb isotopes, geochronology, and wallrock alteration in the Creede mining district, Colorado, and of studies of the evolution of the central San Juan caldera cluster; most of these results are presented as individual contributions to the symposium. These individual studies provide multiple evidences that converge to document a synoptic, but still qualitative and still evolving, model of the Creede hydrothermal system.

Ores were deposited from a single hydrothermal system over a strike length of nearly 8 km, including the recently discovered mineralization in the northern end of the district. The system was dominated by two fortuitiously distinctive meteoric fluids: 1) brines that entered the system from the south, and 2) nearly fresh waters that entered from the north. The southern brines achieved their high salinity and isotopic composition by processes of evaporation in a playa lake in the moat of the Creede caldera and later diagenesis. Much of the ore lead was derived from deep Precambrian sources. The heat-source which drove the system was located near the triple junction of the LaGarita, Bachelor and San Luis calderas, as was the upwelling portion of the hydrothermal plume. Boiling, which occurred in the upwelling part of the plume, contributed to mineral deposition and promoted intense sericitic wallrock alteration by condensation of acid volatiles in the overlying ground water. Mixing of the brine with overlying ground water was the primary cause of mineral deposition south of the upwelling plume. The ore fluids were buffered by the assemblage Fe-chlorite+pyrite+hematite+quartz, and solution-crystal equilibrium was closely approached most of the time. In contrast, aqueous sulfide and sulfate did not equlibrate in the ore zone.

This model has evolved over a period of 25 yrs, and continuing modifications are expected. The convergence of evidences suggests, however, that the main structure of the model is fundamentally sound. (Author's abstract)

BETTISON, L.A., SCHIFFMAN, Peter and SMITH, B.M., 1987, Epidosites: Implications for water/rock interaction in submarine hydrothermal systems (abst.): EOS, v. 68, p. 1546. First author at Dept. Geol., Univ. California, Davis, CA 95616.

Petrographic, fluid inclusion, electron microprobe, XRF, and oxygen isotope data on epidosites (i.e., diabase recrystallized to epidote + quartz ± chlorite, with no relict igneous textures) suggest that these rocks formed within the high T upflow portions of ancient submarine hydrothermal systems. P-corrected Th of aqueous fluid inclusions in quartz from epidosites are bimodal, characterized by a high T (convectively? heated) period of quartz precipitation (325-365°C) and later lower T (conductively? cooled) quartz growth (300-265°C). Salinities and calculated $\partial^{18}O$ of fluids in equilibrium with epidosites (+1.6 to -2.0‰ SMOW) of epidosite-forming fluids are consistent with their derivation from modified Cretaceous seawater. These hydrothermal fluids are presumed to be similar to those venting from modern submarine hot springs: they are Mg-depleted and Ca, Si, and H enriched with respect to seawater. (From the authors' abstract)

BICKLE, M.J., 1987, The transport of heat and matter by fluids during metamorphism (abst.): Abstracts, NATO Advanced Research Workshop, Fluid movements, element transport, and the composition of the deep crust, Lindås, Norway, 18-24 May, 1987 (unpaginated).

BICKLE, M.J. and McKENZIE, D., 1987, The transport of heat and matter by fluids during metamorphism: Contrib. Mineral. Petrol., v. 95, p. 384-392.

BIN, Cui, 1987, The alteration zoning and origin of the Tongguanshan stratabound skarn type copper deposit: Mineral Deposits, v. 6, no. 1, p.

35-44 (in Chinese; English abstract). Author at Beijing Grad. Sch., Wuhan College of Geol.

Td ranges from 340°C to 987°C. (E.R.)

BIRD, D.K., ROGERS, R.D. and MANNING, C.E., 1986, Mineralized fracture systems of the Skaergaard intrusion, East Greenland: Meddr. Grønland, Geosci., v. 16, 68 pp., Copenhagen 1986-12-16.

Extensive fracture systems in the Skaergaard intrusion, including veins, sills and dikes, constitute channels for the flow of magmas and hydrothermal solutions during the subsolidus cooling and deformation of the intrusion. The abundance, orientation, transgressive relations and mineralogy of these fracture systems provides a record of fluid transport and chemical reactions during the Skaergaard's subsolidus cooling history. (From the authors' abstract)

Quartz veins, some with epidote and feldspar, in metabasalts marginal to the Skaergaard intrusion have Th 130-340°C and ~2-10 wt % NaCl eq.(E.R.)

BISHOP, B.P. and BIRD, D.K., 1987, Variation in sericite compositions from fracture zones within the Coso Hot Springs geothermal system: Geochimica Cosmo. Acta, v. 51, p 1245-1256.

BLAKE, Stephen, 1987, Can cumulus crystals be erupted from the floor of a magma chamber? (abst.): Hawaii Symp. on How Volcanoes Work, Abst. Volume, Hilo, Hawaii, Hawaiian Volcano Observatory, p. 21. Author at Geol. Dept., Univ. Auckland, Private Bag, Auckland, New Zealand.

[The results of scaled experiments suggest] that most olivine-accumulative lava have an origin which is not reliant on the presence of unconsolidated cumulates in their source chamber. (From the author's abstract)

BLAMART, D., BOUTALEB, M., MARIGNAC, Ch., SHEPPARD, S.M.F. and WEISBROD, A., 1987, The Walmes granitic complex (central Morocco): An example of subsolidus tin specialization (abst.): Terra Cognita, v. 7, no. 2-3, p. 231. Authors at CRPG, Vandoeuvre-lès-Nancy, France.

Water in equilibrium with the most δD enriched micas have δD values similar to those of the fluid inclusions from the vein cassiterite mineralization (δD - 30%.) indicating that much of the two-mica granite and all of the muscovite granites have been modified by externally derived post-magmatic fluids. (From the authors' abstract)

BLASCH, S.R. and COVENEY, R.M., Jr., 1987a. Goethite-bearing brine inclusions, petroleum inclusions, and the conditions of ore deposition at the Jumbo mine, Kansas (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 590-591. Authors at Dept. Geosci., Univ. Missouri-Kansas City, Kansas City, MO 64110-2499.

Petroleum-bearng fluid inclusions are abundant in sphalerite, calcite, dolomite, and barite at the Jumbo mine in eastern Kansas. These and coexisting Na-Ca-Mg-Fe-Cl brine have Th ranging from 88 to 130°C for sphalerite to below 50°C for barite, similar to inclusions from other Mississippi Valley-type (MVT) ores. The inclusions imply the nearly continual presence of warm hydrocarbon-bearing brines during mineralization.

Daughter minerals are rare in MVT deposits, but orange-red blades and prisms of goethite occur as daughter crystals in calcite-hosted primary brine inclusions at the Jumbo. Goethite has also been tentatively identified in inclusions from the Fletcher mine in southeast Missouri. The abundance of goethite daughter crystals reflects the existence of >200-1200 ppm dissolved Fe in the mineralizing fluids. Its presence implies that oxidation occurred during emplacement of the Jumbo and Fletcher ores, perhaps because of mixing between hydrothermal fluids and groundwater. This suggests the influence of several processes, including cooling or dilution of the ore fluids, pH changes, and oxidation of organo-metallic complexes, as possible causes of ore deposition. (Authors' abstract)

BLASCH, S.R. and COVENEY, R.M., Jr., 1987b Fluid inclusions at the Jumbo mine, Kansas, compared with those from other Mississippi Valley-type ores (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Authors at Dept. Geosci., Univ. Missouri-Kansas City, Kansas City, MO 64110-2499.

The ores of the Jumbo mine are located in a circular structure situated in Middle Pennsylvanian-age cyclothemic strata. Both brines and petroleum occur as fluid inclusions in sphalerite, barite, calcite and dolomite from the now-defunct Jumbo mine. Th and salinities for aqueous inclusions are similar to those in other Mississippi Valley-type ore deposits (e.g., measured Th inclusions hosted by sphalerite = 90 to 130°C), although the mine is located over 100 km from the nearest mining districts, Tri-State and Central Missouri. Oil inclusions in Jumbo mine sphalerite are unusually common and have Th which are about 10-20 degrees lower than coexisting aqueous inclusions. Probably because of the wetting properties of the host mineral, the primary oil inclusions in sphalerite differ in shape from the rounded droplets of organic matter found commonly in fluorite from southern Illinois, in being elongate and stringy. Similar elongate oil inclusions have been found to occur in sphalerite at Oronogo, near Joplin, Missouri.

Aqueous inclusions in calcite contain daughter crystals of goethite, identified using SEM and X-ray diffraction techniques. Goethite (identified tentatively by SEM and optical techniques) also occurs within inclusions hosted by calcite from the Viburnum Trend. The presence of an oxidized iron-bearing mineral species in inclusions may indicate high oxygen fugacities for mineralizing fluids during deposition of calcite in Mississippi Valley-type ores. (Authors' abstract)

BLATTNER, P., McKIBBIN, R. and ABSAR, A., 1987, Stable isotope fronts and crustal buffering - 1-dimensional mass balance and kinetics (abst.): Abstracts, NATO Advanced Research Workshop, Fluid movements, element transport, and the composition of the deep crust, Lindås, Norway, 18-24 May, 1987 (unpaginated).

BOADI, I.O., NORMAN, D.I. and ROBERTSON, J.M., 1987, The Hopewell Lake gold district, Tusas Mountains, New Mexico (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 593. First author at Geosci. Dept., New Mexico Inst. Mining & Tech., Socorro, NM 87801.

The Hopewell Lake deposit occurs in 1.7 to 1.8 Ma metavolcanics intruded by the granite of Hopewell Lake. Au occurs in veins that follow foliation planes and are generally <40 cm wide. Grades exceed 1000 ppm. Veins consist of quartz, Fe-carbonates, pyrite, chalcopyrite, arsenopyrite, native Au, specularite, galena, and sphalerite. Pyrite halos that extend several meters from some mineralized veins contain up to 10 ppm Au. Principal alteration minerals are Fe-carbonate, dolomite, sericite, and chlorite. Au is associated with the Fe-carbonate alteration and dolomite appears to predate ore mineralization.

Primary fluid inclusions are of two types: one has mostly $CO_2$ and the other has 5 to 10% $CO_2$ in a 6.8 to 11.9 eq wt% NaCl brine. Th values are mostly between 270 and 330°C and Pt is calculated to be about 1500 bars. Rb/Sr isotopic measurements of the altered granite yields an isochron age of 1467 ± 32 Ma and IR = 0.70256 ± 29 ($2\sigma$).

The deposit is remarkably similar to Archean Au deposits in the Canadian shield and the fluid inclusions and field evidence are consistent with either mineralization from fluids generated after the peak of metamorphism or from the granite. Rb/Sr isotopic systematics indicate alteration fluids had a juvenile source, hence suggest the ore solutions were magmatic. The fluid inclusions data suggest Au deposition was associated with unmixing of $CO_2$-rich solutions. (Authors' abstract)

BODINE, M.W., Jr., HAY, R.L., MADSEN, B.M. and ALTANER, S.P., 1987, Lacustrine volcaniclastic sediments in the Creede Formation, San Juan Mountains, Colorado (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 261-262. First author at U.S. Geol. Survey, Denver, CO 80225.

Abundant crystal molds with gaylussite morphology suggest lengthy periods of alkaline evaporite-lake conditions. Clinoptilolite, analcime, erionite, and K-feldspar were formed in contact with saline, alkaline pore fluid, but bentonites reflect localized hydrothermal alteration during Creede Formation deposition. Varved lacustrine sediments consisting largely of opal-CT or quartz probably resulted from hydrothermal discharge into the lake, possibly from the travertine-forming vents. Heulandite is anomalous in sediments of a saline, alkaline lake and may have formed by reaction of glass with hydrothermal solutions that displaced the saline, alkaline pore fluid. (From the authors' abstract)

BODNAR, R.J., 1987a Applications of synthetic fluid inclusions to experimental geochemistry and fluid inclusion research (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Author at Dept. Geol. Sci., Virginia Polytech. Inst. & State Univ., Blackburg, VA 24061.

Microthermometric analyses of synthetic fluid inclusions formed by healing fractures in Brazilian quartz at known PTX conditions indicate that the inclusion properties (composition and density) are identical to those of the fluid present at formation conditions. This observation proves that the two basic assumptions of all fluid inclusion studies, that is, (1) that inclusions contain a fluid with a composition identical to that of the parent fluid from which they were trapped, and that (2) fluid inclusions represent constant volume systems, are valid, contrary to other recently published data which suggest that these assumptions are not valid. Because inclusions do trap a fluid representative, in all respects, of the parent solution, they may be used to study a variety of fluid PVTX properties over a range of T and P.

Synthetic fluid inclusions have been used to determine volumetric properties of $H_2O$ and a 20 wt% KCl solution from 300-700°C and 1-3 kb. Comparison of results obtained for $H_2O$ with previously published values indicates that synthetic fluid inclusions provide PVT data that are within a few percent of those obtained using conventional techniques. Studies are currently in progress to determine PVT properties in the geologically important $H_2O$-$CO_2$-NaCl system.

Phase equilibria in the $H_2O$-NaCl system have been determined to 1000°C and 1500 bars using synthetic fluid inclusions trapped in the two-fluid-phase-field. Inclusions that trap the liquid phase contain halite daughter minerals at room T; those which trap the low salinity phase in equilibrium with the liquid are two-phase, vapor-rich inclusions at room T. A complete range in room T phase ratios between these two end member populations is also found; these represent inclusions which have trapped mixtures of the two immiscible phases present at formation conditions. Microthermometric analysis of those inclusions which trapped only a single, homogeneous phase have been used to define phase equilibrium characteristics in the $H_2O$-NaCl system, based on Tm NaCl and Tm ice of high salinity and vapor-rich inclusions, respectively. Studies are currently in progress to determine phase relations in the $H_2O$-NaCl-KCl and $H_2O$-$CO_2$-NaCl systems, as well as the critical points of various electrolyte solutions.

Synthetic fluid inclusions have been used to investigate the problem of re-equilibration of natural inclusions during retrograde metamorphism. Pure $H_2O$ fluid inclusions were trapped at 700°C and 7 kb and then re-equilibrated at 700°C and various P ranging from 2-6 kb. The re-equilibrated inclusions exhibit Th consistent with internal P ~500-1500 bars higher than the confining P at the P-T conditions of re-equilibration. These data suggest that P-T conditions inferred from natural inclusions from regionally metamorphosed samples will correspond to P intermediate between initial formation P and final re-equilibration P. (Author's abstract)

BODNAR, R.J., 1987b Use of fluid inclusions in precious metals exploration (abst.): Program with Abstracts, Symp.: Bulk Mineable Precious Metal Deposits of the Western United States, April 6-8, 1987, Geol. Soc. Nevada, p. 58-59. Author at Dept. Geol. Sci., Virginia Polytech. Inst. & State Univ.

Fluid inclusions provide one of the best techniques available for defining the physical and chemical environment attending various geologic processes, and reconnaissance fluid inclusion petrographic analysis should be a routine and integral part of the geological snd geochemical screening process used to evaluate precious metal targets. Specifically, fluid inclusions provide perhaps the most efficient method available for quickly identifying the general environment of formation (i.e., plutonic, volcanic, metamorphic) because inclusions trapped in these different settings exhibit compositional and thermal properties which are characteristic of the environment of formation. Thus, simple petrographic examination of the inclusions in a sample is sufficient to determine whether the quartz precipitated in the epithermal environment or in the deeper plutonic or medium-to-high grade regional metamorphic environment. Such information is obviously vital to the explorationist, particularly during the initial stages of exploration in a region where the geology is poorly known. It is important to note that, although fluid inclusions may be used to identify environments favorable for precious metal mineralization, they unfortunately will not tell the explorationist whether mineralization is, in fact, present.

Fluid inclusion petrography is particularly useful for identifying samples formed under epithermal conditions. Characteristics of fluid inclusions trapped in the epithermal environment contrast markedly with those of inclusions formed in deeper environments, such as the porphyry environment, and these features may be used to identify samples formed at relatively shallow crustal levels. Most inclusions from the epithermal environment contain only two phases at room T - a low salinity (<5 wt. % NaCl eq.) aqueous solution and a vapor bubble. Daughter minerals of halite, sylvite and opaque phases are not found, although a birefringent, fibrous mineral often identified as dawsonite is not uncommon. Epithermal inclusions rarely homogenize above ~325°C, and most epithermal ore deposits are characterized by inclusions with Th in the range ~250-280°C.

Detailed fluid inclusion studies of many epithermal ore deposits, as well as direct observation of their contemporary equivalents, the terrestrial geothermal systems, indicate that immiscibility (boiling) and the presence of volatiles, mainly $CO_2$ and $H_2S$, significantly facilitate the transport and deposition of gold in the epithermal environment; these observations are supported by numerous theoretical and experimental data. Fluid inclusions provide the best, and often only definitive, evidence for boiling and/or the presence of dissolved gases in the ore fluids. Moreover, results of numerous fluid inclusion studies suggest that the depth range over which precious metal mineralization is found often corresponds to the range over which evidence of boiling is found. [If true], fluid inclusions may provide a powerful exploration tool in the search for epithermal precious metal mineralization. (From the author's abstract)

BODNAR, R.J. and STERNER, S.M., 1987, Synthetic fluid inclusions: Chapt. 17 in G.C. Ulmer and H.L. Barnes, eds., Hydrothermal Experimental Techniques: New York, J. Wiley & Sons, p. 423-457.

A thorough review of the procedures used and the many applications in solubility studies (NaCl-$H_2O$, NaCl-KCl-$H_2O$), P-V-T studies ($H_2O$, KCl-$H_2O$), critical properties ($H_2O$), phase equilibrium properties (NaCl-$H_2O$), and the system NaCl-$H_2O$-$CO_2$. (E.R.)

BOETTCHER, Art, WHITE, B.S. and BREARLEY, Mark, 1987, Nitrogen, argon, and other volatiles in silicate systems at high pressures and temperatures (abst.): EOS, v. 68, p. 1542.

BOHLKE, J.K., KIRSCHBAUM, C., IRWIN, J.J. and GLASSLEY, W.E., 1987, Laser-microprobe analyses of noble gas isotopes in fluid inclusions in neutron-irradiated quartz veins (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 594. First author at Argonne Nat'l. Lab., Argonne, IL.

Individual fluid inclusions and small groups of inclusions from irradiated samples of gold-bearing quartz veins from Alleghany, Calif., were decrepitated under vacuum using a laser, and the noble gases released were analyzed. In addition to natural noble gas abundances and isotopic ratios, the amounts of Cl, K, Ca, Se, Br, Te, I, Ba, and U were obtained from analysis of Ar, Kr and Xe isotopes produced during the neutron irradiation.

Fluid inclusions from Alleghany contain <10 mole % $CO_2$ and <5% total dissolved solids (including bicarbonate). Fluids with relatively high $CO_2$ contents are believed to have caused wall-rock metasomatism (carbonatization) along the veins, and to have transported gold. Analyses of noble gases indicate that the Alleghany fluid inclusions have relatively constant K/Cl ratios (~0.3 by wt), consistent with calculated solid phase Na/K buffers and SEM/EDA analyses of salts from decrepitated inclusions. The halogen ratios are Cl/I = 200-400, Cl/Br = 100-300 by wt. The Cl/I ratios of the included fluids are lower than those of seawater or most hot spring waters and resemble those of NaCl-type connate brines or possibly 'metamorphic spring waters' (D.E. White, USGS PP 440F). The isotopic compositions of dissolved noble gases within inclusions could indicate that some of the vein-forming fluids originated at the Earth's surface, and were modified during deep circulation. The relative abundances of halogens, Xe and Kr are variable, and indicate the possibility of fluid mixing and/or unmixing. (Authors' abstract)

BOIRON, M.-C., 1987, Gold, arsenic and antimony mineralization, hydrothermal alteration, and associated fluids in the Villeranges Basin (Combrailles, Massif Central, France): Géol. Géochim. Uranium, Mem. [CREGU] Nancy, 1987, v.15, 310 pp.

Au-As-Sb deposits occur within highly faulted zones. Three stages of different spatial or metallogenic importance have been recognized in the Villeranges district:

1) An early alteration (1) to chlorite-albite-anatase (± quartz, calcite, phengite, pyrite). Alteration is the result of a pervasive circulation of aqueous fluids, having low salinities (1-4 wt.% eq. NaCl), at ~250-310°C.

2) Late tectonic reactivation produced strong macro and microfaulting and favored intense circulation of hydrothermal fluids. In the Farges area assemblage (1) is changed to phengite + ankerite + quartz + pyrite, ± Au and arsenopyrite, by aqueous fluids having low salinities, at ~240 ± 30°C.

Then quartz + ankerite + pyrite + arsenopyrite + Au, veinlets, and finally massive stibnite. The ore fluids are purely aqueous, have low salinities (<3 wt.% eq. NaCl) and provoke a complete alteration of earlier assemblages to illite + quartz + ankerite association. Arsenopyrite deposition occurred at ~180 ± 20°C, low pH, rather low $fO_2$ and high $fS_2$.

3) Low T (90 ± 20°C) fluids circulated, forming calcite, quartz and pyrite.

Such ore genesis is significantly distinct from other gold-bearing quartz veins commonly described in the French Massif Central. (From the author's abstract)

BOIRON, M.C. and CATHELINEAU, M., 1987a Geothermometry of hydrothermal alterations and associated mineralizations in tuffs of the Villeranges Visean basin (Massif Central, France) (abst.): Terra Cognita, v. 7, no. 2-3, p. 318. Authors at Lab. Pétrol. de la Surface, Poitiers, France.

Combined studies of mineral paragenesis, and fluid inclusions give good constraints to the P-T-X conditions of ore formation.

Three successive but distinct stages are observed: 1. Pervasive fluids first altered Fe-Mg-bearing to chlorite, at ~280 ± 30°C. Then crystallization of K-micas, illites, and ankerite.

Illites are related to the Au, Sb and As ore. Ore fluids are aqueous, 1-3 wt % eq. NaCl, and Tt ~200°C. (From the authors' abstract)

BOIRON, M.C. and CATHELINEAU, 1987b The crystallization temperature of hydrothermal clay minerals: The data from fluid inclusions and clay geothermometers: Summaries - Proc. 6th Meeting of the European Clay Groups, Seville, Spain, 1987, p. 124-126. First author at Lab. Pétrol. de la Surface, Univ. Poitiers, UA CNRS 721, 40, Avenue du Recteur Pineau 86022 Poitiers Cédex, France.

Carboniferous volcanics from the northern part of the French Central Massif are affected by a strong multistage alteration. Two stages can be distinguished: 1) An early pervasive fluid circulation altered biotites to chlorites (brunsvigites), at >300°C. S fluid inclusions indicate Tt >300°C (P correction ~30°C-50°C). 2) Later fluids realtered to K-micas, ankerite and quartz along fractures. Inclusions (P) in coexisting quartz show a minimum Tt of 180 ± 20°C. (From the authors' abstract)

BONEH, Hanoch and KISCH, H.J., 1987, Fluid inclusions in pegmatites and quartz segregations in the metamorphic complex of Elat (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 13-14. Authors at Dept. Geol. & Mineral., Ben-Gurion Univ. of Negev, Beer-Sheva 84105, Israel.

The Precambrian metamorphic complex of Elat is part of the northern margin of the Arabo-Nubian massif. The complex includes a series of pelitic rocks ranging from biotite to cordierite grade (with occurrence of andalusite and/or sillimanite), orthogneisses and ortho-amphibolites, and younger magmatic rocks. Quartz segregations and pegmatites are common throughout the area.

Quartz crystals in the pegmatites and the quartz segregations have been found to be rich in fluid inclusions. Fluids in the inclusions contain $H_2O$, $CO_2$ and salts. $CO_2$ as a separate phase exists only when the metamorphic grade of the host rock exceeds biotite grade. The relationship between metamorphic grade and fluid composition suggests that the P inclusions were formed during the main phase of metamorphism. Similarity of P fluid inclusions in many pegmatites to those in nearby quartz segregations points to synmetamorphic crystallization of those pegmatites. Fluid density, calculated from Th, suggests low P and T metamorphism, in agreement with the metamorphic assemblages.

Inclusions which have undergone natural decrepitation and inclusions with anomalous low fluid density are common in most samples. This phenomenon can be explained by either post metamorphic uplift rates having exceeded cooling rates, and/or later magmatic intrusions. Release of strain within the rocks, especially in zones of strong deformation, might have added to this low fluid density.

The composition of P inclusions indicates that molar fraction of $CO_2$ in the synmetamorphic fluid was variable and reached values >0.50. No corrleation was found between the amount of $CO_2$ and the host rock type suggesting that the $CO_2$-rock system was open. The changes in the $CO_2$-$H_2O$ ratio probably result from variations in the original amount of $CO_2$ which flowed to different zones in the complex. It is suggested that hot $CO_2$ fluxes from a deep source contributed to the high heat flow during the main phase of metamorphism. (Authors' abstract)

BORIANI, A., KOVALENKO, V.I., NAUMOV, V.B. and SOLOVOVA, I.P., 1987, New data on Pantelleria magmatic rock origin based on melt inclusions (abst.): Rendiconti della Soc. Italiana di Mineralogia e Petrologia, v. 42, part 1, p. 179-180. First author at Dipt. Sci. della Terra, Univ. Milano, Italy.

Same as Boriani et al., 1986, Fluid Inclusion Research, v. 19, p. 51. (E.R.)

BORNHORST, T.J., SHEPECK, A.W. and ROSSELL, D.M., 1986, The Ropes gold mine, Marquette County, Michigan, U.S.A. - An Archean hosted lode gold deposit, in GOLD '86, Proceed. Vol., A.J. Macdonald, ed., p. 213-227. First author at Dept. Geol. & Geol. Engrg., Michigan Tech. Univ., Houghton, MI 49931, USA.

The Ropes deposit is confined to a nearly vertical, tabular, schistose, ore host rock body in serpentinite. Archean hydrothermal gold and silver mineralizataion in the form of en echelon quartz veins and associated disseminated halos were a result of metamorphic and/or magmatic fluid flow within the shear zone, particularly in tension gashes. Cumulative evidence suggests that the Ropes ore body is epigenetic and syntectonic.

Fluid inclusions in 9 out of 15 doubly-polished, plates of quartz and carbonate were selected based on their isolation and shape. Due to the presence of abundant fractures, the degree of isolation was often difficult to determine. Isolated inclusions are more common in the less deformed, later stage vein material. Many fluid inclusions follow fractures and cleavage planes. Most of the analyzed fluid inclusions are very small (3-9 µm, average 5 µm) and have a wide variety of shapes. None of the inclusions analyzed exhibited any evidence of necking down and most contained a gas and a liquid phase with relatively constant volume percent. Only one inclusion showed evidence of two fluid components, $H_2O$ and probably $CO_2$.

Th, uncorrected for pressure, of 100 relatively isolated fluid inclusions in quartz show three temperature peaks, 185-235°C, 240-290°C, and 300-320°C. Inclusions along fracture planes homogenized at temperatures between 120° and 180°C. The highest homogenization temperatures were from early Type 1 quartz (240-340°C) whereas Type 2 quartz did not contain fluid inclusions which homogenized above 235°C. Homogenization temperatures for dolomite fall between 215° and 250°C. Salinity measurement by freezing point determinations was not attempted due to the small size of the inclusions. No daughter products were seen in any of the inclusions. By analogy with Archean lode-gold deposits in Canada, the salinity of the fluid may have been low, perhaps <3 equiv. wt. % NaCl.

Quantification of the confining pressure during mineralization at Ropes is not possible from our data base. The regional middle greenschist metamorphic grade of the surrounding Kitchi Schist is similar to that of many other Archean lode-gold deposits where confining pressure estimates have been estimated by Kerrich. If a confining pressure of 2 kb is hypothesized for the Ropes deposit, a pressure corrected temperature for the deposition of Type 1 quartz would be 510° and 440°C, while Type 2 quartz and cabonate veins would be between 390° and 370°C. These conjectural temperatures compare well with the average temperature range of 380° to 480°C determined by Kerrich for Archean lode-gold deposits. (Modified from the authors' abstract)

BORODENKO, Yu.A., KATRICH, N.P. and TIMAN, B.L., 1987, Laws of formation of gaseous inclusions in growth of crystals of leucosapphire: Kristallografiya, v. 32, p. 473-477 (in Russian; translated in Sov. Phys. Crystallogr., v. 32, no. 2, p. 276-278). Authors at Sci.-Ind. Assoc. "Monokristallreaktiv."

The authors make a comparison of the experimentally established laws of formation of gaseous inclusions during growth of crystals of leucosapphire by the method of directed crystallization with the theoretical laws based on the idea of preferential formation of gaseous inclusions on the boundaries of the cellular structure due to concentration supercooling ahead of the crystallization front in the melt. (Authors' abstract)

BOTTINGA, Y. and JAVOY, M., 1987a Comments on stable isotope geothermometry: The system quartz-water: Earth & Planet. Sci. Letters, v. 84, p. 406-414.

BOTTINGA, Y. and JAVOY, M., 1987b Bubble talk (abst.): Terra Cognita, v. 7, no. 2-3, p. 141. Author at Inst. Phys. du Globe de Paris, Paris, France.

Our preliminary calculations indicate that, contrary to popular belief, under ordinary circumstances, characterized by basalts containing less than 400 ppm $CO_2$ in solution at P between 0.25 and 0.5 kbar and T of ~1200°C, nucleation of bubbles is homogeneous and must occur at high degrees of supersaturation (>4) and relative low P (less than 2 kbar). The homogeneous nature of the nucleation process is also indicated by the common spatial distribution of bubbles in submarine basalts. The observed minimum bubble size of about .5 micron radius, the occurrence of more than one generation of bubbles, and the important measured variations in dissolved $CO_2$ in submarine basalts are readily explainable in terms of the high degree of supersaturation needed for homogeneous bubble nucleation. (From the authors' abstract)

BOTTRELL, S.H. and YARDLEY, B.W.D., 1987, A modified crush-leach method for the analysis of fluid inclusion electrolytes (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 15-16. Authors at Dept. Earth Sci., Univ. Leeds, Leeds, LS2 9JT, UK.

New data is presented on the adsorption of ions released during crush-leach analysis onto the new quartz surfaces generated. These show very significant losses of divalent cations from solution when the leaching agent used is pure water. Thus any technique utilizing water as a leaching agent will generate analyses of inclusion electrolytes which are systematically in error. Further experiments were conducted using $H^+$ and $La^{3+}$ in the leach solution as adsorption inhibitors and from the results of these we have developed a crush-leach analysis technique in which errors due to adsorption effects are minimal.

This technique utilizes a variety of leaches tailored to minimize adsorption of one or more ions and to be compatible with analytical procedures for that element. Methods of analysis used are Atomic Absorbtion Spectrometry, Flame Emission Spectrometry, fluorimetry and Specific Ion

Electrode. At present analyses can be performed for Na, K, Li, Rb, Ca, Mg, Fe, Mn, Zn, Al, Cl and F.

Preliminary results on inclusions in quartz veins from both low and high grade metamorphic rocks show good agreement with theoretically predicted compositions from fluid-mineral equilibria for Na, K, Fe, Mn and Zn. However Ca and sometimes Mg are present at levels far higher than predicted; this is thought to be due to the presence of Ca-rich inclusions (which have been identified microthermometrically in some of the samples). A second set of data from post-metamorphic gold-bearing quartz veins from the Monte Rosa district of Italy, where only one generation of inclusion fluids is present, show better agreement with calculated compositions with no excess Ca or Mg. (Authors' abstract)

BOUDREAU, A.E. and McCALLUM, I.S., 1987, Halogens in apatites from the Stillwater Complex: Preliminary results (abst.): EOS, v. 68, p. 1518. Authors at Univ. Washington, Dept. Geol. Sci., AJ-20, Seattle, WA 98195.

The F, Cl and OH variation in apatite is not constrained by crystal-chemical factors (in contrast to micas and amphiboles), and thus changes in the abundance of these components provide an excellent indicator of halogen fugacity variations. To date, we have examined apatites from 9 subzones of the Stillwater Complex, ranging from the Basal series to the top of the Upper Banded series. The apatites, all of which are noncumulus, fall into two distinct compositional fields. F-rich apatites, which contain >1.2 wt. % F and <2.5 wt. % Cl, occur throughout the complex but mainly in quartz-bearing anorthosites. The most F-rich occur at the top of the complex. Cl-rich apatites, which contain <1.2 wt. % F, >3.0 wt. % Cl and up to 2 wt. % $Ce_2O_3$ + $La_2O_3$, occur with olivine and biotite-bearing assemblages in the Ultramafic series and OB I of the Banded series. Cl and F contents in both groups are lower in rocks affected by low T metamorphic fluids. Because no common minerals, hydrous or otherwise, are likely to fractionate Cl in preference to F, the increase in F with stratigraphic height and the lack of Cl-rich apatite high in the complex suggest that Cl was lost to an exsolving volatile fluid over the course of crystallization. Any high T fluids exsolving and circulating through the lower 1/3 of the complex must have been enriched in Cl and may have transported trace metals. Comparison with published data suggests a broad correlation of Cl content of apatite with the PGE content of sulfide-bearing rocks. (Authors' abstract)

BOULLIER, A.M., MICHOT, G. and PECHER, A., 1987, Diffusion and/or plastic deformation around fluid inclusions in synthetic quartz: X-ray topography and T.E.M. investigations (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 157. Also in Abstracts, NATO Advanced Research Workshop, Fluid Movements, Element Transport, and the Composition of the Deep Crust, Lindås, Norway, 18-24 May, 1987. (Also in Terra cognita, v. 7, p. 131.) First author at Centre de Rech. Pétrogr. & Géochim., B.P. 20, 54501 Vand.-lès-Nancy Cedex, France.

Synthetic quartz containing fluid inclusions ($H_2O$ + 0.5N NaOH) was annealed at high T (448°C) and confining P (Pc = 200 or 350 MPa). Changes in the shape of the inclusions were observed together with variations of their filling densities which depend on the value of the internal P, Pi; the latter tends to equilibrate with the confining P, Pc. X-ray topography after treatment reveals a contrast around the modified fluid inclusions.

The changes of shape are due to dissolution-crystallization processes and are sensitive to Pi. The density variations are independent of the change of shape: they indicate that diffusion processes (positive or negative exchange between quartz and fluid inclusion) took place together with a possible plastic deformation of the wall (few dislocations have been observed in T.E.M.). The driving force could be the elastic strain energy due to the difference in P between the fluid inclusion and the confining medium. (Authors' abstract)

Note - This abstract was a late addition and hence is not in the bound volume of abstracts. (E.R.)

BOURCIER, W.L. and BARNES, H.L., 1987, Ore solution chemistry - VII. Stabilities of chloride and bisulfide complexes of zinc to 350°C: Econ. Geol., v. 82, p. 1839-1863.

BOWMAN, J.R., PARRY, W.T., KROPP, W.P. and KRUER, S.A., 1987, Chemical and isotopic evolution of hydrothermal solutions at Bingham, Utah: Econ. Geol., v. 82, p. 395-428. First author at Dept. Geol. & Geophys., Univ. Utah, Salt Lake City, UT 84112.

Systematic changes in mineral assemblages, mineral compositions, fluid inclusion characteristics, and hydrogen and oxygen isotope compositions in altered igneous rocks in the Bingham, Utah, porphyry copper deposit record the chemical and isotopic evolution of the hydrothermal solutions.

Temperatures and salinities from fluid inclusions range from greater than 600°C and 50 eq wt % NaCl for the potassic zone to ~370°C and 33 wt % for the propylitic zone. Coexisting liquid-rich and vapor-rich inclusions which homogenize at T similar to the liquid and vapor phase, respectively, suggest boiling from the potassic core out to the potassic-propylitic transition zone. Compositions and Th for fluid inclusions suggest average $P_{(f)}$-T conditions which vary smoothly from the potassic core to the propylitic fringe: 600°C and 800 bars for the potassic zone, 450°C and 500 bars for the transition zone, and 350°C and 200 bars for the outer propylitic zone.

The extent of oxygen isotope exchange between the hydrothermal vein fluids and the igneous rock matrix in the Bingham stock increases with increasing T, abundance of alteration and quartz veins, thickness of veins, and fracture intensity. Calculated $\delta^{18}O$ and $\delta D$ values of early fluid range from 6.8, -67 per mil in the potassic core to 5.1, -41 per mil in the outer propylitic zone, showing a systematic trend of $^{18}O$ depletion and deuterium enrichment with decreasing T outward from the innermost potassic zone. This trend is inconsistent with the progressive influx of local meteoric waters ($\delta D < -80\%$ ). Either of two alternative hypotheses may account for the observed trend.

Late-stage fluids responsible for sericitic and argillic alteration are progressively depleted in $^{18}O$ and deuterium, consistent with an increasing, and finally dominant, meteoric water component. If fluid-rock isotopic exchange has been the dominant mechanism in defining the isotopic compositions of the hydrothermal fluids at Bingham, then this later hydrothermal system was characterized by shallower circulation and higher water/rock ratios than was the system responsible for the development of the early hydrothermal fluids. (From the authors' abstract)

BOYD, S.R. and PILLINGER, C.T., 1987, Do nitrogen isotopes allow us to relate terrestrial mantle carbon to meteorite progenitors? (abst.): Meteoritics, v. 22, p. 334. Authors at Planet. Sci. Unit, Dept. Earth Sci., Open Univ., Milton Keynes, UK.

To investigate the covariance of $\delta^{13}C$, nitrogen concentration and aggregation state and $\delta^{13}C$ both within and between diamonds of known provenance we have been studying 250 x 250 x 250 μm [samples] which have been laser sectioned from centimeter sized specimens after characterization by various spectroscopic techniques and cathodoluminescence. A data base established for 200+ analyses is able to recognize specific regions in $\delta^{13}C$

vs $\delta^{15}$NB space which can be discussed within the frame work of the models suggested to explain $\delta^{13}$C only. (From the authors' abstract)

BOYD, S.R., PILLINGER, C.T., MILLEDGE, H.J., MENDELSSOHN, M.J. and SEAL, M., 1987, Another way to fractionate isotopes (abst.): Meteoritics, v. 22, p. 334-335. First author at Planet. Sci. Unit, Dept. Earth Sci., Open Univ., Milton Keynes, UK.

A discussion of the effect of host structure on isotopic fractionation, involving $\delta^{13}$C and $\delta^{15}$N in octahedral and cubic types of diamond. (E.R.)

BRADLEY, M.A., 1987, Vein mineralogy, paragenetic sequence and fluid inclusion survey of the Silver district, La Paz Co., Arizona: MS thesis, Univ. Arizona.

The Silver mining district contains 1-10 m-wide epithermal veins that are steep normal faults in the upper plate of a regional detachment fault. Mineralization is subdivided into three parageneses: (1) massive black calcite-fluorite-quartz with argentiferous galena and zinc minerals; (2) black calcite-quartz-barite with minor lead; (3) massive white barite and quartz without economic mineralization. Solutions were low-T (130-190°C), moderate-salinity (15-18 wt% NaCl eq.) brines. From mineralogical and fluid inclusion evidence, solution pH is estimated at 5.0-6.0, with $fO_2$-values between $10^{-45}$ and $10^{-47.5}$ and a maximum $fS_2$ of $10^{-26.7}$. Maximum dissolved sulfur content was $10^{-2.25}$ m, predominantly as $SO_4^{2-}$.

Mineral deposition probably occurred through mixing and cooling; $H_2S$ was introduced by mixing or sulfate reduction resulting in sulfide and accompanying calcite and fluorite precipitation. Stage III barite represents late introduction of $Ba^{2+}$ into a cooler, oxygenated solution depleted in metals. The detachment surface and related structure served as passive structural controls for ore. (Author's abstract)

BRAME, Simon, 1979, Mineralization near the northeast margin of the Nelson batholith, southeast British Columbia: MS thesis, Univ. Alberta.

The Scranton, Flint and Vigilant lead-zinc deposits near the northeast margin of the Nelson batholith have been investigated and related to the better documented Bluebell deposit.

The sulphur isotope results suggest that the ore sulphur is igneous in origin with a small sedimentary component. These values, showing $\delta^{34}$S depletion relative to a meteoritic standard, contrast strongly to sulphur isotopic values at the Bluebell deposit. The T obtained from galena-sphalerite pairs are: Vigilant (160-390° C), Scranton (300-510° C) and Bluebell (650° C). The Flint deposit samples show apparent reequilibration at lower T. Each deposit has unique sulphur isotope characteristics which indicate that the mineralizing solutions were well mixed prior to deposition but the source areas were localized and at least partially separated.

A study of the fluid inclusions from sphalerite and quartz shows that the mineralizing solutions were relatively hot, indicative of a primary hydrothermal origin. The fluid inclusion T from Scranton (380-465° C) and Vigilant (370-390° C) correspond well with the sulphur isotope T determinations using galena-sphalerite pairs. The presence of dxls indicates that the solutions were made up of complex saline brines with up to about 40 wt.% NaCl eq. Heterogeneous trapping ("boiling") of gas-rich and brine-rich fluid inclusions at Flint indicates that the deposits were precipitated close to the surface (500 m?). The solutions were probably injected into the fissures at high velocities, depending on the varying P conditions produced by simultaneous tectonic movement. S fluid inclusions from Scranton show Tf similar to that of the P, again indicating tectonic movement during deposition. (From the author's abstract)

BRATUS', M.D., TATARINTSEV. V.I. and SAKHNO, B.E., 1987, Composition of fluid inclusions in quenched particles from explosive ring-like structures and kimberlite pipes: Geokhimiya, v. 11, p. 1563-1568 (in Russian; English abstract).

BRAY, C.J., SPOONER, E.T.C., HALL, C.M., YORK, D., BILLS, T.M. and KRUEGER, H.W., 1987, Laser probe $^{40}Ar/^{39}Ar$ and conventional K/Ar dating of illites associated with the McClean unconformity-related uranium deposits, north Saskatchewan, Canada: Can. J. Earth Sci., v. 24, p. 10-23. First author at Dept. Geol., The Univ. Toronto, Toronto, Ontario, Canada M5S 1A1.

Ten laser probe $^{40}Ar/^{39}Ar$ dates are consistent with fluid-inclusion data, which indicate that mineralization took place at ~160-220°C beneath ~3000 m of cover at a relatively advanced stage in the evolution of the basin. (From the authors' abstract)

BRAY, C.J., THOMAS, A.V. and SPOONER, E.T.C., 1987, Fluid inclusion gas geochemistry of the beryl fringe and quartz zone, Tanco granitic pegmatite, S.E. Manitoba (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 599. Authors at Dept. Geol., Univ. Toronto, Toronto, Ontario M5S 1A1, Canada.

The beryl fringe and quartz zone were among the last primary units to crystallize in the Tanco pegmatite. Microthermometry indicates that these zones were deposited from phase separating fluids in the system $H_2O$-NaCl-$CO_2$ at 291 ± 37°C and 265 ± 29°C, respectively. The chemistry of fluid inclusion gases from 10 samples containing primary and pseudosecondary inclusions has been determined in duplicate using a heated (~105°C) crusher connected directly to the inlet system of a Hewlett Packard 5890 gas chromatograph with a Porapack Q column at 50°C, and a high sensitivity TCD. The stainless steel (#316) crusher, modified from the design of Andrawes and Gibson (1979), has a 1.9 cm diameter piston so that ~0.5-2.5 g of cleaned (25% $HNO_3$ at ~40°C for 1 hr), quartz (~1.5-5 mm) were crushed 2-4 times to a final pressure of ~6000 psi at which it is estimated that ~80%- 90% of contained gases were released. Before crushing, the sample chamber is flushed overnight, including ~5 hrs at ~105°C, with helium. Crushing is carried out at ~105°C to ensure instant volatilization of $H_2O$ and to prevent gas adsorption (very effective for $CO_2$), but not at too high a T for gas reactions to occur. The system blank for all gases is zero at current detection limits, as determined by crushing heat treated (900°C/4 hrs) Brazilian quartz. 90% of all duplicate $CH_4/(CH_4 + CO_2)$ ratios agree to within $\pm 1\sigma$ (0.11; n = 20). $H_2O$, $CO_2$, $CH_4$, a composite ($N_2 \pm CO \pm Ar \pm O_2 \pm NO$), $C_2H_6$ and $N_2O$ peaks have been identified. The beryl fringe has a higher $CH_4/(CH_4 + CO_2)$ ratio (0.72 ± 0.23%; n = 4) and detectable $C_2H_6$ compared with the quartz zone (0.38 ± 0.16%; n = 6); data consistent with $CH_4$ and $C_2H_6$ loss during phase separation. $fO_2$ estimates calculated from $CH_4:CO_2$ ratios using Ohmoto and Kerrick's (1977) equilibrium constant formulation and fugacity coefficients from Kerrick and Jacobs (1981) are $1 \times 10^{-36}$ for the beryl fringe and $1 \times 10^{-38}$ for the quartz zone, plotting just above QFM; values consistent with topaz rhyolite data. (Authors' abstract)

BRAY, C.J., THOMAS, A.V., WOOD, P.C., CALLAN, N.J. and SPOONER, E.T.C., 1987, Fluid inclusion gas geochemistry of the Hollinger and Renabie Archean Au-quartz vein systems, Ontario (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 599. Authors at Dept. Geol., Univ. Toronto, Toronto, Ontario M5S 1A1, Canada.

The chemistry of fluid inclusion gases from samples containing best primary inclusions (4 quartz and 4 scheelite from Hollinger) and strain related secondary inclusions (4 quartz from Hollinger and 6 quartz from

Renabie) have been determined using a heated (~105°C) crusher connected directly to the inlet system of a HP 5890 gas chromatograph with a high sensitivity TCD (for analytical method see Bray et al., 1987). Sample wts were ~1.5 g for quartz and ~2.5 g for scheelite. It is estimated that ~80-90% of the contained gas is released by crushing to ~6000 psi. On Porapak Q the principal peaks identified in order of retention time are composite ($N_2$ ± CO ± Ar ± $O_2$ ± NO), $CH_4$, $CO_2$, and large $H_2O$. In addition, well defined peaks identified from retention times for standards as NO, $N_2O$ and $C_2H_6$ have been detected. As far as is known these are the first analyses to detect NO and $N_2O$ from fluid inclusions in minerals. $H_2$, Ne, $NH_3$ and $H_2S$ were not detected. $CH_4/(CH_4 + CO_2)$ molar ratios for primaries and secondaries decrease upwards in Hollinger from 18.00 ± 17.35% ($1\sigma$; n = 6; 1500' and 1800' levels) to 1.37 ± 0.81% (n = 5; surface; 200', 800' levels). Renabie ratios for samples from all depths (1.07 ± 0.35%; n = 6) are similar to the surface and near surface Hollinger ratios. The vertical decrease in Hollinger is interpreted to be a result of $H_2O$-$CO_2$ phase separation, since $CH_4$ has a high gas/liquid partition coefficient (Drummond and Ohmoto, 1985). Renabie is an oxidized Archean Au system (anhydrite; negative sulphide $\delta^{34}S$) whereas Hollinger is reduced (pyrite-pyrrhotite; $\delta^{34}S = +3.5 \pm 1.4‰$). Hence, the gradational upward decrease in $CH_4/(CH_4 + CO_2)$ in Hollinger to values similar to Renabie documents $H_2O$ (liquid) oxidation by loss of reduced gas species ($H_2$, $CH_4$, $H_2S$) during $H_2O$-$CO_2$ phase separation, a process suggested for the origin of oxidized Archean Au-quartz vein systems (e.g., McIntyre Cu-Au orebody, Golden Mile, Renabie; Spooner et al., 1987). (Authors' abstract)

BREIT, G.N., MEUNIER, J.D., ROWAN, E.L. and GOLDHABER, M.B., 1987, Alteration related to red bed copper mineralizing brines and other fault-controlled solutions in Lisbon Valley, Utah, and the Slick Rock district, Colorado (Extended abst.): U.S. Geol. Survey Circular 995, p. 7-8.

Fluid-inclusion studies of calcite in the fractures and isotopic and chemical studies of authigenic minerals in sandstones surrounding the faults indicate that three distinct solutions moved sequentially along the faults. These fluids not only formed the Cu deposits, but also precipitated calcite, barite, and dolomite and dissolved Fe oxides in zones up to 5 km from the faults.

Calcite, barite, and Cu minerals precipitated from the earliest of the solutions. This water had a $\delta^{18}O$ of about 0 per mil (SMOW), an average T of 95°C, and a dissolved solid content greater than 8 wt% NaCl eq. Fluid inclusions with different salinities indicate that this brine mixed with a dilute ground water during growth of the calcite. Collectively, the data suggest that the saline water was a connate water from the underlying [evaporite-bearing] Hermosa Formation. This saline water extracted copper from the Hermosa or from the red beds that occur between the evaporites and the Dakota and Morrison Formations. Interaction of the brines with the intervening clastic rocks is indicated by the Sr isotope composition of barite within the fault zones ($^{87}Sr/^{86}Sr$ of 0.7103).

Simultaneous with or shortly after the first brine, a second solution moved through the Dolores zone of faults, precipitating dolomite. This water had an estimated $\delta^{18}O$ of -8 per mil, which suggests that a component of the solution was meteoric water.

The final solution to move through the fractures was a very dilute ground water that precipitated calcite within the Dolores zone of faults. This solution had a T of 50°C and a $\delta^{18}O$ near -16 per mil.

These solutions were forced upward by Laramide tectonism when uplift of anticlines cored by the Hermosa evaporite expelled fluids along fractures.

Waters with isotopic and chemical compositions similar to these solutions currently exist within the Hermosa and overlying units. (From the authors' abstract)

BRENAN, J.M. and WATSON, E.B., 1987, Transport of $CO_2$ in polycrystalline olivine at elevated P-T conditions (abst.): EOS, v. 68, p. 466. Authors at Dept. Geol., Rensselaer Polytech. Inst., Troy, NY 12180-3590.

The preponderance of high density $CO_2$-rich fluid inclusions in many upper mantle xenoliths, coupled with phase equilibria constraints, suggests that $CO_2$ is a free fluid phase in portions of the upper mantle; knowledge of its transport behavior is thus of fundamental importance to the understanding of upper mantle processes. To evaluate $CO_2$ transport rates and mechanisms, polycrystalline olivine (w/ and w/o dispersed MgO) was subjected, by means of decarbonation reactions, to influx of $^{14}C$-bearing $CO_2$ at 1.0-1.3 GPa and 1050-1350°C. The post-experiment distribution of $CO_2$ was mapped by beta-track autoradiography. Transport distance vs. time data show initial rapid infiltration (mm/min) followed by gradual deceleration to 1-10 microns/minute at t >5 minutes. Fluid concentration profiles show an abrupt step at the leading edge, indicating front-like advance through the olivine. Despite a wetting angle >> 60°, fluid infiltration is pervasive behind the front. Results suggest that 1) $CO_2$ transport occurs via hydrofracturing, the extent of infiltration being limited by fluid overpressure; 2) as fluid pressure wanes, $CO_2$ tends to isolate at grain-edge pockets, effectively immobilized; and 3) in nature, pervasive fluid infiltration may be expected at the scale of cm-m, but large-scale fluid transport via hydrofracturing may be precluded at least under conditions of mechanical equilibrium. (Authors' abstract)

BRENNER, I.B., LANG, Y., LE MARCHAND, A. and GROSDAILLON, P., 1987, A versatile technique for multielement ICP-AES analysis of geological samples: Am. Lab., v. 19, no. 10.

BRETT, Robin, EVANS, H.T., Jr., GIBSON, E.K., Jr., HEDENQUIST, J.W., WANDLESS, M.-V. and SOMMER, M.A., 1987, Mineralogical studies of sulfide samples and volatile concentrations of basalt glasses from the southern Juan de Fuca Ridge: J. Geophys. Res., v. 92, no. B11, p. 11,373-11,379. First author at U.S. Geol. Survey, Reston, VA.

Sulfide samples obtained from the U.S. Geological Survey's DSRV Alvin dives on the southern Juan de Fuca Ridge closely resemble those from the same area described by Koski et al. (1984). Major minerals include sphalerite, wurtzite, pyrite, marcasite, isocubanite, anhydrite, and chalcopyrite. Equilibrium, if attained at all, during deposition of most sulfides was a transient event over a few tens of micrometers at most and was perturbed by rapid temperature and compositional changes of the circulating fluid. Two new minerals were found: one, a hydrated Zn, Fe hydroxy-chlorosulfate, and the other, a (Mn, Mg, Fe) hydroxide or hydroxy-hydrate. Both were formed at relatively low temperatures. Lizardite, starkeyite, and anatase were found for the first time in such an environment. Sulfide geothermometry involving the system Cu-Fe-S indicates a vent temperature of <328°C for one sample. Fluid inclusion studies on crystals from the same vicinity of the same sample give P-corrected Th of 268° and 285°C. Tm ice on inclusions from the same sample are about -2.8°C, indicating that the eq. salinity of the trapped fluid is about 50% > seawater. Volatile concentrations from vesicle-free basalt glass from the vent field are about 0.013 wt % $CO_2$ and 0.16 wt % $H_2O$. $CO_2$ contents in these samples yield an entrapment depth of 2200 m of seawater, which is the depth from which the samples were collected. (Authors' abstract)

BRIDGWATER, D., AUSTRHEIM, H., PEDERSEN, S. and WINTER, J., 1987, Element mobility, and isotopic changes during retrogression and prograde metamorphism of Archean gneisses in the Nagssugtoqidian mobile belt of southern East Greenland (abst.): Abstracts, NATO Advanced Research Workshop, Fluid movements, element transport, and the composition of the deep crust, Lindås, Norway, 18-24 May, 1987 (unpaginated).

Oxygen isotopes (Kerrich, Blattner) suggest that the fluids were derived from the lower crust or mantle. Bulk geochemical studies and mineralogical studies show that the fluids were aqueous, highly enriched in Cl and oxidized sulphur species. These fluids were highly reactive, carried K, Rb, Sr, Ba and Pb and were capable of corroding zircons and leaching some metals such as Cu from the granulites. Fluid inclusion studies on the retrogressed rocks show the loss of $CO_2$ inclusions seen in the granulites and a late stage formation of halite. (From the authors' abstract)

BRIDGWATER, D., AUSTRHEIM, H., ROSING, M. and SCHIØTTE, L., 1987, The effect of fluid-controlled element mobility during polymetamorphism on whole rock isotope systems, some theoretical aspects and possible examples (abst.): Abstracts, NATO Advanced Research Workshop, Fluid movements, element transport, and the composition of the deep crust, Lindås, Norway, 18-24 May, 1987 (unpaginated).

BRIL, H. and NENERT, S., 1987, Paragenesis and fluid inclusions from the Benevent l'Abbaye gold-antimony district, Limousin (France) (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 135 (in French; translation by R.J. Bodnar). First author at U.A. 384 du CNRS, Maison des Volcans, Chateau St. Etienne, 1500 Aurillac, France.

Four types of veins, all Au-bearing, have been distinguished: quartz veins with arsenopyrite, berthierite and Au; stockworks of quartz, arsenopyrite, tourmaline and scheelite; quartz-carbonate veins with pyrrhotite ± gudmundite; and Au-bearing shear zones rich in Pb-Sb sulfosalts.

Fluid inclusions in the first type were studied. The quartz grains were subhedral and showed little deformation. Inclusions are two-phase, rarely three-phase [$H_2O$-$CO_2$], and are both gas-rich and liquid-rich. The latter usually occur along fractures.

Preliminary results suggest an early, low salinity, $CO_2$-rich fluid circulating at T >400°C. A second hydrothermal event of uncertain significance occurred at ≈250°C. These results confirm high T for Sb-Au deposits, that the deposits are part of an early regional metallogenic event, and that an association of hydrothermal circulation systems with W, Au or Sb veins [exists], as has been shown for other districts. (From the authors' abstract)

BROADHURST, J.R., 1986, Mineral reactions in xenoliths from the Colorado Plateau; implications for lower crustal conditions and fluid composition, <u>in</u> Dawson, J.B., Carswell, D.A., Hall, J. and Wedepohl, K.H., eds., The nature of the lower continental crust: Geol. Soc. Spec. Publ., no. 24, p. 331-349. Author at Dept. Geol., Univ. Sheffield, Mappin Street, Sheffield, S1 3JD, UK.

A study of lower crust and upper mantle xenoliths from Moses Rock Diatreme, Utah, has led to the discovery of evidence for low temperature/high pressure, in situ hydration of pyroxene and garnet granulites in isolated parts of the lower crust of the Colorado Plateau. The origin of the cold hydrating fluid is linked to the presence of low T/high P group 'C' eclogites in the suite, xenoliths which may represent relics of a subducted/underplated fragment of the Farollan plate. (From the author's summary)

BROCKERHOFF, F.G. and FRIEDMAN, G.M., 1987, Paleo-depth of burial of Middle Ordovician Chazy Group carbonates in New York State and Vermont: Northeastern Geol., v. 9, no. 1, p. 51-58. First author at Dept. Geol., Brooklyn College of City Univ. New York, Brooklyn, NY 11210.

Using fluid inclusion techniques, vitrinite reflectance, and stable isotopes, data obtained on formation T of calcite cements and vein fillings of the Chazy Group carbonates, located in the Champlain Valley in New York and Vermont, indicate that these limestones were at one time subjected to T far in excess of what has been inferred previously for rocks of this region. Th of fluid inclusions in calcite cements of the Chazy Group, combined with vitrinite reflectance data and conodont-color alteration data, indicate that these T could only have been attained, assuming a normal geothermal gradient of 26°C/km, at depths exceeding 5 km. A study of Th of fluid inclusions found in calcite veins in the Chazy Group indicates precipitation of T exceeding those at the surface and corresponding to depths shallower than those of the coarse cements. These data are supported by stable isotope data and by freezing T of fluid inclusions. These indicate T of formation from saline brines betweeen 87° and 104°C. (Authors' abstract)

BRODYLO, L.A. and SPENCER, R.J., 1987, Depositional environment of the Middle Devonian Telegraph salts, Alberta, Canada: Bull Canadian Petrol. Geol., v. 35, no. 2, p. 186-196. First author at Dept. Geol. & Geophys., Univ. Calgary, Calgary, Alberta T2N 2N4, Canada.

The Middle Devonian Telegraph Member of the Muskeg Formation contains well-preserved primary depositional fabrics and textures similar to those found in modern shallow-water ephemeral brine pans. The Telegraph halite is the lowermost of a series of halite units deposited in the Elk Point basin in northeastern Alberta.

A 16-cm section of core at 682 m (2237 ft, sample 2237) was chosen for detailed fluid inclusion study. This sample appears typical of the entire cored interval within the lower salt (675 to 692 m; 2215-2270 ft). Thin sections were prepared in series from this sample. The sample is divided into six depositional sequences by anhydrite partings. The Th are determined by the disappearance of the vapor phase in original two-phase (liquid-vapor) inclusions. The T (18° to 38°C) are within the range expected for primary halite formation. The average T at which the first evidence of melting after warming of the frozen inclusions within halite-hopper-raft, equant-cube, chevron and cornet inclusions was observed. The T range from -60° to -55°C, indicating the presence of a multicomponent (Na-K-Ca-Mg-Cl-$SO_4$) aqueous phase within the inclusions. Some inclusions in the "clear halite" have similar T of first melting, while others begin melting near -24°C, which indicates the presence of nearly pure Na-Cl brines.

Inclusions in the hopper rafts, equant cubes, chevrons and cornets had final melting or clearing between -45° and -32°C. Each depositional sequence shows a systematic trend upward toward higher T of clearing. This behavior is interpreted to represent the final melting of Ca-Mg chloride hydrates. The T of melting is a function of the ratio of Mg to Ca in solution. Ratios of Mg to Ca calculated from the inclusion clear T are presented along with results obtained by atomic absorption on fluids extracted from the inclusions. In some freezing runs, additional phases nucleated after the clearing and showed final melting near -6°C. This phase is interpreted to be a sodium sulphate hydrate (mirabilite). Hydrohalite melting was observed in only a few samples at about -0.4°C. (From the authors' abstract and text)

BROMAN, Curt, 1986, Fluid inclusions associated with the massive sulfide ores of the Kristineberg area, Skellefte district, Sweden (abst.): 17th Nordiska Geologmötet Helsing. Univ., p. 18. Author at Ore Res. Group, Dept. Geol., Univ. Stockholm, S-106 91 Stockholm, Sweden.

The Kristineberg area forms the western part of the Skellefte ore district in northern Sweden. The country rock, that consists of volcanics and sediments of Proterozoic age, has been deformed in connection with the intrusion of granitoids and regionally metamorphosed to green-schist facies.

Kristineberg, Rävliden and Hornträskviken ores are three of several massive volcano-sedimentary hosted Fe-Cu-Zn-Pb sulfide deposits in the area. The origin of the ores is considered to be related to submarine volcanism.

Fluid inclusions in samples from the Rävliden and the Hornträskviken ores reflect early stages of mineralization at 200°C and 300°C in non-boiling Ca-Na-Cl solutions with a salinity of 1-3 eq. wt.% NaCl, conditions similar to other volcanogenic sulfide deposits formed within seawater dominated convective systems.

The Kristineberg ore, situated in strongly metasomatically altered rock sequences, displays a complex history of hydrothermal events indicated by fluid inclusion data;

(1) calcite precipitation at 270°C from Ca-Na-Cl solutions with a salinity of 10 eq. wt.% NaCl,

(2) sphalerite recrystallization around 100°C in highly saline Mg-rich solutions,

(3) healing of microcracks in quartz concretions around 200°C in coexisting C-H fluids and aqueous solutions composed of 15 eq. wt.% NaCl. (Author's abstract)

BROMAN, C., 1987, Fluid inclusions of the massive sulfide deposits in the Skellefte district, Sweden: Chem. Geol., v. 61, no. 1/4, p. 161-168.

Full paper for abstract in Fluid Inclusion Research, v. 18, p. 65, 1985. See also previous abstract. (E.R.)

BROOKS, J.W. and LARSON, P.B., 1987, Oxygen and hydrogen isotopes as an exploration tool in the epithermal environment: Example from the Mammoth Revenue vein, Platoro caldera, San Juan Mountains, Colorado (abst.): Geol. Soc. Am. Abst. with Programs, v. 19, p. 362. Authors at Dept. Geol., Washington State Univ., Pullman, WA 99164-2812.

The Mammoth Revenue vein, a complexly brecciated structure, hosts early base metal mineralization and later precious metal mineralization in the Platoro mining district, San Juan Mountains, Colorado. Three distinct mineralization stages are recognized in the vein. Earliest mineralization is economically unimportant and consists of base metal sulfides. Initial precious metal mineralization consists of a low grade, silver-rich (Ag:Au about 30:1) assemblage of silver sulfosalts and silver-rich electrum (Au:Ag 1:1). Later precious metal mineralization consists of a high grade, gold-rich (Ag:Au about 3:1) assemblage of gold-silver tellurides and gold-rich electrum (Au:Ag about 3:1). Quartz codeposited with mineralization yields homogenization temperatures of 200 to 350°C, salinities <3.4 wt.% NaCl equiv., and evidence of boiling only from quartz with base metals. Both sulfosalt and telluride mineralization occurred over the temperature range of 200 to 230°C, but oxygen isotopic analyses of vein quartz and altered host rocks and hydrogen isotopic analyses of fluid inclusion fluids reveal important differences in these two fluid compositions. Sulfosalts were deposited from fluids with $\delta^{18}O$ of -5.2 per mil and $\delta D$ of -113 per mil, whereas tellurides were deposited by fluids with $\delta^{18}O$ of -6.3 per mil and $\delta D$ of -110 per mil. Whole rock $\delta^{18}O$ values of host rocks associated with sulfosalt mineralization range from +5.5 to +6.1 per mil, whereas similar analyses of whole rocks near telluride mineralization range from +4.6 to +4.9 per mil. These data suggest that in this district, characterized by poor exposure of mineralized quartz, the isotopic composition of barren quartz and altered host rocks can be used to distinguish favorable and unfavorable exploration targets. (Authors' abstract)

BROWER, K., APODACA, L. and NORMAN, D.I., 1987, Hydrocarbon gases in fluid inclusions (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Authors at New Mexico Inst. of Mining & Tech., Socorro, NM 87801.

Methods to extract and quantitatively analyze organic constituents in fluid inclusions were developed. Inclusions from the Cochiti epithermal Au-Ag deposit were chosen for study because analysis of Cochiti inclusions by mass spectrometer indicated they have a mixture of $C_2$ to $C_5$ organic compounds in addition to $CO_2$, $H_2S$, $H_2$, $CH_4$, CO, He and Ar. The organic species could not be identified because of the complex mass spectra.

Volatiles were extracted in vacuum from scrupulously clean quartz by crushing and by thermal decrepitation at several T. Volatiles are separated into water, condensable gas, and noncondensable gas fractions by use of dry ice-alcohol and liquid $N_2$ traps. The condensable gas fraction is frozen into a 3 x 100 mm Pyrex capillary tube that is sealed by flame. The capillary is removed from the vacuum line, broken under glycerine, the bubble of gas in the tube removed by a syringe and analyzed in a Hewlett Packard gas chromatograph-mass spectrometer (Model Nos. 5890- and 5970).

Analyses indicate $CO_2$, $H_2S$, ethane, ethylene, propane, propylene, the four isomers of $C_4H_8$, the two butenes, and at least four isomers of $C_5H_{10}$. The most abundant hydrocarbon component is propylene. The same species are measured from samples crushed, and those decrepitated at 350, 400, 450, and 500°C. We conclude that the organic compounds are from fluid inclusions and that there is little pyrolysis of the compounds during thermal decrepitation of inclusions.

The predominance of alkenes and branched structures contrasts sharply with the straight-chain saturated character of hydrocarbons from petroleum or natural gas. The composition is somewhat suggestive of thermally cracked petroleum, but the low ratio of ethylene to propylene is not understandable on the basis of this hypothesis. Pyrolysis of oil shale gives approximately 35% olefins and naphthenes which seems a bit more promising, but the gas fraction contains about twice as much alkane as alkene. The components in order of abundance are $CO_2$, $H_2$, CO, $CH_4$, $C_2H_6$, and $C_3H_8$.

A preliminary experiment on pyrolysis of sucrose in water yielded a gas containing $CO_2$, CO, $C_3H_6$, and $C_4H_8$. The hydrogen content has yet to be determined. It is noteworthy that $CH_4$, $C_2H_4$, $C_2H_6$, and $C_3H_8$ were not detected. It thus appears possible that the hydrocarbons in fluid inclusions are formed by pyrolysis of carbohydrate material or "humic acid." (Authors' abstract)

BROWN, I.J., 1985, Gold-bismuth-copper skarn mineralization in the Marn skarn, Yukon: MS thesis, The University of Alberta.

Low-grade Au-Cu-Bi mineralization occurs in two skarn bodies on the northern and southern contacts of a tongue-like projection of the Mount Brenner Stock. Only the northernmost of these two skarns contains significant and potentially economic grades of Au. The contrast in metal grades between the two skarns is a result of differences in the skarn development from the earliest period of prograde skarn at >600°C, through a later mineralization stage, until a final period of limonitic alteration.

The style of mineralization is similar in the two skarns. Pyrrhotite and chalcopyrite were deposited from fluids between 300°C and 500°C [from fluid inclusions?] by the replacement of earlier skarn silicates. Bi and Au-bearing minerals, including hedleyite ($Bi_{14}Te_6$), native Bi and electrum, formed below 300°C as veinlets and blebs closely associated with the more voluminous sulphides.

The prograde assemblages of the iron-rich and mineralized skarns are represented by $\log fO_2$-$\log fS_2$ diagrams and define a reduced skarn environment similar to those determined for reduced W skarns of Japan. The conditions of mineralization are not well constrained; however the sulphide mineralogy suggests $\log fS_2$ = -8 to -10, the absence of magnetite places a maximum $fO_2$ on the mineralizing fluids. (From the author's abstract)

BROWN, P.E. and LAMB, W.M., 1987a Mixing of $H_2O$-$CO_2$ in fluid inclusions (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Authors at Dept. Geol. & Geophys., 1215 W. Dayton, Univ. Wisconsin, Madison, WI 53706.

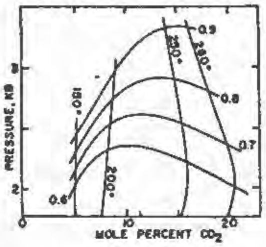
Many types of ore deposits and most regional metamorphic rocks contain $H_2O$-$CO_2$ fluid inclusions with variable salinities. Examination of these inclusions often documents a wide range of $H_2O/CO_2$ ratios requiring entrapment above the $H_2O$-$CO_2$ solvus. A modified Redlich-Kwong (MRK) equation of state of $H_2O$ and $CO_2$ was used to calculate bulk molar volumes, mole fractions and $CO_2$ densities for mixed volatile fluid inclusions. The results allow very useful P-T diagrams to be constructed (for fixed $CO_2$ density) and contoured with volume percent $CO_2$ observed in the laboratory (Brown and Lamb, 1986[1]). These diagrams permit rapid qualitative or quantitative determination of the P-T path for a bulk inclusion isochore above the solvus in the system $H_2O$-$CO_2$(± NaCl).

These diagrams were calculated for L-V systems and are not directly applicable in the presence of either $H_2O$-$CO_2$ clathrate or water ice. For $CO_2$ densities $\gtrsim 1.03$ gm/cc (Th(L-V)$CO_2$ $< -20$°C), it is usually necessary to cool the inclusion below ~-30°C to nucleate a vapor bubble. Under these conditions the clathrate-hydrate (nominally $CO_2 \cdot 5.75H_2O$) will form and change both the amount of $CO_2$(L) and the density relationships in the inclusion. Because the clathrate is apparently ~15% more dense than liquid water, the measured $CO_2$ density, in the presence of the clathrate, would be lower than the true density by an amount that depends on the density of the clathrate, the $CO_2$-$H_2O$ ratio in the clathrate, and the absolute amount of the clathrate that forms in the sluggish reaction. To cover the range of possibilities, two end member cases were calculated and the results are shown in a table [not reproduced here]. For all these calulations, a density of 1.15 gm/cc was chosen for the clathrate (Takenouchi and Kennedy, 1965[2]). The top half of the table is for the case where clathrate only forms from the $CO_2$ already in solution in the water at the time the clathrate freezes. The effect was maximized by using 5 mole % dissolved $CO_2$ (Collins, 1979[3]) for these calculations. The bottom half is for a case where clathrate forms until one of the original fluid phases is consumed. The actual inclusion behavior almost certainly lies between these end members and, for rapid freezing in the lab, probably approaches most closely the conditions of the upper calculation. If it is necessary to cool below ~-60°C to nucleate a vapor bubble in the $CO_2$, then water ice may become a further problem. For most inclusions found in nature, measurements of $CO_2$ densities can be made without clathrate formation hence avoiding the kinds of problems discussed here. In the Adirondacks, for example, high $CO_2$ densities have not been found in $H_2O$-rich inclusions and examination of the literature suggests that such problem inclusions are rare (or nonexistent). (Authors' abstract)

BROWN, P.E. and LAMB, W.M., 1987, Estimation of mole fraction $CO_2$ and pressure in fluid inclusions: An improved graphical approach (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 603. First author at Dept. Geol., Univ. Wisconsin, Madison, WI 53706.

One of the weakest links in the calculation of fluid inclusion phase equilibria in the system $H_2O$-$CO_2$-NaCl is the estimation of volume % $CO_2$. The uncertainties stem mainly from irregularities in the inclusion's shapes, the extent in the 3rd dimension and optical effects related to differences in the refractive indices of the various phases. Errors of volume estimation can easily equal 50 to 100% of the amount present for a wide range of $XCO_2$. Using suitable equations of state, it is possible to calculate the volume % (or X) $CO_2$ if one additional observation can be made instead of the problematic volume estimate. We present here new diagrams that are a modification of the method outlined by Parry (1986, E.G. 81, 1009-1013).

To use programs like those presented by Nicholls and Crawford (1985) to calculate isochores in the system $H_2O$-$CO_2$-NaCl, it is necessary to observe and quantify 3 variables: $CO_2$ L-V Th, clathrate Tm, and volume % $CO_2$. The latter has been replaced here (and in Parry, 1986) by the $H_2O$-$CO_2$ Th (or decrepitation T). Results for the salt-free system are given in Figure 1. The near vertical lines are the locations of the $H_2O$-$CO_2$ solvus while the concave downward lines on this Figure are contoured in density of the $CO_2$ portion of the inclusion, an easily measurable quantity. This Figure thus provides a pressure and $XCO_2$ at Th (but only limits upon decrepitation) from phase transformations readily observed in the lab. Analogous figures for a wide range of NaCl wt % will be presented and copies are available. These diagrams are much more useable and suggest higher P than the results of Parry (1986). Furthermore, these high P suggest that inclusions are stronger than commonly quoted. (Authors' abstract)



BRUHN, R.L. and PARRY, W.T., 1987, Structural and fluid characteristics of normal faults: Implications for earthquake rupture propagation (abst.): Int'l. Union of Geodesy & Geophys., XIX Gen. Assembly, Vancouver, Canada; Aug. 9-22, 1987; Abstracts, v. 1, p. 340. Authors at Dept. Geol. & Geophys., Univ. Utah, Salt Lake City, UT 84112, USA.

The division of normal fault zones into rupture segments that extend for several ten's of kilometers is a fundamental feature of extending regions. Rupture segments are commonly linked by jogs in the fault trace that reflect changes in fault zone attitude, branching of the zone into multiple strands, and changes in slip vectors. These zones of fault linkage form "geometrical barriers" which affect the initiation, propagation and arrest of earthquake ruptures. Structural studies of geometrical barriers in the Wasatch normal fault zone, Utah, the Lost River fault zone, Idaho, and the Dixie Valley fault zone, Nevada, illustrate the occurrence of different types of geometrical barrier. Barrier types include those that formed between overlapping fault segments, at cross-faults bounding rotating crustal blocks, and barriers developed at what may be positions of lateral changes in the depth to extensional decollement. These barriers have played a fundamental role in controlling the generation and propagation of historic and prehistoric earthquake ruptures (M 6.5 to 7.5).

Internally, geometrical barriers consist of multiple sets of mutually interacting faults that interact mechanically and chemically with crustal fluids. The structure reflects the mode of origin and the evolutionary history of the barrier. Analyses of fluid inclusions and alteration mineral assemblages in faulted rock provide information on the fluid-chemical and fluid-mechanical properties of rupture barriers. Studies of fluid inclusions from fault rock in a barrier at the southern end of the Salt Lake segment of the Wasatch fault zone indicate that fluid pressures may undergo transient behavior, alternating between near lithostatic and hydrostatic values at depths near the quasi-plastic-frictional transition (Z ~ 11 km, T ~ 350°C). Generation of high fluid pressures by time-dependent changes in permeability and porosity, accompanied by stress corrosion, will enhance the failure of asperities and promote rupture growth leading to the next large earthquake. Preliminary fluid inclusion data from the Dixie Valley fault zone indicates that cataclasis of quartzo-felsapthic rock occurred at temperatures in excess of 350°C at hydrostatic fluid pressures to depths of ~2 km. Fluids in both fault zones are high salinity brines, but the Wasatch fault fluids have higher $CO_2$, suggesting greater chemcial reactivity with faulted rock. (Authors' abstract)

BUISSON, Gerard and LEBLANC, Marc, 1987, Gold in mantle peridotites from Upper Proterozoic ophiolites in Arabia, Mali, and Morocco: Econ. Geol., v. 82, p. 2091-2097. Authors at Centre Géol. & Géophys., Univ. Sci. Tech. du Languedoc, 34060-Montpellier, France.

Fluid inclusion data from the literature for gold-bearing carbonatized peridotites (i.e., listwaenites) are discussed briefly (p. 2095-2096).(E.R.)

BULL, K.F. and BUNDTZEN, T.K., 1987, Greisen and vein Au-W mineralization of the Black Creek stock, the Flat area, west-central Alaska (abst.): Geol. Soc. Am. Abst. with Programs, v. 19, p. 362-363. First author at Dept. Geol., Univ. Alaska, Fairbanks, AK 99775.

The Flat area, located 130 km SW of McGrath, has yielded 2 million oz. of gold. Most Au was won from placer operations, although lode deposits in the Black Creek stock yielded 535 tons of Au-Ag-W-Pb ore. Mineralization of the Black Creek stock occurs in at least two stages: greisen related to a felsite porphyry phase of the stock, and younger quartz veins which parallel major northeast structures in the area. The stock is an alkali-calcic, zoned pluton with an olivine biotite monzodiorite rim and a biotite monzonite core. Late syenite and felsite quartz porphyry dikes cut the major phases. White mica-fluorite-pyrite(py)-arsenopyrite(asp)+tourmaline greisen is proximal to the quartz porphyry and is surrounded by a zone of sericitized plagioclase and bleached mafics. Greisen alteration contains anomalous Au and W. Breccias with greisen-altered felsite clasts and a matrix of quartz+dolomite are cut by stibnite veins. Tourmaline-matrix breccias occur in the monzonite phase.

Quartz veins cut all phases of the stock. Microprobe analysis of asp in asp-py-Au-scheelite-calcite-stibnite-galena-chalcopyrite-quartz veins indicates temperatures of 350°C, while fluid inclusion studies of smaller, more distal cinnabar-quartz+stibnite veins indicate 150°C.

Trace element analyses of Kuskokwim Group sediments surrounding the Black Creek and neighboring Chicken Mountain stocks show an enrichment halo (2x to 50x) of Au, As, Sb, Mo, Ni and Co extending approximately one mile beyond the stocks. As metal values beyond that distance are close to average shale values, an igneous source for the metals is implied. (Authors' abstract)

BUNTEBARTH, G. and STEGENA, L., 1986, Methods in paleogeothermics: Lecture

Notes in Earth Sci., v. 5, p. 5-39. First author at Inst. Geophysik, TU Clausthal Arnold-Sommerfeld-Str. 1, D-3392 Clausthal-Zellerfeld, FRG.

An excellent review of many geothermometers, including fluid inclusions. (E.R.)

BURCH, C.R., 1987, Metallic inclusions in Chatham synthetic corundums: J. Gemm., v. 20, no. 5, p. 267-269.

BUREAU OF MINERAL RESOURCES, GEOLOGY, AND GEOPHYSICS, 1987, Yearbook: Canberra, Australia Govt. Publishing Services.

Includes status reports on various projects, many involving fluid inclusion studies. See G.R. Ewers, N.C. Higgins, J.H.C. Bain, I.B. Lambert and H. Etminan, and C.A. Heinrich and R.W. Henley, this volume. (E.R.)

BURKE, E.A.J. and LUSTENHOUWER, W.J., 1987, The application of a multichannel laser Raman microprobe (Microdil-28) to the analysis of fluid inclusions: Chem. Geol., v. 61, no. 1/4, p. 11-17.

Full paper for abstract in Fluid Inclusion Research, v. 18, p. 68-69, 1985. (E.R.)

BURLINSON, K., 1987a A practical decrepitation instrument and its application in research and exploration (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 17-18. Author at Burlinson Geochem. Svcs. Pty. Ltd., Darwin, Australia.

The BGS model 04 decrepitometer is the result of 7 years of design development, during which time over 3000 samples have been analyzed. It is capable of providing highly reproducible results which are free of subjective bias. The instrument is simple to operate and can be used by unskilled staff and provides a fully automated analysis to avoid the introduction of operator bias in the results. It can be operated up to 800°C and at heating rates of 5, 10, 20 or 40°C per minute, of which 20°C per minute is the most convenient heating rate.

The instrument comprises a specially designed electric furnace which is mounted in a sound isolation enclosure. The furnace temperature is read by a microprocessor system which controls the power supply to the furnace, thus providing a constant heating rate. The signal from the microphone, located near the sample, is amplified and decrepitation bursts are electronically counted, the results being collected by the microprocessor and presented as a histogram, both on the video screen and on a printer. The data can also be transferred to an external computer for subsequent processing if required. The sample used is quite small, only 0.5 gms of crushed and sieved grains being required, and is easy to prepare as no thin section is needed.

At the Tennant Creek gold mines, NT, Australia, some magnetite shows intense decrepitation at temperatures up to 800°C while other magnetite samples have negligible decrepitation. Hematite samples also show marked variations in their decrepitation and it is clear that there are several different genetic types of hematite and magnetite in the area. Pyrite samples can also be decrepitated although it is best to limit them to temperatures below 650°C due to oxidation. Pyrite of sedimentary origin typically gives no decrepitation response while hydrothermal pyrite decrepitates strongly between 400 and 600°C, which provides a quick check on the origin of the pyrite. Galena samples from Pine Point, NWT, Canada, decrepitate strongly between 300 and 500°C. This result is surprising in view of the microthermometric work which has deduced a formation temperature near 100°C for this deposit. Although decrepitation can give useful data on opaque minerals it is not clear whether mechanisms other than fluid inclusions are involved and some caution in the interpretation is necessary until the mechanism of decrepitation is better understood.

Many quartz samples show a low-T decrepitation peak between 150°C and 350°C. Microscope observations have shown that the presence of this peak is related to the occurrence of $CO_2$-rich inclusions in the sample. Hence the decrepitation data can provide a simple check for the presence of $CO_2$-rich inclusions in the sample. (Inclusions with low $CO_2$ partial P may not be detectable however.)

Observation of the decomposition temperature of carbonates has been used in one study as a siderite/calcite monitor, which has application in exploration for some classes of hydrothermal gold deposits.

In all this work secondary inclusions present in the samples do not seem to have interfered with the results. Decrepitation studies have been done on samples upon which microthermometric data on the secondary inclusions has been collected. In these studies the decrepigrams have lacked any response which could be attributed to the secondary inclusions, showing only peaks related to the primary inclusions. The lack of interference from secondary inclusions is extremely fortuitious, but not understood. It is tentatively suggested that secondary inclusions either do not decrepitate because they are too small (less than ~3 μm) or that they merely leak quietly into the fractures which they occupy. (Author's abstract)

BURLINSON, Kingsley, 1987b The decrepitation method: What it is and why use it?: Int'l. Liaison Group on Gold Mineralization Newsletter, no. 5, p. 60-61. Author at Burlinson Geochem. Services Pty Ltd., P.O. Box 37134, Winellie, N.T. 5789, Australia.

A review of some of the author's applications of decrepitometry in the search for ore deposits. (E.R.)

BURROWS, D.R. and SPOONER, E.T.C., 1987, Generation of a magmatic $H_2O$-$CO_2$ fluid enriched in Mo, Au, and W within an Archean sodic granodiorite stock, Mink Lake, northwestern Ontario: Econ. Geol., v. 82, p. 1931-1957. Authors at Dept. Geol., Univ. Toronto, Toronto, Ontario, Canada M5S 1A1.

The most important $MoS_2$ mineralization spans a silicate melt-hydrothermal fluid transition showing the following sequence: (1) $MoS_2$-bearing aplites and quartz segregations which have carbonate and phyllic alteration selvages indicating fluid-rock interaction, (2) locally $MoS_2$-rich carbonate alteration zones, (3) $MoS_2$-bearing quartz ± K-feldspar-pyrite±calcite-chlorite veins with marginal carbonate and phyllic alteration, and (4) late, barren quartz veins with strong green phyllic alteration.

The $MoS_2$ mineralization was deposited by $H_2O$-$CO_2$ fluids undergoing phase separation at ~280° to 300°C (n = 99); the fluids are characterized by a relatively pure $CO_2$ component ($CO_2$ melting point = -56.4° ± 0.8°C; n = 57; cf. pure $CO_2$ at -56.6°C) and a relatively low-salinity aqueous component (5.6 ± 1.2 eq. wt % NaCl; n = 48). The fluid $\delta D$-$\delta^{18}O$ box defined by the bulk of the fluid $\delta D$ and $\delta^{18}O$ estimates (10 $\delta D$ values direct from fluid inclusion analysis; 19 $\delta^{18}O$ values calculated from 6 quartz and 13 carbonate determinations) shows a significant overlap (~60%) with the general magmatic water box. Carbonate $\delta^{13}C$ values of -3.3 ± 0.4 per mil (n = 13) are compatible with a deep igneous C source but, according to presently available data, are incompatible with derivation by greenschist-amphibolite or granulite facies metamorphic processes. The $\delta^{34}S$ values are uninformatively typical of much Archean sulfur (+1.6 ± 0.9‰; n = 8).

Considering the above and additional evidence, it is concluded that the Mink Lake $MoS_2$ fluids were magmatically derived from the host sodic granodiorite stock. Hence, a high $CO_2$ content in Archean hydrothermal fluids is not necesarily an indication of a "metamorphogenic" origin, as has been suggested for Archean Au-quartz-Fe-carbonate-pyrite ± tourmaline ± tellurides ± W (scheelite) ± Mo vein systems. In fact, the close similarities in fluid properties between Mink Lake $MoS_2$ and Archean Au-quartz-carbonate-pyrite vein mineralization, and particularly, the statistically identical carbonate $\delta^{13}C$ values suggest that Archean Au-quartz-carbonate-pyrite vein deposits may have been magmatically derived. (From the authors' abstract)

BURRUSS, R.C., 1987a Crushing-cell, capillary column gas chromatography of petroleum fluid inclusions: Method and application to petroleum source rocks, reservoirs, and low temperature hydrothermal ores (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Author at U.S. Geol. Survey, Box 25046, MS 940, Federal Center, Denver, CO 80225.

A crushing cell placed inside the injection port of a capillary column gas chromatograph equipped with a flame ionization detector (FID) allows analysis of the $C_1$ to $C_{30}$ hydrocarbons in petroleum fluid inclusions. The working surfaces of the crushing cell are glass, and the sample is crushed manually. Cell volume and carrier-gas flow path minimize dead volume, allowing analysis of inclusions in small samples (1 mg) of host rocks. Inclusions in these small samples can be characterized by UV-fluorescence and microthermometry before crushing. Analytical conditions are 1) crush at 200°-300°C, 2) column T program -20° to 300°C at 10°C/min and held at 300°C for 18 min, 3) FID at 350°C, and 4) carrier flow (He) of 1 $cm^3$ min (at 80°C). With a fused silica column (0.2 mm dia., 0.3 um nonpolar bonded phase, 30 m length), these conditions resolve $C_2$ to $C_{30}$ hydrocarbons. Methane and ethane are resolved at lower column T (-60°C) or with a thicker film column.

Samples analyzed include carbonate vein fillings from petroleum source and reservoir rocks (Hartford, and Newark basins), carbonate veins from a Wilbur Springs, Calif., Hg-Au deposit, and fluorite from the S. Illinois fluorspar-Pb-Zn district. The chromatographic results reveal variations in fluid chemistry that are not detected by microthermometry, fluorescence microscopy, or routine solvent-extraction organic geochemistry. Petroleum inclusions in calcite veins in organic-rich shale (Jurassic Feltville Fm., Newark Basin) are petrographically early and have a composition distinct from later, solvent-extractable oil stains. Inclusions in veins in basalt from the Hartford basin, the Hg-Au hot spring deposit, and the S. Illinois fluorspar district all show alteration of petroleum consistent with contact by varying amounts of hot water. (Author's abstract)

BURRUSS, R.C., 1987b Diagenetic paleotemperatures from aqueous fluid inclusions: Reequilibration of inclusions in carbonate cements by burial heating: Min. Mag., v. 51, p. 477-481. Author at USGS, Box 25046, MS 921, Denver, CO 80225, USA.

Diagenetic palaeotemperatures determined from aqueous fluid inclusions can be affected by reequilibration during burial heating. Calculations based on the observed behavior of inclusions in fluorite under external confining P allows prediction of the T and depths of burial necessary to initiate reequilibration of aqueous inclusions in the common size range 40 to 4 µm. Heating of 20° to 60°C over the initial Tt may cause errors of 10° to 20°C in the Th. This suggests reequilibration may cause aqueous inclusions in carbonates to yield a poor record of their low-T history, but a useful record of the maximum T experienced by the host rock. Previous work suggests inclusions containing petroleum fluids will be less susceptible to reequilibration. (Author's abstract)

BURTON, Roy, 1986, Fluid inclusion studies of gold-bearing quartz veins from the Golden Valley mine, Zimbabwe: Undergrad. thesis, Southampton Univ., 93 pp.

Heating and freezing measurements have been undertaken on 70 three-phase ($CO_2$-rich) P inclusions contained within quartz taken from an Archaen gold-quartz vein in the Golden Valley Mine, Zimbabwe. The salinity ranges from 0-6 wt.% NaCl eq. and may show some correlation between low salinity and high Au content but further analysis is essential to confirm or refute this.

Homogenization temperatures are relatively high for this type of deposit (210-319°C) but with no apparent differences between samples, which vary in their Au content from 1.0 ppm to greater than 45 ppm. (From the author's abstract)

CAMERON, E.M. and HATTORI, Keiko, 1987, Archean gold mineralization and oxidized hydrothermal fluids: Econ. Geol., v. 82, p. 1177-1191. First author at Geol. Survey of Canada, Ottawa, Ontario, Canada K1A 0E8.

Sulfate minerals, hematite, and isotopically fractionated sulfides are relatively rare in rocks of Archean age. Several Archean Au deposits, however, contain one or more of these features indicative of oxidized hydrothermal fluids. They include Hemlo, McIntyre-Hollinger, Macassa, Lake Shore, and Ross which are all in Ontario, Canada, and Kalgoorlie in Australia. Examples of lesser deposits are in Hislop Township and in the Matachewan area, Ontario, Canada. With the exception of Hemlo, these are quartz-carbonate vein deposits spatially and temporally associated with felsic plutonism. Because metamorphic fluids and Archean surface waters were mostly reducing, the most feasible general source for the fluids was felsic magmas.

Parent magmas were relatively oxidized, hydrous, and $CO_2$ rich. The oxidized character may have favored the incorporation of Au into the partial melt and its partitioning into magmatic aqueous fluids. High contents of $CO_2$ are conducive to the separation of an aqueous fluid from magma at greater depth than otherwise. Fluid inclusion data support the formation of major Archean Au vein deposits at deeper crustal levels than more recent magmatic-hydrothermal mineralization, such as porphyry Cu deposits. $CO_2$-rich fluids can unmix into two phases at relatively high T and P: a saline aqueous liquid and a low-salinity, $H_2O$-$CO_2$ liquid. This can cause partitioning of Cl-complexed base metals from other metals including Au, Sb, and As. The extensive carbonatization around most deposits has consistent $\delta^{13}C$ values in the range of juvenile-magmatic $CO_2$. (Authors' abstract)

CAMERON, W.E. and NISBET, E.G., 1987, Composition and origin of olivine in a fresh komatiite flow, Zimbabwe (abst.): GAC-MAC, AGC-AMC Joint Ann. Mtg., Program with Absts., v. 12, p. 28. First author at Dept. Geol., Australian Nat'l. Univ., Canberra, Australia.

Olivine morphology can be correlated with chemical composition in the 10.7 m thick flow. The largest equant grains (0.5-2 mm) are $Fo_{92.0-93.5}$. Some contain inclusions of glass and quench pyroxene; most are slightly resorbed. Skeletal, more strongly resolved grains with acicular morphology are $Fo_{91.0-92.0}$. Both olivine types are confined to the lower 10 m of the floor but do not form a cumulus texture. Skeletal plate olivine in the upper 0.5 m of the flow is $Fo_{90-91.5}$ zoned to $Fo_{87}$. Small equant grains and plates in the groundmass in the lower part of the flow have similar composition. Late crystallizing skeletal olivine, including spinifex, is $Fo_{89.5-88}$ zoned to $Fo_{84}$.

Ni and Ca in olivine vary systematically with Mg number from a maximum of 3600 ppm and minimum of 1500 ppm respectively at the highest Mg number. Cr contents reach a maximum of 1500-1600 ppm in skeletal plate olivine but drop to 1200 ppm in the phenocrysts and late skeletal olivine. The composition of olivine in equilibrium with the flow top MgO content of 18% is

$Fo_{91-91.5}$. The most magnesian crystals ($Fo_{92+}$) are xenocrysts from a komatiitic magma with >25% MgO. (Authors' abstract)

CAMPBELL, A.C., BOWERS, T.S., EDMOND, J.M., MEASURES, C.I. and KENISON FALKNER, Kelly, 1987, A time series study of hydrothermal fluid chemistry in the Guaymas Basin, Gulf of California (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 610.

CAMPBELL, A.C., EDMOND, J.M., BOWERS, T.S., MEASURES, C.I., PALMER, M.R. and BROWN, E.T., 1987, Geochemistry of Salton Sea Scientific Drilling Project hydrothermal fluids and comparisons to Red Sea brines (abst.): EOS, v. 68, p. 439. Authors at Dept. Earth, Atmos. & Planet. Sci., M.I.T., Cambridge, MA 02139.

Hydrothermal fluids from both flow tests of the Salton Sea Scientific Drilling Project have been analyzed for all major and a number of minor elements. Many of the "minor" metals have solution concentrations 100-1000X higher than in vent waters from ridge crest hydrothermal vents at 21°N. A more appropriate comparison may be made to the Red Sea Brines (RSB) that, like the Salton Sea Brines (SSB), have a high salinity due to the circulation of fluids through evaporite sequences. Both systems have very similar Cl concentrations (SSB = 4.314 M/kg and RSB = 4.40 M/kg [Brewer & Spencer, 1969]). The Na concentrations in SSB are 40% lower than in RSB (2.42 vs. 4.03 M/kg). Both K and Ca have higher values in SSB (10X and 5X respectively). These differences may, in part, reflect differences in the evaporite compositions for the two regions. In addition, the reaction substrates and secondary mineral assemblages also must play a role in these differences. Some of the minor elements in the Salton Sea fluids, e.g., Zn, Cu, and Pb are about 100X enriched relative to the Red Sea brines. Both areas have similar pH values (SSB = 5.2-5.4 and RSB = -5.5 [Shanks & Bischoff, 1977]). The metal enrichments of the Salton Sea fluids may reflect greater availability of these elements in the reaction substrate.

Boron isotope measurements on fluids from the four sampling ports indicate a linear decrease in $\delta^{11}B$, which can only be due to precipitation within the sampling system. This result, in conjunction with a concomitant decrease in silica, indicates that some sampling artifacts are present. Thus minor element values must be considered minimum numbers due to the possible effects of coprecipitation. (Authors' abstract)

CAMPBELL, Andrew, 1987a Investigations of fluid inclusions in wolframite using infrared microscopy (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 19-20. Author at New Mexico Inst. Mining & Tech., Socorro, NM 87801, USA.

In the study of W deposits, depositional conditions of wolframite are often inferred from observations and thermometric measurements of inclusions in associated quartz or other transparent gangue minerals. As textural evidence for contemporaneous growth can be ambiguous, one occasionally can only assume that the ore and gangue minerals were truly codeposited. IR microscopy is a technique which offers an alternative to this assumption by allowing direct observation and measurement of inclusion[s] in wolframite and some other opaque ore minerals. Wolframite from some localities is IR opaque due to high concentrations of trace elements. The IR microscope used in this study is sensitive to wavelengths from 0.8 to 1.2 micrometers.

Fluid inclusions in wolframite from four deposits were examined and compared with inclusions in quartz.

At Panasqueira Portugal, both liquid-rich and gas-rich inclusions were found in wolframite. Kelly & Rye (1979) report finding liquid-rich and gas-rich inclusions only in that quartz associated with the wolframite, even though many generations of quartz are present. Salinities from inclusions in wolframite range from 8-13 eq. wt% NaCl, which is slightly higher than 5-10 reported by Kelly & Rye (1979) from quartz. Th measurements could not be made because as the wolframite was heated the sample became opaque before Th. T of opacity ranged from 170-225°C. At both San Cristobal, Peru, and Black Pine, Montana, USA, inclusion phase assemblage, salinity and Th measurements were comparable between inclusions in both wolframite and quartz. Quartz and wolframite from the Victorio Mountains, New Mexico, USA, appear to be intergrown in hand samples. However, two-phase inclusions in quartz have Th values ranging from 140-370°C, whereas for the wolframite hosted inclusions, Th values range from 280-380°C with an average Th almost 100°C higher than those in quartz. In addition, the quartz commonly hosts three-phase inclusions containing $CO_2$. No $CO_2$ is observed in wolframite inclusions.

Care must be used in comparing microthermometric measurements between the minerals because factors such as degrees of thermal contraction, fracturing, and rehealing may lead to different inclusion assemblages after formation. On the other hand, if the differences in inclusions from Victorio Mountains are P, then the inclusions themselves may be a better measure of contemporaneity than mineral textures. Care must be used when inferring conditions of deposition of one mineral from another. (Authors' abstract)

CAMPBELL, A.R., 1987b, Investigations of fluid inclusions in wolframite using infrared microscopy (abst.): Abstracts, Inter. Symp. on Petrogenesis and Mineralization of Granitoids, Dec. 7-10, 1987, Guangzhou, China, p. 20-21.

See previous abstract (E.R.)

CAMPBELL, A.R., 1987c A sulfur isotopic study of the San Cristobal tungsten-base metal mine, Peru: Mineral. Deposita, v. 22, p. 42-46. Author at Dept. Geosci., New Mexico Inst. Mining & Tech., Socorro, NM 87801, USA.

The San Cristobal W-base metal deposit differs from other quartz-wolframite vein deposits in that it has a major period of base metal mineralization consisting of pyrite, chalcopyrite, sphalerite, and galena. Th of P and PS inclusions were measured in augelite (260-400°C), quartz (230-350°C) and sphalerite (180-220°C). The $\delta^{34}S$ value of $H_2S$ in solution in equilibrium with the vein minerals range from 1.6 to 9.0 permil increasing through the paragenesis. The relatively heavy $\delta^{34}S(H_2S)$ values suggest a nonmagmatic source for the sulfur. Evaporitic sulfates are a likely source of heavy sulfur and sedimentary anhydrite is known to occur near the San Cristobal region. In contrast to San Cristobal are three similar quartz-wolframite vein deposits, Pasto Bueno, Panasqueira, and Tungsten Queen. They each have an average $\delta^{34}S$ value for sulfides of about 0 permil, suggesting a sulfur of magmatic origin. At San Cristobal an influx of sedimentary sulfur could not only account for the distinctive isotopic signature of the sulfides but also for the presence of the base metal mineralization. (Author's abstract)

CAMPBELL, A.R., 1987d The application of infrared microscopy to fluid inclusions in opaque minerals (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Author at Dept. Geosci., New Mexico Inst. Mining & Tech., Socorro, NM 87801.

Fluid inclusion studies have traditionally involved microthermometric measurements on transparent gangue minerals because most ore minerals are opaque to visible light. This situation introduces the assumption that data obtained from the gangue minerals reflects the conditions of formation of the ore minerals. Infrared microscopy is a new technique which offers a way around this assumption by the direct observation and measurement of fluid inclusions in some opaque minerals. Normally opaque minerals which are transparent to visible light include wolframite, molybdenite, stibnite, bournonite, bertherite [berthierite?], enargite, pyrargyrite, polybasite, hematite, chromite, pyrrhotite, cobaltite and arsenopyrite. Infrared transparency appears to vary with trace element concentration and thus while any of the above minerals may be tansparent from one locality, it may be infrared opaque from another.

In order to test the assumption that fluid inclusions in quartz are representative of the inclusions in coexisting wolframite, quartz-wolframite pairs from four deposits were examined.

| Deposit | Salinity eq. wt.% NaCl | Th(°C) | Other |
|---|---|---|---|
| San Cristobal | | | |
| Qtz | 2.7-6.3 | 230-350 | 2° FI Th = 150-230 |
| Wolf | 1.6-6.6 | 250-340 | 2° FI Th = 190-220 |
| Black Pine | | | |
| Qtz | 4.7 | 250-280 | |
| Wolf | 5.1-8.1 | 210-280 | |
| Panasqueira | | | |
| Qtz | 5-10 (Kelly & Rye, 1979) | | evidence of boiling seen in both |
| Wolf | 8-13 | not measureable | |
| Victorio Mts. | | | |
| Qtz | 1.3-10.0 | 140-320 | Contains $CO_2$ |
| Wolf | 5.4-8.9 | 280-380 | No $CO_2$ observed |

Three of the deposits (San Cristobal, Black Pine and Panasqueira) show good agreement between quartz and wolframite fluid inclusions. However, at Victorio Mts., N.M., the quartz and wolframite give discrepant fluid inclusion information even though in hand sample they appear to be cogenetic.

Work is continuing on other quartz-wolframite pairs from deposits in England and China. Addition work is planned looking at arsenopyrite from the same stage of mineralization as wolframite and quartz at Panasqueira. (Author's abstract)

CAMPBELL, A.R. and ROBINSON-COOK, Sylveen, 1987, Infrared fluid inclusion microthermometry on coexisting wolframite and quartz: Econ. Geol., v. 82, p. 1640-1645. Authors at Dept. Geosci., New Mexico Inst. Mining & Tech., Socorro, NM 87801.

See Fluid Inclusion Research, v. 19, p. 70. (E.R.)

CAMPEAU, R.M. and KISSIN, S.A., 1987, Project Wapa: A lead-zinc occurrence in Middle Devonian carbonates of northern Saskatchewan (abst.): GAC-MAC, AGC-AMC Joint Ann. Mtg., Program with Absts., v. 12, p. 29. Authors at Dept. Geol., Lakehead Univ., Thunder Bay, Ontario, P7B 5E1.

Stratabound occurrences of pyrite, galena, sphalerite and fluorite, accompanied by extensive dolomitization occur within the Eifelian Smoothstone River Formation (Lower Elk Point Group) in the Lac La Ronge area. An extensive drilling program failed to locate economic ore bodies, although analysis of the region suggests that it is not an unfavorable environment for formation of carbonate-hosted lead-zinc ores. The mineralized strata contain zones of brecciation attributed to collapse due to solution of gypsum. Brecciation has been interpreted as occurring in two phases, one during early diagenesis and the other post-diagenetic and presumably accompanying sulfide deposition. Sparry dolomite and chalcedony accompany the ore minerals, and primary fluid inclusions are abundant in the dolomite. Homogenization temperatures fall into two populations, one at ca. 100°C and one that did not homogenize at temperatures >180°C. These temperatures strongly sugegest that ore-depositing fluids were of deep origin, probably from an adjacent sedimentary basin, based on geological considerations, the Elk Point Basin. Mineralization, however, is not a good analogy to that at Pine Point, in that it is not controlled by a marked facies change, and mixing of sulfur- and metal-bearing solutions is not strongly indicated. A more apt comparison is in the deposits of the Mississippi Valley, particularly in the Viburnum Trend. A sandstone aquifer pinching out beneath a carbonate unit appears to have directed basinal brines to the site of deposition. Sulfur was carried either with the solution in reduced form or derived by inorganic reduction of sulfate. The failure of the process to form economic deposits seems to be a function of inadequate local paleohydrologic factors. Thus, potential for carbonate-hosted lead-zinc deposits appears to be present on a regional basis in northern Saskatchewan. (Authors' abstract)

CAMPOS, E.G., XAVIER, R.P. and OLIVEIRA, S.M.B. de, 1987, Characterization of mineralizing fluids related to auriferous quartz-veins from Cuiabá Group, Mato Grosso State, Brazil: Proc. First Brazilian Congress of Geochem., Porto Alegre, Oct. 30-Nov. 2, 1987, Vol. I, p. 417-435 (in Portuguese; English abstract). First author at the IGCE/UNESP, Rio Claro, CEP 13500, SP, Brazil.

Au mineralization in the Cuiabá Group - Mato Grosso State - is related to quartz veins which occur in this metasedimentary sequence. Within the evolutionary frame work of Au metallogeny in this group, a stage of metamorphism and deformation can be recognized with which several sets of Au-bearing quartz veins are thought to be associated.

Field data and microthermometry distinguished two vein generations. The first, striking NE, is concordant with the regional lineament and involved metamorphic fluids which leached dispersed Au from the metasediments and concentrated it in the veins. These fluids are low-salinity aqueous fluids, rich in $N_2$ with minor amounts of $CO_2$, and show Th varying from 180 to 360°C. The second fills NW fractures and are discordant. In this case, the mineralizing fluids seem to be related to a granite intrusion, located relatively close to the Au-bearing quartz veins. Data on the inclusions in these are not conclusive, but suggest a zoning with respect to the intrusive body. (Authors' abstract)

CANDELA, P.A., 1987, Theoretical constraints on the chemistry of the magmatic aqueous phase (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 610.

CARON, J.-M., 1987, Structural control of fluids migration in metamorphic rocks (abst.): Abstracts, NATO Advanced Research Workshop, Fluid movements, element transport, and the composition of the deep crust, Lindås, Norway, 18-24 May, 1987 (unpaginated). Author at Lab. Pétrol., U.A. 726, Univ. Lyon I 27-43 Bd du 11 Novembre, 69622 Villeurbanne Cedex, France.

It is concluded from the structural constraints that a free fluid phase was not present at any place and at any time in the metamorphic rocks of the deep crust, even during a low temperature prograde evolution. (From the author's abstract)

CARROLL, M.R. and STOLPER, E.M., 1987, Argon solubility and diffusion in silica glass (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 612.

CARTEN, R.B., 1987, Evolution of immiscible Cl- and F-rich liquids from ore magmas, Henderson porphyry molybdenum deposit, Colorado (abst.):

Geol. Soc. Am. Abstracts with Programs, v. 19, p. 613. Author at U.S. Geol. Survey, MS 905, Box 25046, Denver Fed. Center, Denver, CO 80225.

Mineralization in the Henderson deposit appears to be related to the nearly simultaneous generation of separate Cl- and F-bearing liquids in the apices of stocks. Studies of fluid inclusions from the Seriate stock, constrained by detailed time-space relations, suggest that both a $NaCl-KCl-FeCl_2-FeCl_3-MnCl_2-H_2O-CO_2$ liquid and a $SiO_2-Al_2O_3-K_2O-FeO-F-H_2O$ liquid formed during solidification of the upper 200 m of the intrusion, a region which contains an abundance of pegmatitelike textures (USTs). These two liquids principally were trapped in separate secondary planes. Inclusions of either liquid are scarce to absent below the zone of USTs. Maximum salinity of the Cl-rich liquid (daughters = halite + hematite + manganosiderite ± sylvite ± erythrosiderite?) decreases from 62 eq. wt% NaCl in early solidified, high levels of the apex to 16-20 wt % in late solidified, deeper levels. This distribution pattern together with homogenization behavior, dominantly $Th_l$ (280 ± 35°C(1σ)) <Tm(NaCl), and absence of contemporaneous low-salinity, vapor-rich inclusions imply derivation of these high-salinity liquids directly from a magma. F-bearing, aluminosilicate liquids are most abundant in USTs and vein dikes. Individual inclusions contain tens of similar micalike daughter minerals (~50% of volume) with variable Fe/Al ratios; Cl daughters are not present. The remaining volume is composed of aqueous liquid ($Th_l$ = 346 ± 30°C; Tm ice = -3.4 ± 1.9°C). Daughters appear to melt (400-550°C) to a brown liquid that is miscible with the aqueous fluid. The Cl-rich and F-rich liquids represent peralkaline and peraluminous fractions derived from magma enriched in ore components. Cl-soluble components (dominantly Fe, Mn, Na, and probably Cu, Pb, Zn, and Ag) preferentially partitioned into the peralkaline fraction, and F-soluble components (dominantly Si, Al, and probably REE, Zr, Nb, Ta, Mo, Sn, and W) partitoned into the peraluminous fraction. Each liquid followed a unique geochemical path. Cl-rich liquids may have produced proximal potassium metasomatism and distal base-metal mineralization associated with F-poor sericitic alteration; F-rich liquids may have produced intense silicification, thick proximal veins of quartz + fluorite ± molybdenite ± K-feldspar ± biotite ± zircon ± monazite ± ilmenorutile, and distal F-rich veins and alteration assemblages containing topaz and sericite. (Authors' abstract)

CARTWRIGHT, I., 1987, The prograde and retrograde transitions between amphibolite and granulite facies assemblages: The transition between fluid-absent and fluid-present petrogenesis? (abst.): Abstracts, NATO Advanced Research Workshop, Fluid movements, element transport, and the composition of the deep crust, Lindås, Norway, 18-24 May, 1987 (unpaginated).

CASE, J.B. and DEAL, D.E., 1987, Preliminary hydrologic and geomechanical evaluations of brine inflow from bedded salt to a nuclear waste repository (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 614.

CATHELINEAU, Michel, 1987a The P-T-$\bar{V}$-X conditions in an active geothermal field: A comparison between the present day and the fluid inclusion data (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 21-22. Author at CREGU and GS CNRS-CREGU, BP 23, 54501 Vandoeuvre les Nancy Cedex, France.

Fluid inclusions were analyzed systematically in samples from different wells and depths of the Los Azufres (Mexico) active hydrothermal system. Fluids were studied either in authigenic minerals (P inclusions) in quartz, calcite or anhydrite, or in magmatic minerals (S inclusions in microcracks).

1) About 800 inclusions are analyzed in several thick sections from cores of wells, A1, A3, A4, A9, A12, A21 and A23. Three types of inclusions

were identified based on microscopic and microthermometric data: type L1 (liquid-rich inclusion, and L'1, with in addition, a trapped solid inclusion) and, two types in minor abundance, L2 (no gas bubble) and V (vapor-rich inclusion). L1 inclusions ($0.7 < flw < 0.95$) dominate largely in the whole field, in calcite and quartz samples. They occur in homogeneous groups, which exhibit very constant liquid-vapor volumetric ratios and low scattered Th. They are related to an homogeneous trapping of a single-phase fluid. Rare type V inclusions were observed together with L1 inclusions in very few samples (A4-1000 for instance) and mainly in anhydrite. In such cases the very different Flw or type V and L1 inclusions and the lack of apparent necking down argue in favor of heterogeneous trapping of a liquid phase plus a vapor phase. Type L2 corresponds to low Tt ($T < 100°C$) and a metastability phenomenon (lack of gas bubble nucleation).

A great number of inclusions were analyzed in different samples of a same well (A3 and A23) in order to get the range of variation of microthermometric parameters. Wells A3 and A23 are the only ones where cores are available at three different depths. Most of fluid inclusions have very high Tmi around -0.2 to -1.2°C, which corresponds to very low salinities around 1-2 eq. wt % NaCl. Th increases from the shallowest levels (-600 m, Th = 250 ± 10°C) to the deepest ones (-1874 m, $300 < Th < 350°C$). In most samples, the Th ranges is small (10-15°C), and the mode of the histogram gives an accurate estimation of the T.

Fluids are aqueous and have low salinity, around 1 eq. wt % NaCl. They are trapped in P-T conditions very close to that fixed by the liquid-vapor equilibrium curve. Fluid P is lower than the calculated hydrostatic one assuming a liquid-dominated system, because of the existence of a two-phase vapor-dominated zone at a depth between 500 and 1500 meters. Such low P are important to consider in geological process[es], especially in the case of fossil hydrothermal systems.

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

CATHELINEAU, Michel, 1987b, U-Th-REE mobility during albitization and quartz dissolution in granitoids: Evidence from south-east French Massif Central: Bull. Minéral., v. 110, p. 249-259.

CATHELINEAU, M., MARIGNAC, C. and PUXXEDU, M., 1987, P-T-X conditions of contact and thermal metamorphism in the Larderello geothermal field: The fluid inclusions data (abst.): Terra Cognita, v. 7, no. 2-3, p. 129. Authors at CREGU, Vandoeuvre-les-Nancy, France.

Fluid inclusions were studied in samples from [1500-4000 m] in the Larderello field. Two very distinct states of fluid trapping are distinguished:

1) First stage is thought to be contemporaneous with the intrusion of the Larderello magmatic body which provokes a contact metamorphism of which the age is known to be around 1.3 Ma. Two types of fluids are observed: liquids and vapors belonging to a complex system ($H_2O$, NaCl, KCl, $CaCl_2$, ...) and characterized by variable but very high salinities, and $CO_2$-$CH_4$-($H_2O$)-rich inclusions which issue [from] the metamorphism of C-rich local lithologies. Both T and P are very high, ~500-650°C and ~1.0-1.4 kbars, and are consistent with the estimates deduced from mineral assemblages.

Thus, P conditions at this stage are purely lithostatic.

2) Second stage represents the progressive establishment of the active geothermal system of Larderello. The fluids are mixtures in any proportions of three types: $H_2O$-$CO_2$-vapor-rich inclusions, with a low $CH_4$ content as compared to that of the stage 1 fluids, brines ($H_2O$-NaCl-KCl), and dilute waters. The P and T estimates indicate a progressive shifting towards the present conditions (hydrostatic P and lower T of ~350°C). (From the authors' abstract)

CATHLES, L.M., 1986, The geologic solubility of gold from 200-350°C, and its implications for gold-base metal ratios in vein and stratiform deposits, in Clark, L.A., ed., Gold in the Western Shield: The Canadian Inst. Mining & Metal., Special Vol. 38, p. 187-210. Author at Chevron Oil Field Res. Co., P.O. Box 446, La Habra, CA 90631.

Silicate and sulfide buffers that control the major element chemistry and pH of geothermal solutions in common geologic environments are used to investigate the "geologic" solubility of Au as a function of T and solution salinity. The geologic solubility of Au is much greater in low-salinity solutions, and for any given salinity is probably maximum at about 300°C. The selectivity of low-salinity solutions for Au and against base metals (which are carried as chloride complexes), and conversely, the selectivity of higher salinity solutions for base metals and against Au, explains the distinct bimodal metal contents of vein and stratiform deposits which have either high Au and little or no base metals, or lower Au and abundant base metals. The 300°C maximum in Au solubility could expalin why Au veins tend to have somewhat lower maximum T of formation than base metal veins and massive sulfide deposits. A basin evolution model is suggested that can account for both the metal ratios and locations of Au and base metal deposits in greenstone belts. (Author's abstract)

CATHLES, L.M., SCHOELL, M. and SIMON, R., 1987, $CO_2$ generation during steamflooding: A geologically based kinetic theory that includes carbon isotope effects and application to high-temperature steamfloods: 1987 Int'l. Symp. on Oilfield Chem., Proc. [Soc. Petroleum Engineers], p. 255-270.

CATTALANI, Sergio, 1987, A fluid inclusion and stable isotopic study of the St. Robert, W-Ag-Bi vein deposit, Eastern Townships, Quebec: MS thesis, McGill Univ.

See next two items. (E.R.)

CATTALANI, Sergio and WILLIAMS-JONES, A.E., 1986, Geological and fluid inclusion studies at the Saint-Robert Ag, W, Bi deposit, Eastern Townships, Quebec, in Current Research, Part A, Geol. Survey Canada, Paper 86-1A, p. 365-374.

See next item and Fluid Inclusion Research, v. 19, p. 75-76, 1986. (E.R.)

CATTALANI, S. and WILLIAMS-JONES, A.E., 1987, Fluid inclusion and stable isotope studies of the St. Robert Ag-W-Bi deposit, Eastern Townships, Quebec (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Authors at Dept. Geol. Sci., McGill Univ., 3450 Univ. St., Rm. 238, Montreal, Quebec, H3A 2A7, Canada.

W-Ag-Bi mineralization at St. Robert, Eastern Townships, Quebec, occurs in high-level hydrothermal quartz veins. The major veins are steeply-dipping and include a Ag-bearing set in the southern part of the property and W and Bi-bearing sets in the central and northern parts respectively. Narrower, subhorizontal W-rich veins cross-cut the steeply-dipping sets.

Concordant granodioritic, and discordant lamprophyric dike swarms are associated with the deposit and are concentrated within a 2.5 km x 400 m thermal metamorphic aureole, indicating a larger intrusive stock at depth. The aureole is overprinted by fault-controlled alteration of proximal argillic and distal phyllic facies.

Microthermometric data on fluid inclusions in quartz, scheelite, and sphalerite indicate that there were early, low salinity fluids containing variable proportions of $H_2O$ and a carbonic phase, and later, low salinity, post-ore aqueous fluids. Raman microprobe analysis of the carbonic phase confirms the presence of $CO_2$, $CH_4$, and $N_2$. Entrapment T for the early fluid ranged from 160°C to 300°C whereas sulphur isotope geothermometry points to fluid T as high as 350°C. Later aqueous fluid were trapped at 140°C to 210°C.

Oxygen and sulfur isotopic data and phase equilibrium calculations suggest that the metals were transported with sulfur of marine origin in a slightly acidic meteoric water-dominated hydrothermal system. Mineral deposition is believed to have occurred as a result of volatile phase effervescence and $fO_2$ fluctuations during episodic wall-rock fracturing and resealing. (Authors' abstract)

CAVARRETTA, G., DE VIVO, B., TECCE, F. and SERRACINO, M., 1987, Fluid inclusion microthermometry and sulfur isotope composition of hydrothermal anhydrite from the geothermal well Isola di Vulcano-1: CNR, Boll. Gruppo. Naz. Vulcanol. 1987, p. 253-261 (in Italian).

Hydrothermal minerals (smectite, calcite, anhydrite, chlorite, epidote and garnet) are widely present in the Isola di Vulcano-1 (IV-1) well (Aeolian Islands), drilled for geothermal exploration down to 2050 m. The country rocks consist of trachybasaltic and trachyandesitic lavas and pyroclastics, and of a monzogabbro intrusion at depth.

Fluid inclusions in anhydrite are monophase (L or V), biphase (L+V), or triphase (L+V+S - the solid often recognized as halite). Th corrected for hydrostatic P give a wide range of Tt (about 120° to 350°C), mostly higher than measured in-hole T, especially at shallow depths. They are interpreted to reflect either repeated episodes of crystallization/fluid trapping, or, less probably, necking down/leakage phenomena.

Salinity values also are widely variable from 0.3 to 22.7 wt.% NaCl eq. [These values apparently do not account for the halite-bearing inclusions - P.L.] They are interpreted to result from various extents of interaction between meteoric waters and volcanic fluids.

One anhydrite sample gave a $\delta^{34}S$(CDT) value of 14.87 ± 0.06 per mil. The isotopic T calculated assuming isotopic equilibrium with fumarolic $H_2S$ ($\delta^{34}S$(CDT) = -5.4 per mil) is 334°C, in fair agreement with calculated Tt of fluid inclusions.

Hydrothermal anhdyrite from the IV-1 well may have been precipitated by interaction of phreatic waters with volcanic $SO_2$. The large variations of both salinity and T of the trapped fluids are ascribed to repeated episodes of trapping-leaking-refilling, in agreement with the protracted volcanotectonic activity in the area. (Abstract translated by P. Lattanzi)

CAVARRETTA, G. and TECCE, F., 1987, Contact metasomatic and hydrothermal minerals in the SH2 deep well, Sabatini volcanic district, Latium, Italy: Geothermics, v. 16, no. 2, p. 127-145. Authors at Centro di Studio per la Geol. dell'Italia Centrale del C.N.R. c/o Dipart. di Sci. della Terra, Univ. degli Studi di Roma "La Sapienza" I-00185 Roma, Italy.

Includes no data on fluid inclusions, but discusses the probable nature of the fluids responsible for the alteration. (E.R.)

CERCONE, K.R., 1987, Fluid migration along stylolites: Evidence from ultraviolet fluorescence microscopy (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 615-616. Author at Geosci. Dept., IUP, Indiana, PA 15705-1087.

Stylolitization and other types of P solution create thin layers of insoluble clays, oxides and degraded organic matter in sedimentary rocks. The low hydraulic conductivity of such material has caused many workers to regard stylolites as barriers to subsurface fluid flow. Other studies have suggested that irregularities along a P solution surface could allow fluids to migrate within and parallel to solution seams. The use of ultraviolet microscopy permits fluid migration paths around stylolites to be documented in cases where the migrating fluid is liquid hydrocarbon. As hydrocarbon fluids pass through pores and microfractures, they leave behind fluorescent fluid inclusions along their migration pathways. These inclusions are commonly so minute that they can only be detected under ultraviolet illumination. Examination of stylolitic carbonate units from the Silurian of Michigan, Cretaceous of Oman and Mississippian of Alabama reveals that hydrocarbon fluids were able to migrate along P solution seams provided that hydrocarbon generation and stylolitization were contemporary. In such cases, hydrocarbon fluids seem to have migrated along stylolites only for short distances (1-5 cm) before being diverted into microfractures at stylolitic teeth. Based on this evidence, P solution seams alone do not appear to significantly impede or enhance fluid flow in the subsurface. However, such features do exert an indirect control on fluid migration by funneling fluids into fracture systems where they can flow most efficiently. (Author's abstract)

CHACKO, Thomas, KUMAR, G.R.R. and NEWTON, R.C., 1987, Metamorphic P-T conditions of the Kerala (South India) khondalite belt, a granulite facies supracrustal terrain: J. Geol., v. 95, p. 343-358. First author at Dept. Geol., Univ. North Carolina, Chapel Hill, NC 27514, USA.

Partially decrepitated $CO_2$ inclusions in quartz at the Ponmudi mixed biotite gneiss-charnockite quarry have significant $CH_4$ and/or $N_2$ and are texturally late. The probable sequence of events in metasediments was (1) migmatization, (2) charnockite formation, (3) symplectitic cordierite formation, and (4) late $CO_2$ entrapment. Phase equilibrium diagrams of anatexis in aluminous systems and Fe-Mg exchange between garnet and biotite indicate metamorphic T of 650-850°C for the khondalites. T based on garnet-orthopyroxene Fe-Mg exchange in charnockites are 755 ± 60°C, which probably refers to a vapor-induced charnockitization event. Paleopressures of khondalites and charnockites are mostly 5-6 kbar over the entire Belt, with a few P over 6 kbar adjacent to the charnockitic orthogneiss massif which borders the Belt on the northeast. The texturally-deduced sequence of events can logically be related to a continuous P-T cycle, with maximum P of 6.5 kbar generated in the deepest parts of the metasedimentary section overlying an orthogneiss basement. Paracharnockites and cordierite symplectites may have formed at the beginning of the P-release cycle of uplift. $CO_2$ influx, possibly from below the crust, facilitated charnockite formation. Entrapment of late $CO_2$ in quartz occurred during uplift at 3-4 kbar. Some mechanism of burial of a vast tract of sediments at a nearly uniform depth under nearly a continental thickness of overburden is necessary to explain the monotonous paleopressure pattern. An "A-subduction" model used for the northern Norwegian Caledonides, in which a continental shelf sequence was entrained at the flat interface of colliding continents in near-horizontal subduction, may be a plausible mechanism. Radioactive self-heating of a doubly-thick continent or pervasive streaming of hot $CO_2$ from the mantle through tectonic shear zones could have raised regional T to the granulite facies. (From the authors' abstract)

CHAKOUMAKOS, B.C. and LUMPKIN, G.R., 1987, Constraints on the crystallization of the Harding pegmatite, Taos County, New Mexico (abst.): GAC-MAC, AGC-AMC Joint Ann. Mtg., Program with Absts., v. 12, p. 30. Authors at Dept. Geol., Univ. New Mexico, Albuquerque, NM 87131.

A P-T path for the crystallization of the Harding pegmatite magma has been constrained by the following: 1) the experimentally determined liquidus, solidus and phase assemblages for a bulk sample of the pegmatite, 2) isochores for $CO_2$-NaCl-$H_2O$ fluid inclusions in quartz and beryl from the various lithologic units of the pegmatite, 3) the conditions of metamorphism of the surrounding host rock, and 4) pegmatite mineral equilibria, including the Li-Al-silicates, micas, and feldspars. The magmatic portion of crystallization began at 650°C and 330-350 MPa (11-12 km depth) and continued isobarically to 550°C. The host rock temperature at the time of intrusion was 0 to 150°C below the solidus temperature. Considering cooling models for an infinite slab, the magmatic crystallization (giant crystal texture) occurred in 100 years or less. The subsolidus hydrothermal replacement and reequilibration (i.e., "stewing in its juices") continued for several million years. Isobaric cooling continued to 400-300°C, followed by uplift and erosion. Li-Be margarite, prominent in the hanging-wall metasomatic aureole, crystallized below the pegmatite solidus. Quartz-spodumene intergrowths exposed in footwall aplite are interpreted as pseudomorphic replacements of early formed petalite. Eucryptite to spodumene replacement occurred during uplift, and is not associated with the hydrothermal phase. (Authors' abstract)

CHANGKAKOTI, Amarendra, 1985, Mineralogic, fluid inclusions and isotopic investigations of the Great Bear Lake silver deposits, Northwest Territories: MS thesis, The University of Alberta.

See Changkakoti et al., 1985, Fluid Inclusion Research, v. 18, p. 78, and 1986, Fluid Inclusion Research, v. 19, p. 77-78. (E.R.)

CHANGKAKOTI, A., GRAY, J., KRSTIC, D., MORTON, R.D. and CUMMING, G.L., 1987, Determination of radiogenic isotope compositions of fluid inclusion waters (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). First author at Dept. Physics, Univ. Alberta, Edmonton, AB Canada T6G 2J1.

The need for precise geochronological methods applicable to mineral deposits has long been apparent, particularly for those ore deposits which lack K-, Rb-, U-, Pb-, Nd- and Sm-bearing phases or which yield anomalous ages. In many cases the geochronological results on constituent ores and gangue minerals may lead to ambiguous dates for specific hydrothermal pulses which are distinguishable through fluid inclusion studies. Thus the possibility of applying geochronological techniques to the fluids in fluid inclusions is a very recent and intriguing development.

Normal and Landis (Econ. Geol., 1983) and Medford et al. (Econ. Geol., 1983) have reported the use of radiogenic isotopes in fluid inclusion waters as tracers and Shepherd and Darbyshire (Nature, 1981) have reported radiogenic dating of ore deposits. These reports involved Rb and Sr isotopes. We report here preliminary results on the age determination of mineralization using Rb/Sr, Pb and Nd/Sm isotope ratios of fluid inclusion waters extracted from fluid inclusions in quartz samples from the Bluebell Pb-Zn deposit, British Columbia, Canada. The method involves thermal decrepitation of the quartz sample to release the fluid inclusion waters. Leachates are chemically treated using standard ion exchange techniques to separate the elements and mass spectroscopic measurements made using a MicroMass 354 isotope ratio instrument.

Common lead results exhibit a range of $^{206}Pb/^{204}Pb$ isotope ratios from 17.44 to 18.87. $^{87}Rb/^{86}Sr$ and $^{87}Sr/^{86}Sr$ ratios range from 0.5 to 4.7 and 0.714 to 0.716 respectively, with an approximate initial $^{87}Sr/^{86}Sr$ ratio of 0.712. $^{143}Nd/^{144}Nd$ ratios range from 0.512 to 0.528 and $^{147}Sm/^{144}Nd$ ratios from 0.12 to 3.0. These preliminary results will be augmented and presented at the meeting. (Authors' abstract)

CHANGKAKOTI, A., GRAY, J. and MORTON, R.D., 1987, The role of basinal brines and thermal springs in the genesis of carbonate-hosted fluorite-witherite mineralization in the Liard River area, British Columbia, Canada: N. Jb. Miner. Mh, v. 5, p. 217-232.

The Tam fluorite-witherite-barite deposit of northeastern British Columbia, Canada, is a carbonate/mudstone-hosted epigenetic type. Fluid inclusion studies show the deposit to have formed from brines of 6.43 to 16.98 wt% NaCl equiv. salinity at T between 125° and 240°C. Oxygen and hydrogen isotopes suggest two isotopically distinct fluids responsible for the formation of the deposit.

The deposit owes its origin to stratafugic oilfield brines which escaped from the deeper sectors of the Western Canada Sedimentary Basin during the onset of the Cordilleran orogeny. Fluorite and barite were deposited in structural traps, such as zones of decollement. Later incursion of meteoric (thermal spring) water into the reservoirs caused thermochemical reduction of primary sulfates and witherite partly replaced primary barite. This deposit, and associated deposits in the vicinity, provide an insight into the chemistry of the evolving hydrothermal systems associated with the tectonic evolution of the Western Canada Sedimentary Basin during the encroachment of the Cordilleran front. (Authors' abstract)

CHANGKAKOTI, A., GRAY, J., MORTON, R.D. and SARKAR, S.N., 1987, The Mosaboni copper deposit, India - A preliminary study on the nature and genesis of the ore fluids: Econ. Geol., v. 82, p. 1619-1625. First author at Dept. Physics, Univ. Alberta, Edmonton, Alberta, Canada T6G 2J1.

A study of Th (275-450°C), salinity (35-51 wt.%), $\delta D$ and $\delta^{18}O$ of inclusions in quartz from this Precambrian shear-zone-type deposit suggest a meteoric source for the ore-forming fluids. (E.R.)

CHAPMAN, H.J., BICKLE, M.J. and WICKHAM, S.M., 1987, Fluid flow monitored by strontium isotopic measurements in metamorphic rocks from the Pyrenees (abst.): Abstracts, NATO Advanced Research Workshop, Fluid movements, element transport, and the composition of the deep crust, Lindås, Norway, 18-24 May, 1987 (unpaginated).

CHAREF, A. and SHEPPARD, S.M.F., 1987, Pb-Zn mineralization associated with diapirism: Fluid inclusion and stable isotope (H, C, O) evidence for the origin and evolution of the fluids at Fedj-el-Adoum, Tunisia: Chem. Geol., v. 61, no. 1/4, p. 113-134.

Full paper for abstract in Fluid Inclusion Research, v. 18, p. 78, 1985. (E.R.)

CHAUDHURI, S., BROEDEL, V. and CLAUER, N., 1987, Strontium isotopic evolution of oil-field waters from carbonate reservoir rocks in Bindley field, central Kansas, USA: Geochimica Cosmo. Acta, v. 51, p. 45-53. First author at Dept. Geol., Kansas State Univ., Manhattan, KS 66506, USA.

Oil-field waters produced from Mississippian carbonate reservoir rocks in Bindley field, Kansas, had an average salinity of about 42.8 mg/l.* They were enriched in Ca, Sr, Na, K, Rb, and Li and depleted in Mg relative to

*See next page

sea water at the same level of either Cl or Br concentration. The average abundances of different elements are as follows: Na - 13,460 mg/l, K - 325 mg/l, Rb - 0.9 mg/l, Li - 12 mg/l, Ca - 1,515 mg/l, Sr - 42 mg/l, Mg - 430 mg/l, Cl - 23,000 mg/l, $SO_4$ - 2,630 mg/l, Br - 32 mg/l. The $^{87}Sr/^{86}Sr$ values of the waters ranged between 0.7221 and 0.7230, whereas the values of the host carbonate rocks were between 0.7090 and 0.7093. The very high $^{87}Sr/^{86}Sr$ values of the waters probably occurred as a result of their reaction with alkali feldspar minerals in buried Precambrian crystalline rocks to the east of the Bindley field. The study demonstrates that despite their residence in carbonate reservoir rocks oil-field waters can retain sufficiently distinct isotopic memory that may provide important clues about mineral-water interactions in the chemical evolutionary history of the waters. The study further indicates that very late diagenetic reactions in many carbonate rocks are of minor extent. Difference in the Sr isotopic data among the oil-field waters suggests that the Sr isotopic data can be used as a reliable guide in recognizing existence of separate pools in an oil field. (Authors' abstract) *Presumably a misprint for g/l.

CHAUSSIDON, M., ALBARÈDE, F. and SHEPPARD, S.M.F., 1987a Sulphur isotope heterogeneity in the mantle from ion microprobe measurements of sulphide inclusions in diamonds: Nature, v. 330, p. 242-244. Authors at Centre de Recherches Pétrogr. & Géochim. et ENS Géol. BP 20, 54501 Vandoeuvre Cedex, France.

The sulphur isotope composition of the mantle has been generally considered to be 0 ± 2‰. There is, however, considerable uncertainty in the mean $\delta^{34}S$ value of the mantle and in its range because there have been very few analyses of unaltered sulphide phases of direct mantle origin and $\delta^{34}S$ values of sulphides from large mafic intrusions range from -9 to +17‰. We report here ion microprobe $\delta^{34}S$ determinations from two mantle derived sulphide inclusions(≈100 µm) preserved in a diamond ($\delta^{13}C$ = -4.25‰) of peridotitic(?) paragenesis from Premier (South Africa) and in four diamonds of eclogitic paragenesis from Orapa (Botswana). Three octahedral sulphides have lower $\delta^{34}S$ values (+2.3 ± 1.4‰) than three platelet-like sulphides (+8.2 ± 0.9‰). This evidence for mantle heterogeneity for sulphur is interpreted in terms of recycling of crustal material into the eclogitic region of diamond growth in the mantle. (Authors' abstract)

The sulfide inclusions are believed to be the result of trapping, during diamond growth, of an immiscible sulfide (Fe-Cu-Ni) melt. The cover of this issue of Nature shows a color photograph of a pyroxene crystal from a xenolith with regularly-arrayed sulfide inclusions, as occur from nucleation on the surface of a growing crystal (Roedder, 1984, Rev. in Min., fig. 2-33, p. 32). (E.R.)

CHAUSSIDON, M., ALBARÈDE, F. and SHEPPARD, S.M.F., 1987b Sulfur isotope composition of sulfide inclusions from diamonds and megacrysts by ion microprobe (abst.): EOS, v. 68, p. 440. Authors at CRPG-ENSG, BP 20, 54501 Vandoeuvre Cedex, France.

$\delta^{34}S$ has been determined with a CAMECA IMS 3F ion probe with a precision of ± 1 permil. The conditions were: $O^{2+}$ primary beam, positive secondary ions, mass resolution of 2700 (with correction of occasional hydride interference). Each analysis was for about 2 hours on a spot of 60 µm diameter. Instrumental mass fractionation established on mineral standards was reproducible and amounted to -62.0 ± 0.5‰ for chalcopyrite, -65.7 ± 0.5‰ for pyrite, -59.5 ± 0.5‰ for pyrrhotite, and -47.3 ± 0.5‰ for pentlandite.

Sulfide inclusions (<100 µm) were from a diamond from Premier and polysulfide globules from a Cr-poor clinopyroxene megacrysts from the Uintjiesberg kimberlite (South Africa). The $\delta^{34}S$ values are: Premier pentlandite at +1.1‰; Uintjiesberg pyrrhotite-pentlandite exsolutions -2.2‰ with a lower confidence because of some uncertainty on the pyrrhotite-pentlandite ratio in the crater. These data are the first $\delta^{34}S$ measurements on inclusions in minerals which crystallized within the mantle.

The inclusion from the clinopyroxene indicates that the $\delta^{34}S$ of the kimberlitic melt from which it precipitated at high temperature did not differ significantly from the meteoritic value. Although the inclusions in diamond cannot be definitely assigned a primary origin and may be conceivably related to cracks, their $\delta^{34}S$ do not deviate from the generally accepted mantle value.

Continuing studies are aimed at identifying eventual recycling of crustal sulfur in the mantle. (Authors' abstract)

CHEILLETZ, A. and GIULIANI, G., 1982, The role of granitic deformation in the genesis of feldspathic episyenites from the Lovios-Geres (Galice) and Zaër (Central Morocco) batholiths: Relations with associated tungsten-tin deposits: Mineral. Deposita, v. 17, p. 387-400 (in French; English abstract). First author at Centre de Recherche Pétrogr. & Géochim. C.R.P.G., Nancy, France.

The study of the deformation of two Hercynian granites in the border zone of feldspathic episyenites suggests a tectonic model for their structural characteristics. The development of the feldspathic episyenite veins takes place at the final stage of granite emplacement and results from a local stress field. This process increases the pore fluid pressure until it produces hydraulic fracturing. The generation of intragranitic tungsten-tin veins spatially associated with the episyenites must be related to later tectonic and fluid circulation events. (Authors' abstract)

CHEN, C.-T. A., 1987, High-pressure specific heat capacities of pure water and seawater: J. Chem. Eng. Data, v. 32, p. 469-472.

CHEN, Shien, 1987, The induced-controlled fault: A typical fracture for vein-like W(Sn)-deposits: Geol. & Prospecting, v. 23, no. 11, p. 16-22 (in Chinese; English abstract). Author at No. 938 Geological Team, The Nonferrous Metals Explor. Co., Guangdong Bureau of Metallurgical Industry.

First order large faults, occurring either singly or in a group, are found in many vein-like W(Sn) deposit areas characterized by multiperiodic activity. Mineral-bearing fractures may be of this type, and mineralization in such fractures is controlled by the fault. For this reason it is named an induced-controlled fault. The faults play an important role in controlling volatile element halo anomalies, metallogenesis, vertical zoning, the position of enriched zones, the distribution of useful components, mineralization T, ore-bearing fluid (composition and flow direction) and the dip of the ore veins. Their study is significant for exploration for semi-concealed 'five storeys' type W(Sn) deposits. (From the author's abstract)

Many data from fluid inclusion studies of such deposits are presented. (H.-Z. Lu)

CHEN, Xianpei and GAO, Jiyuan, 1987, Thermal water precipitation and lead-zinc-barite deposits: Chenji Xuebao, v. 5, no. 3, p. 149-158 (in Chinese).

CHENG, Chuanyan, 1987, The hydrothermal alteration of Fuzhou geothermal field: Geology of Fujian, v. 6, no. 3, p. 163-185 (in Chinese; English abstract).

Presents fluid inclusion homogenization and salinity data on various authigenic alteration phases. (H.E.B.)

CHINESE SOC. OF MIN., PETR., AND GEOCHEM., 1987, Studies of Fluid Inclusions in Minerals: Papers from Chinese Second National Conf. on Fluid Inclusion Studies and Experimental Geochemistry, Guiling, Guangxi Province, 16-22 Nov. 1987. (in Chinese). See translations.

CHIPLEY, D.B.L. and KYSER, T.K., 1987, Fluid inclusion evidence for the deposition and diagenesis of the Patience Lake member of the Prairie Evaporite formation (abst.): GAC-MAC, AGC-AMC Joint Ann. Mtg., Program with Absts., v. 12, p. 31. Authors at Dept. Geol. Sci., Univ. Saskatchewan, Saskatoon, S7N OWO.

Bromine concentrations, radiometric age dates and textural relations among sylvite and halite in the Devonian potash deposits of southern Saskatchewan as well as large scale dissolution and collapse features indicate that diagenetic processes and late influxes of water have variably recrystallized and reworked the deposit. Fluid inclusions, found almost exclusively in halite, differentiate between primary and secondary events. In clear halite, the inclusions are evenly distributed and consist of two phases, saline water and solid daughters. In cloudy halites, the inclusions are primarily a single phase of saline water and define growth bands forming chevron textures. Homogenization temperatures of two-phase inclusions are 55° to 65°C, whereas lower temperatures of 35° to 45°C, occur in single phase inclusions of the chevron halites. The temperatures recorded in the primary fluid inclusions of the chevron-textured crystals most likely represent conditions during original deposition of the Prairie Evaporite. The higher temperatures of the two-phase fluid inclusions in the clear halite may represent a dissolution or recrystallization event which occurred as a result of maximum burial and diagenesis during Late Cretaceous time. (Authors' abstract)

CHIVAS, A.R., BARNES, Ivan, EVANS, W.C., LUPTON, J.E. and STONE, J.O., 1987, Liquid carbon dioxide of magmatic origin and its role in volcanic eruptions: Nature, v. 326, p. 587-589. First author at Res. Sch. of Earth Sci., The Australian Nat'l. Univ., G.P.O. Box 4, Canberra, A.C.T. 2601, Australia.

Natural liquid carbon dioxide is produced commercially from a 2.5-km-deep well near the 4,500-yr-old maar volcano, Mount Gambier, South Australia. A magmatic origin for the fluid is suggested by the geological setting, $\delta^{13}C(PDB)$ of -4.0‰ for the $CO_2$ (where PDB represents the carbon-isotope standard), and a relatively high $^3He$ component of the contained helium and high $^3He/C$ ratio ($6.4 \times 10^{-10}$). The $^3He/^4He$ and He/Ne ratios are 3.0 and >1,370 times those of air, respectively. (From the authors' abstract)

CHOQUETTE, P.W. and JAMES, N.P., 1987, Diageneis in limestones - 3. The deep burial environment: Geosci. Canada, v. 14, no. 1, p. 3- . First author at Explor. & Prod. Tech., Marathon Oil Co., P.O. Box 269, Littleton, CO 80160.

An extensive review that briefly discusses literature data on fluid inclusions. (E.R.)

CHOU, I.-M., 1987a Calibration of the graphite-methane buffer using the $f(H_2)$ sensors at 2-kbar pressure: Am. Mineral., v. 72, p. 76-81.

CHOU, I.-M, 1987b Estimation of the bulk compositions of fluid inclusions from the dissolution temperatures of halite in the system $NaCl-H_2O$ (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Author at 959 National Center, U.S. Geol. Survey, Reston, VA 22092.

The bulk compositions of $NaCl-H_2O$ binary fluid inclusions containing the three phases halite-liquid-vapor at room T, in which halite disappears first upon heating, can be approximated by the liquid composition at halite dissolution, Tm (that is, halite solubility along the three-phase curve at Tm). The error resulting from this method of approximation is not more than 0.6 wt.% NaCl if Tm is below 350°C and the vapor phase at Tm occupies less than 25 volume % of the inclusion. However, for a higher Tm and (or) a larger vapor bubble, the difference between the bulk composition of the inclusion and the liquid phase composition at Tm, Δwt.% NaCl, can be significant. The bulk composition ($X_B$ in wt.% NaCl) can be calculated from the liquid composition at Tm ($X_L$ in wt.% NaCl) and the densities of the liquid [$d_L$ (g/cm$^3$)] and vapor [$d_V$ (g/cm$^3$)] phases at Tm through the relation

$$X_B = d_L\ (100 - y)\ X_L\ /\ [d_L\ (100 - y) + d_V y],$$

where y is volume % of the vapor phase at Tm.

Values of $d_L$ between 350° and 550°C can be obtained by extrapolating the isothermal density-composition relation of vapor-saturated liquids reported by Urusova (1975, Russian Jour. Inorganic Chem. 20, 1717-1721) to halite saturation. Those above 550°C can be obtained by interpolating the low-T values and the density of pure NaCl liquid at 800°C and 1 atm. (1.56 g/cm$^3$; Huber et al., 1952, U.S. Bur. Mines Rept. Inv. 4858). Because the solubilities of NaCl in the gas phase along the three-phase curve are small (<0.15 wt.% NaCl; see Fig. 3 of Pitzer and Pabalan, 1986, Geochim. et Cosmochim. Acta 50, 1445-1454), $d_V$ can be approximated by the density of pure $H_2O$ at the same P-T condition as calculated from the specific volume data of Burnham et al. (1969, Geol. Soc. America Spec. Paper 132). Values of $X_L$ can be calculated from the halite-solubility equation along the three-phase curve given by Chou et al. (1986, EOS 67, 408).

The compositional differences, Δwt.% NaCl = $X_L - X_B$, are shown in the diagram as a function of y, volume % of vapor, for several isotherms. The data indicate that for a given volume % of vapor, the maximum Δwt.% NaCl is around 550°C. Also, the bulk compositions of fluid inclusions estimated by this method are not sensitive to the uncertainties associated with the estimated values of $d_L$ and $d_V$, and the estimation of y is potentially the largest source of error. (Author's abstract)

CHOU, I.-M., 1987c Phase relations in the system NaCl-KCl-$H_2O$. III: Solubilities of halite in varpor-saturated liquids above 445°C and redetermination of phase equilibrium properties in the system NaCl-$H_2O$ to 1000°C and 1500 bars: Geochimica Cosmo. Acta, v. 51, p. 1965-1975. Author at 959 Nat'l. Center, U.S. Geol. Survey, Reston, VA 22092, USA.

Halite solubilities along the three-phase curve in the binary system NaCl-$H_2O$ determined by DTA experiment can be represented by the equation

$$\text{Wt.\% NaCl}(\pm 0.2) = 19.39 - 0.0364T + 3.553 \times 10^{-4}T^2 - 2.298 \times 10^{-7}T^3,$$

where $447 \leqslant T \leqslant 800$°C. Even though these halite solubilities are up to ~7 wt.% higher than those reported in literature, extrapolated values at temperatures below 447°C merge with the literature values. It is considered that the equation adequately describes halite solubilities between 382 and 800°C. The newly established solubility data are believed to be more reliable because they are compatible with data obtained by using synthetic fluid inclusions and with the observed DTA signals and also because they were measured in a relatively corrosion-free system.

In an earlier publication (Gunter et al., 1983), we were puzzled greatly by multiple and rather unreproducible DTA peaks appearing during isobaric cooling (heating experiments were nondefinitive) at pressures below about 500 bars. These DTA signals apparently suggested that the "halite liquidus" swung sharply upward in temperature as pressure decreased from about 500 bars to that of the halite-saturated boiling curve. Further analysis of the data and helpful discussions with several individuals have revealed that the behavior is a consequence of the initial (precooling) separation of the fluid into NaCl-poor gas and NaCl-rich liquid that failed to homogenize in the short time encompassed by the DTA experiments. The present analysis is based on extrapolations of the dP/dT slopes from pressures above 500 bars.

Through use of these new halite solubility data and the data from synthetic fluid inclusions [formed by healing fractures in inclusion-free Brazilian quartz in the presence of two coexisting, immiscible NaCl-$H_2O$ fluids at various temperatures and pressures (Bodnar et al., 1985)], phase equilibria in the system NaCl-$H_2O$ have been redetermined to 1000°C and 1500 bars. (Author's abstract)

CHRISTENSON, B.W., 1987, Fluid-mineral equilibria in the Kawerau hydrothermal system, Taupo volcanic zone, New Zealand: PhD dissertation, Univ. Auckland, (>451 pp.).

A fairly extensive study was made of over 900 fluid inclusions in quartz, calcite, anhydrite, wairakite, and sphalerite, and the data used to interpret the probable environment at the time of trapping. $CO_2$ in solution is the major species responsible for depression of the freezing point of these fluids, and boiling during mineral growth has caused major decreases in the apparent "salinity." Th (225-300°C) values are close to present day temperatures. (E.R.)

CHU, Tongqing and WANG, Henian, 1987, A study of inclusions in minerals from different mineralized pegmatites: Mineral Deposits, v. 6, no. 3, p. 77-84 (in Chinese; English abstract). Authors at Dept. Geol., Nanjing Univ., Nanjing, Jiangsu.

Gaseous and liquid $CO_2$-containing triphase inclusions are mainly contained in REE pegmatite, while triphase inclusions with NaCl dxl occur in Nb pegmatite, somewhat similar to the corresponding mineralized granites. Th of the pegmatites is 140°C to 270°C, lower than the Tf of granites.

The gases are mainly water with some $CO_2$ and small amounts of $CH_4$, $N_2$, $O_2$ and CO. The REE pegmatite inclusions are enriched in $CO_2$.

The liquid phase in inclusions of mineralized pegmatite are enriched in $Na^+$ and $K^+$ but depleted in $Ca^{2+}$ and $Mg^{2+}$. REE pegmatite is enriched in $HCO_3^-$; Nb pegmatite is abundant in $F^-$; Au-bearing pegmatite is rich in $Cl^-$; and Be pegmatite contains certain amounts of both $F^-$ and $Cl^-$. Each type of mineralized pegmatite is characterized by a high content of the corresponding metallogenic element, and this serves as a good indicator for geochemical ore prospecting.

In REE distribution, the inclusion solutions are similar to the bulk rock and every mineralized pegmatite is similar to corresponding mineralized granite. This suggests that REE distribution of the inclusion solution might be used to investigate the sources of ore-forming materials. (From the authors' abstract)

CHUEH, Meideng and XIA, Weihua, 1987, Nature of ore-forming fluid and mechanism of mineralization of the Dajishan tungsten deposit, southern Jiangxi, China (abst.): Actas del Dicimo Congreso Geologico Argentino, v. IV, p. 41-42 (in English). Authors at Dept. Min. Resources, Wuhan College of Geol., Wuhan, PRC.

Dajishan W deposit consists of 111 mineralized quartz veins. The authors believe it is theoretically proved that a special viscous fluid composed mainly of silica probably emerged in some stages of the differentiation and evolution of granitic magma. The possible complexes responsible for W transportation are discussed. (E.R.)

CLEMENS, J.D. and NAVROTSKY, A., 1987, Mixing properties of $NaAlSi_3O_8$ melt-$H_2O$: New calorimetric data and some geological implications: J. Geol., v. 95, p. 173-186.

CLINE, J.S., 1987, Precious metal precipitation mechanisms in the Sixteen-To-One epithermal Ag-Au deposit, Esmeralda County, Nevada (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Author at Dept. Geol. Sci., Virginia Polytech. Inst., Blacksburg, VA 24061.

Fluid inclusion characteristics and enthalpy-salinity relationships indicate Ag-Au mineralization precipitated primarily in response to T reduction resulting from fluid mixing. Boiling contributed to metal precipitation locally. Wall rock alteration related to precious metal mineralization is minor. The character of the hydrothermal fluids was essentially unchanged as a result of alteration and it is unlikely that fluid/rock interactions contributed to precious metal precipitation.

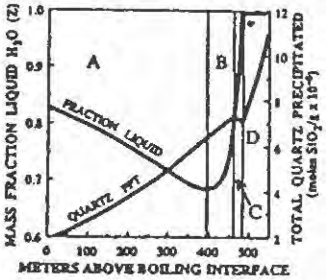
Quartz and sphalerite inclusions in vein samples from six underground mine levels exhibit Th and salinities which range from 145° to 225°C and 3.5 to 11.5 equiv. wt. % NaCl, respectively. T and salinities vary consistently with elevation and decrease an average of 40°C and 1.4 wt. % NaCl equiv. over an elevation increase of 130 meters. Th versus Tm diagrams reveal clustered T and salinities in lower and mid mine levels, and highly variable T and salinities in upper mine levels, coincident with strongest Ag mineralization. Th are significantly reduced in the uppermost level examined.

Observed patterns of Th versus Tm suggest both mixing and boiling contributed to T reduction coincident with Ag mineralization. Minor amounts of calcite, adularia, and epidote within quartz veins and veinlets are consistent with local boiling. Enthalpy-salinity relationships permit determination of the relative importance of mixing and boiling within the system. A mixing line defined by enthalpy and salinity values for the "average" fluid from each level and two end member fluids, suggests average deepest level fluids of 209°C and 10.0 equiv. wt. % NaCl, mixing with near surface fluids of 90°C and 0 salinity, could produce most of the fluids observed within the system. Mixing of deep hydrothermal fluids with 12 to 54 vol. % cooler surface fluids would account for the T and salinities observed in upper mine levels, coincident with mineralization. Elevated salinities on two levels suggest boiling contributed to their fluid evolution. Inclusion crushing experiments revealed variable $CO_2$ contents in fluids indicating both boiled and unboiled fluids were present throughout the vertical extent of the mine. (Author's abstract)

CLINE, Jean, BODNAR, R.J. and RIMSTIDT, J.D., 1987, Quantitative evaluation of quartz transport and deposition in boiling solutions: Application of epithermal gold deposits (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 621. Authors at Dept. Geol. Sci., Virginia Polytech. Inst. & State Univ., Blacksburg, VA 24061.

Temporal and spatial relationships between gold mineralization and multiple episodes of brecciation and silicification in epithermal gold deposits suggest these processes occurred under similar chemical and physical conditions in the presence of boiling fluids. A quantitative model evaluating two phase fluid flow and quartz precipitation was developed to examine the effects of boiling on quartz precipitation. Silica solubility in this model assumes the fluid is in equilibrium with quartz.

The accompanying diagram illustrates total quartz precipitation and mass fraction $H_2O$ liquid (Z) as a function of distance above the depth of initial boiling, assuming the following initial conditions: a 300°C liquid with a mass flux of $10^{-7}$ g/cm$^2$ sec at the base of the system, rock permeability = $10^{-12}$ cm$^2$, and the saturated rock thermal conductivity = 3.0 x $10^{-3}$ cal/cm sec °C. The fluid boils immediately and Z is reduced to 82%. Within area A, fluid T decreases from 300° to 238°C as the fluid rises to 396 m above the boiling interface. Both decreasing T and decreasing Z cause quartz to precipitate at an increasing rate. As T decreases to 209°C in zone B, fluid condensation causes Z to decrease; decreasing T continues to cause quartz precipitation, but at a reduced rate. In area C, fluid condensation increases the capacity of the fluid to transport $SiO_2$ and quartz dissolves. At 196°C Z reaches 100%; quartz continues to precipitate in response to decreasing T as the fluid approaches the surface (area D). Gold deposition will be associated with early quartz precipitation (area A) in response to initial boiling and loss of volatiles. (Authors' abstract)



CLOCCHIATTI, R. and METRICH, N., 1987, Contribution of fluid inclusions to understanding magmatic and volcanic processes at Etna (Sicily, Italy) (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 23-24 (in French; translation by R.J. Bodnar). Authors at Lab. Pierre Süe, Groupe des Sci. de la Terre, CEN Saclay, 91191 Gif-sur-Yvette Cedex, France.

Fluid inclusions in phenocrysts (olivine, clinopyroxene, plagioclase, iron and titanium oxides) from lavas from historic eruptions (1986, 1985, 1983, 1892, 1865, 1763, 1669, 1329) were used to study the different petrogenetic processes (crystallization, fractionation, mixing, degassing) that have controlled the recent evolution of Etna magmas. Variations in the chemical composition of glass inclusions indicate two stages of crystallization of Etna magmas (basalts, basic hawaiites). The first stage is characterized by the separation of olivine (Fo82) and diopside from a basaltic liquid, and the second stage by crystallization of olivine (Fo<80), salitic clinopyroxene, plagioclase and titanomagnetite from a hawaiitic to mugearitic magma. The crystallization T determined by optical thermometry varies between 1140 ± 10°C and 1080°C, the lower limit corresponding to the T of extrusion of the lava. Fluid P estimated from fluid inclusions in pyroxene and plagioclase are between 80 and 110 MPa. The evolution of composition of glass inclusions in this group of eruptions indicates that the transition from alkalic basalt to hawaiite is controlled by fractional crystallization.

The amount of S and Cl in the glass inclusions was determined to (1) predict the amount of these elements in the magma before degassing, (2) follow their behavior during the course of mineral separation and, (3) establish the relationship between the volumes of magma and gas emitted. Basaltic liquids trapped in minerals are characterized by enrichment in volatile elements (2500 to 2000 ppm S, 3500 to 1700 Cl, and possibly $H_2O$). During differentiation the amount of S decreases to 1500 ppm in the hawaiitic liquid and drops to <100 ppm in the matrix. Cl decreases from 3500 to 1700 ppm, but does not decrease as regularly as S. The behavior of these two elements suggests degassing of ≈90% of the S at shallow depths and ≈50% of the Cl gas at greater depths. During the recent Etna summit eruption (Sept. 24, 1986), 3600 tons of S and 4800 tons of Cl were emitted. Mixing and contamination processes were also tested by optical observations and analyses of glass and fluid inclusions. Finally, the amount and distribution of C in glass inclusions in olivine was examined with a nuclear microprobe. This element shows heterogeneous distribution and is concentrated in the vicinity of shrinkage bubbles; C concentration in basaltic to hawaiitic glass varies from 120 to 500 ppm. (Authors' abstract)

COCKER, M.D., 1987a Pressure solution in igneous rocks resulting from hydrothermal activity in the Breckenridge mining district, Summit County, Colorado (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 148. Author at 2009 Lambert Ct., Plano, TX 75075.

An unusual occurrence of pressure solution in hydrothermally altered igneous rocks is related to centers of boiling hydrothermal fluids accompanying base - and precious - metal mineralization.

Pressure solution occurred in weak to moderately sericitized rocks in or peripheral to hydrothermal-intrusive systems characterized by multiple stages of intrusion, veining and brecciation. Fluid inclusion data suggest T of mineralization accompanying phyllic alteration ranged from 190 to 540°C with most T in the 270 to 400°C range. Fluid salinities were from 4 to 60 eq. wt. % NaCl. Numerous intrusive breccia pipes and abundant vapor rich inclusions associated with these systems indicate boiling which greatly increased P. Elevated T, P, and salinity of hydrothermal fluids significantly increased silica solubility thereby facilitating P solution. (From the author's abstract)

COCKER, M.D., 1987b Bonanza Au-Ag-telluride mineralization in the root zone of a hot-spring system, Mayflower mine, Madison County, Montana (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 266-267.

COLE, D.R., MOTTL, M.J. and OHMOTO, Hiroshi, 1987, Isotopic exchange in mineral-fluid systems. II. Oxygen and hydrogen isotopic investigation of the experimental basalt-seawater system: Geochimica Cosmo. Acta, v. 51, p. 1523-1538.

COLTORTI, Massimo, GIRARDI, V.A.V. and SCHORSCHER, J.H.D., 1987, Liquid immiscibility in the Archean greenstone belt of Piumhi (Minais Gerais, Brazil): Lithos, v. 20, p. 77-91. First author at Istit. Mineral., Univ. Ferrara, Corso E. I d'Este, 32, 44100 Ferrara, Italy.

Liquid immiscibility has been used for explaining several modern situations either in effusive or in intrusive rocks, including the variolitic structures in the Archean rocks of the Abitibi Greenstone belt, Ontario. (From the authors' abstract)

COMBREDET, Nicole, GUILHAUMOU, Nicole, CORMY, Gérard and TIFFER, E.M., 1987, Petrographic correlations and analysis of fluid inclusions in hydrothermal quartz crystals from four wells in the Momotombo geothermal field, Nicaragua: Geothermics, v. 16, no. 3, p. 239-254. First author at Soc. Prospection & d'Etudes Géotherm. Argenteuil, France.

Four wells of the geothermal field of Momotombo (Nicaragua) have been studied. Their primary and hydrothermal petrology have been described and correlations established. They are composed of andesites and tuffs. The description of the hydrothermal paragenesis allows us to conclude that the geothermal conditions are situated at the limit of the albite-zeolite and greenschist facies. In three of them, hydrothermal quartz crystals gave Th ranging from 160 to 275°C. The fluid is assumed to be pure water of meteoric origin; boiling did not occur. But in MT37 well there could be up to 0.83 moles % of $CO_2$, which would place the histograms in the vapor region of the curve. Gaseous inclusions were analyzed, giving a mixture of $CO_2$, $CH_4$, $N_2$. (Authors' abstract)

CONRAD, M.E. and PETERSEN, Ulrich, 1987, Mineralogic evidence for early, high temperature fluid circulation in the Tayoltita fossil geothermal system (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 626. Authors at Dept. Earth & Planet. Sci., Harvard Univ., Cambridge, MA 02138.

The Tayoltita district (Durango, Mexico) is one of the richest hydrothermal silver/gold deposits in the world. Mineralogic assemblages indicate an early episode of high T fluid circulation (>350°C?) giving way to lower T as the geothermal system evolved (fluid inclusions indicate that the quartz in the veins was deposited at about 260°C). (From the authors' abstract)

COOK, K.H., 1986, Conodont color alteration; a possible exploration tool for ore deposits: MS thesis; New Mexico Inst. Mining & Technology, Socorro, NM, 125 pp.

COOKRO, T.M., SILBERMAN, M.L. and BERGER, B.R., 1987, Gold-tungsten bearing hydrothermal deposits in the Yellow Pine mining district, Idaho (abst.): Program with Abstracts, Symp.: Bulk Mineable Precious Metal Deposits of the Western United States, April 6-8, 1987, Geol. Soc. Nevada, p. 40.

Oxygen isotope ratios of stockwork vein quartz are in a range +10 to +13 $\delta^{18}O$. These values are similar to oxygen isotope ratios found in quartz from lode-gold deposits hosted in metamorphic rocks. However, deuterium-hydrogen ratios ($\delta D$) of inclusion fluids are in the range -100 to -114 $\delta D$ per mil and are suggestive of meteoric quartz-precipitating fluids.

The hydrothermally altered and mineralized rocks in the Yellow Pine district probably resulted from deep circulation of meteoric fluids along regional shear zones. The fluids were probably heated by late cooling phases of the Cretaceous batholith. The ascending fluids leached metals from metasedimentary and/or metavolcanic rocks and redeposited them in a vertical range of several thousand feet, from mesothermal at the Yellow Pine mine to epithermal at the Fern prospect. (From the authors' abstract)

CORAZZA, M., CORSINI, F., LATTANZI, P. and TANELLI, G., 1987, The granite-associated Sn-polymetallic deposits of Dachang (P.R. China): Sulfide chemistry and fluid inclusion data (abstr.): Internatl. Symp. Petrogen. Mineraliz. Granitoids, Guangzhou, PRC, Dec. 1987, p. 48-49. (Also in Rendiconti Soc. Ital. Mineral. Petrol., v. 42, p. 333-334, 1987.)

CORNIDES, István and KECSKÉS, Árpád, 1987, Deep-seated carbon dioxide in Slovakia: Additional comments on the problem of its origin: Geologicky Zbornik-Geol. Carpathica, v. 38, no. 4, p. 429-435. Authors at Dept. Physics, Pedagogical Fac., Lomonosova 1, 949 01 Nitra.

Data from isotopes of He, and $\delta^{13}C$ for total dissolved carbonate support a mantle origin for the $CO_2$. (E.R.)

COUTY, R. and FABRE, D., 1987, A Raman spectrometric study of methane compressed up to 3 kbar (abst.): Terra Cognita, v. 7, p. 14.

COUTY, R., DAHAN, N., MASSARE, D. and CLOCCHIATTI, R., 1987, Effect of continuous loading (P-T) on fluid inclusions in synthetic quartz (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 25-26 (in French; translation by R.J. Bodnar). First author at ER 224, ENS Lab. de Geol., 46 rue d'Ulm, 75230 Paris, France.

The effect of T and P on fluid inclusions in synthetic quartz was studied. The material was provided by the S.I.C.N. Society and was grown hydrothermally in an $H_2O$-NaOH solution. The quartz contains aqueous inclusions in the shape of elongated cylinders and which have Th 260°C. The variation in Th was determined as the mineral was subjected to gas P between atmospheric and 4000 bars and T between 25° and 325°C.

Two heating stages were used in these experiments. The first series of experiments used a stage that operates between -200°C and 490°C and P to 1000 bars (Figure 1). The second set of experiments used an internally heated furnace with sapphire windows mounted on a microscope; the furnace operates to ≈4000 bars and 765°C.

These two stages allow the inclusions to be observed and photographed during the experiment. A decrease in Th of inclusions with increasing P was observed. Similar results have previously been obtained for inclusions in fluorite. (Authors' abstract)

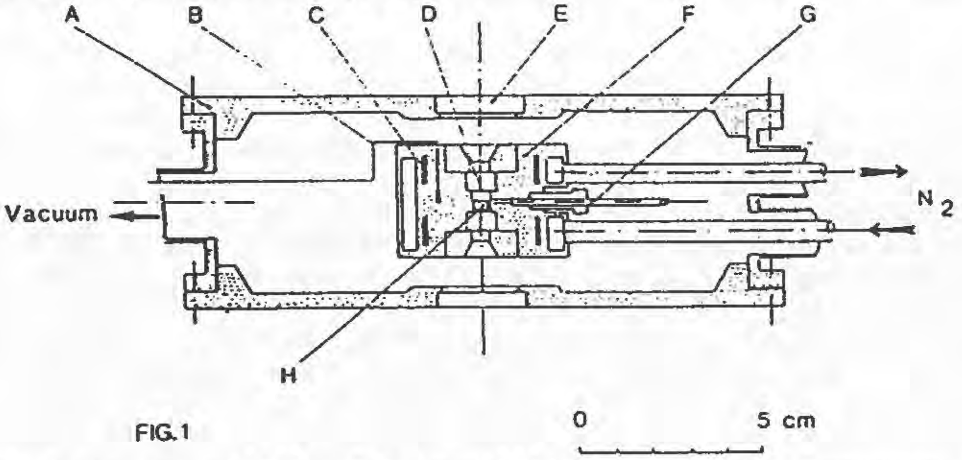


FIG.1

COVENEY, R.M., Jr., GOEBEL, E.D. and RAGAN, V.M., 1987, Pressures and temperatures from aqueous fluid inclusions in sphalerite from midcontinent country rocks: Econ. Geol., v. 82, p. 740-751. Authors at Dept. Geosci., Univ. Missouri-Kansas City, Kansas City, MO 64110-2499.

Microthermometric and crushing data are given for inclusions in sphalerite from 33 localities. Pressures at Th ranged from 3.5 to 496 atm (mostly <20 atm); Th ranged from 66 to 260°C, but high values are assumed to be spurious, from overheating during core drying. Reliable measurements ranged from 66 to 118°C. Te values are -50 to -60°C, and Tm values are mostly in the -20 range. (E.R.)

COVENEY, R.M., Jr., LEVENTHAL, J.S., GLASCOCK, M.D. and HATCH, J.R., 1987, Origins of metals and organic matter in the Mecca Quarry Shale Member and stratigraphically equivalent beds across the Midwest: Econ. Geol., v. 82, p. 915-933. First author at Dept. Geosci., Univ. Missouri-Kansas City, Kansas City, MO 64110-2499.

Uses (p. 930) literature data and some unpublished data on fluid inclusions. (E.R.)

COWDEN, Alistair and WOOLRICH, Paul, 1987, Geochemistry of the Kambala iron-nickel sulfides: Implications for models of sulfide-silicate partitioning: Canadian Mineral., v. 25, p. 21-36.

COX, S.F., ETHERIDGE, M.A. and WALL, V.J., 1987, The role of fluids in syntectonic mass transport, and the localization of metamorphic vein-type ore deposits: Ore Geol. Reviews, v. 2, p. 65-86.

CRADDOCK, J.P. and VAN DER PLUIJM, B.A., 1987, Migration of Late Paleozoic brines through cratonic carbonates by calcite twin 'pumping;' a hypothesis (abst.): Geol. Soc. Amer. Abstracts with Programs, v. 19, no. 4, p. 194

CRAIG, H., 1987, Comment on "Carbon isotope systematics of a mantle hotspot: A comparison of Loihi Seamount and MORB glasses" by R.A. Exley, D.P. Mattey, D.A. Clague and C.T. Pillinger: Earth & Planet. Sci. Letters, v. 82, p. 384-386. Author at Scripps Inst. Oceanography, Univ. California at San Diego, La Jolla, CA 92093, USA.

See Exley et al., Fluid Inclusion Research, v. 19, p. 128, and in this volume. (E.R.)

CRAIG, J.R. and VAUGHAN, D.J., 1986, Paragenetic studies of growth-banded sphalerites in Mississippi Valley-type zinc deposits of the Appalachians: Min. Parageneses, J.R. Craig, et al., eds., p. 133-158. First author at Dept. Geol. Sci., Virginia Polytech. Inst. & State Univ., Blacksburg, VA 24061, USA.

Presents a brief review of published fluid inclusion data from the East Tennessee district and its relationship to generic MVT deposits.(H.E.B.)

CRAW, D., JOHNSTONE, R.D. and RATTENBURY, M.S., 1987, Gold mineralization in a high uplift rate mountain belt, southern Alps, New Zealand: Pacific Rim Congress 87, 26-29 August, 1987, Australasian Inst. Mining & Metallurgy, Victoria, Australia, p. 95-98. Authors at Dept. Geol., Univ. Otago, Dunedin, New Zealand.

Quartz-calcite veins containing Au, As, W, Cu, Pb, Zn and Fe cross-cut Alpine Fault-related structures in the Alpine Schist of South Island, New Zealand. These veins, and some other related veins have been deposited by metamorphic fluids at 250°C to >320°C at pressures of a few hundred bars. The fluids were very variable in composition, with 0 to 50 mole % $CO_2$ and 2 to 18 wt. % NaCl equivalent. Penetration of hot metamorphic fluids to shallow levels in the crust was facilitated by rapid uplift of hot rocks at a compressive plate margin. Fluid immiscibility at shallow levels caused concentration of salts and metals into the aqueous phase. Au precipitation was caused by reduction by pelitic country rock and/or dilution by other aqueous fluids. (Authors' abstract)

See also next item. (E.R.)

CRAW, D. and McKEAG, S.A., 1987, Near-surface hydrothermal activity in the eastern Otago schist: New Zealand J. Geol. & Geophys., v. 30, p. 437-443. Authors at Dept. Geol., Univ. Otago, P.O. Box 56, Dunedin, NZ.

The quartz-gold-stibnite-bearing Consolidated Lode at Nenthorn, eastern Otago, contains abundant prismatic quartz crystals and hydrothermal breccia. Fluid inclusion data imply that boiling occurred during mineral deposition at about 190°C at very shallow levels, possibly within 120 m of the surface. This type of vein system may be common in eastern Otago. Gold may be found beneath Sb and/or Hg deposits formed by similar near-surface hydrothermal activity. (Authors' abstract)

CRAW, D., RATTENBURY, M.S. and JOHNSTONE, R.D., 1987, Structural geology and vein mineralization in the Callery River headwaters, Southern Alps, New Zealand: New Zealand J. Geol. & Geophys., v. 30, p. 273-286. Authors at Geol. Dept., Univ. Otago, P.O. Box 56, Dunedin, NZ.

Three late-stage vein types are recognized on the basis of mineralogy and fluid inclusion studies. Type 1 veins consist of calcite and quartz, and were formed by $H_2O$-$CO_2$ fluids (about 12 mole % $CO_2$) at >270°C and >2-3 km depth. Type 2 veins consist of quartz and calcite with minor biotite and sulphides, and traces of scheelite and Au. These minerals were deposited where hot (>320°C) brines mixed with cooler, less saline waters. Metal deposition involved interaction with pelitic schist. Type 3 veins consist of quartz, calcite, and adularia deposited from low-salinity water which may have boiled at about 240°C.

High regional uplift rates and shallow formation of veins indicate a maximum age of vein mineralization of about 1.7 million years, and a minimum age of Type 3 veins of about 117,000 years. Mineralization is believed to have resulted from passage of fluids, at least some of which are metamorphic in origin, induced by high heat flow during rapid uplift of the Southern Alps. (From the authors' abstract)

CRAWFORD, L.D., 1987, Paleomagnetic dating of calcite speleothems in Arbuckle Group limestones, southern Oklahoma; a possible relationship between hydrocarbons and authigenic magnetite: MS thesis, Univ. Oklahoma, Norman, OK, 75 pp.

CRISS, R.E., GREGORY, R.T. and TAYLOR, H.P., Jr., 1987, Kinetic theory of oxygen isotopic exchange between minerals and water: Geochimica Cosmo. Acta, v. 51, p 1009-1108.

CROWE, B.M., FINNEGAN, D.L. and ZOLLER, W.H., 1987, Trace element geochemistry of volcanic gases and particles emitted during eruptive episodes 11, 13 and 16 (1983-1984) of the Pu'u O'o vent, Kilauea volcano (abst.): Hawaii Symp. on How Volcanoes Work, Abst. Volume, Hilo, Hawaii, Hawaiian Volcano Observatory, p. 49.

CROWE, B.M., FINNEGAN, D.L., ZOLLER, W.H. and BOYNTON, W.V., 1987, Trace element geochemistry of volcanic gases and particles from 1983-1984 eruptive episodes of Kilauea volcano: J. Geophys. Res., v. 92, no. B13, p. 13,708-13,714. First author at Los Alamos Nat'l. Lab., Los Alamos, NM.

Compositional data have been obtained for volcanic gases and particles collected from fume emitted at the Pu'u O'o vent on the east rift zone of Kilauea volcano. INNA analyses show bromine-normalized enrichment factors (x $10^5$) range from $10^1$ to $10^2$ for Na, K, and Cu; $10^2$ to $10^5$ for Zn, W, Sb, In, Ir, Ag, F, and As; and $>10^5$ for Au, Cd, Re, Cl, Se, and S. The F/Cl ratio of cooling vent samples is higher than those of active vent or aircraft samples, and the ratio is inversely correlated with enrichment factors for most volatile metals. (From the authors' abstract)

CRYSDALE, B.L., 1987, Fluid inclusion evidence for the origin and diagenesis of sparry calcite cement in the Capitan Limestone, McKittrick Canyon, Permian basin, west Texas (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Author at U.S. Geol. Survey, Denver Federal Center, MS-921, P.O. Box 25046, Denver, CO 80225.

Sparry calcite cement is responsible for major porosity loss in the reef and forereef facies of the Capitan Limestone, Permian basin. This cement occurs throughout the massive reef facies where it fills large vugs as much as 0.5 m in diameter, with individual crystals up to several cm in length. Sparry cement in the forereef facies is less extensive and fills smaller vugs than in the reef, although individual crystals can be as large. The cement is composed of coarse, equant, clear to milky calcite, rich in fluid inclusions.

Th of P fluid inclusions trapped during cementation record formation temperatures from 55-85°C. Using a relatively low geothermal gradient of 2°C/100 m would suggest cementation occurred at moderate burial depths of 1-2 km. Precipitation of sparry cement in fractures and brecciated areas also indicates cementation postdates minor burial compaction. Freezing temperatures ($T_f$) [presumably Tm ice] for P fluid inclusions range from about -1 to 0°C (<1.7 wt % NaCl equiv.) suggesting the cement was formed in fresh to brackish waters. This range of $T_f$ data is consistent with cement formation in a relatively deep lens of meteoric to mixing-zone waters.

S fluid inclusions with $T_f$ of about -12°C (>16 wt % NaCl equiv.) indicate that highly saline brines may have migrated along secondary fractures in the cement during later deposition of evaporites in the adjacent Castile and Salado Formations. (Author's abstract)

CUI, Bin, 1987, The alteration zoning and origin of the Tongguangshan stratabound skarn-type copper desposit: Mineral Deposits, v. 6, no. 1, p. 35-40 (in Chinese; English summary).

CUNNINGHAM, C.G., CHOU, I.-M., ASHLEY, R.P., HUANG, T.S., WAN, C.Y. and LI, W.K., 1987, New discovered disseminated gold deposits in the Peoples's Republic of China (abst.): Program with Abstracts, Symp.: Bulk Mineable Precious Metal Deposits of the Western United States, April 6-8, 1987, Geol. Soc. Nevada, p. 11. First author at U.S. Geol. Survey, National Center, Reston, VA 22092.

Five disseminated gold deposits (Getany, Banqi, Yata, Sanchahe, and Ceyang) recently discovered in southwestern Guizhou Province of the People's Republic of China are described here for the first time in Western literature. The deposits have features similar to those of some major sedimentary-rock-hosted precious metal deposits in Nevada. Preliminary fluid inclusion homogenization temperatures range from 120° to 240°C, and associated salinities are less than 5 wt % NaCl eq. Alteration minerals are predomiantly hydrothermal illite and kaolinite. (From the authors' abstract)

CUNNINGHAM, C.G., NAESER, C.W., CAMERON, D.E., BARRETT, L.F., WILSON, J.C. and LARSON, P.B., 1987, The Pliocene paleothermal anomaly at Rico, Colorado, is related to a major molybdenum deposit (abst.): Geol. Soc. Am. Abst. with Programs, v. 19, p. 268-269. First author at U.S. Geol. Survey, Reston, VA 22092.

A major paleothermal anomaly is present around the Silver Creek molybdenum deposit at Rico, Colorado. Fission-track ages in apatite and zircon from Laramide-age hornblende-latite sills have been partially reset as far away as 6 km. The reset ages become systematically younger toward the center of the hydrothermal system and approximate a "bullseye" over the molybdenum deposit and its associated alaskite dikes. The molybdenum deposit is 3-5 Ma and the hornblende-latite sills in the Rico district closest to the site of the deposit give Pliocene ages from apatite and zircon that were totally reset. The paleothermal anomaly extends more than twice as far as epithermal silver, lead, and zinc vein and replacement deposits that are peripheral to the molybdenum deposit.

The molybdenum deposit, which was recently discoverd by the Anaconda Minerals Co., contains approximately 44 million tons of 0.31% Mo. Projections of the 0.2% Mo outline indicate that the deposit may contain more than 200 million tons. The ore body is in Precambrian quartzite and greenstone and was localized along the axis of the Rico dome by major faults. The top of the ore body is 1,200 m below Silver Creek near the east end of the Rico district. Fluid inclusions in the veins have homogenization temperatures of 200°-300°C and salinities less than 5 wt % NaCl, whereas those in the molybdenum deposit give 350°-420°C with variable salinities. Stable isotopes indicate that meteoric water is dominant in the epithermal vein systems, but the magmatic water is dominant in the molybdenum deposit. (Authors' abstract)

CURTI, Enzo, 1987a Isotope geochemistry and fluid inclusion studies on the late metamorphic gold-quartz veins of the Monte Rosa area, northwestern

Alps, Italy: The origin of metals and fluids: PhD dissertation, Swiss Fed. Inst. Tech. (E.T.H.), Zurich, 121 pp.

In the Monte Rosa area (northwestern Italian Alps) swarms of epigenetic, quartz-sulfide-gold-bearing veins occur within a terrane affected by a Tertiary regional metamorphism of greenschist to amphibolite grade. The separation of the ore leads in two distinct data fields is probably the result of ore deposition from at least two hydrothermal systems, which were separated in space and possibly also in time.

Oxygen analyses yielded isotopic compositions consistent with a metamorphic origin of the ore fluids, except for the Toppa mine, where lighter, probably surface-derived water was involved. Fractionations between mineral pairs in metasediments and granites indicate metamorphic peak T of 450-600°C, in agreement with those infered from petrological evidence. These T and fluid inclusion data were used as input parameters in a simple model to predict the oxygen isotope compositions of gangue quartz. The comparison of predicted with experimental values shows that the model is consistent with the assumption that the fluids were generated by metamorphic devolatilization within the metapelites and granitoids, in agreement with the lead isotope data.

Fluid inclusion microthermometry confirmed that the Au-transporting fluids are of metamorphic origin, as indicated by the ubiquitous presence of $CO_2$ in P inclusions and by their low salinities. Evidence was found that the $CO_2$-bearing brine mixed to some extent with an essentially aqueous, cooler solution. This dilution and cooling could have favored Au precipitation, as low sulfur activities and low T strongly reduce its solubility. The inclusion data, used in conjunction with depositional T (estimated from arsenopyrite compositions) or with the inferred load P, allowed the determination of approximate P, T-conditions of trapping. The calculations indicate T between 280-360°C and fluid P >1.2 kbars for the Val Toppa and Val Sesia districts, whereas in the main district of Valle Anzasca T of ore deposition were 350-475°C and fluid P ranged from 0.8 to 1.5 kbars.

The results of this study suggest that the Au-bearing fluids were generated by metamorphic devolatilization during the late stage of the Tertiary Alpine metamorphism. The Pb, and possibly the Au, were supplied by rocks derived from the continental crust, in opposition to current genetic models for Archean Au deposits, which require a mantle source. Furthermore, it is indicated that regional metamorphism and extensional tectonics played an important role in the genesis of the Monte Rosa ores, in analogy with most greenstone-hosted, Precambrian Au-vein deposits. (From the author's abstract)

CURTI, Enzo, 1987b Lead and oxygen isotope evidence for the origin of the Monte Rosa gold lode deposits (western Alps, Italy): A comparison with Archean lode deposits: Econ. Geol., v. 82, p. 2115-2140. Author at Inst. Geol., Univ. Oslo, P.O. Box 1047 Blindern, N-0316, Oslo 3, Norway.

In the Monte Rosa area of the northwestern Italian Alps swarms of epigenetic, quartz sulfide gold-bearing veins occur within a terrane affected by Tertiary regional metamorphism of greenschist to amphibolite grade. Oxygen isotope fractionations between mineral pairs in metasediments and granites indicate metamorphic peak T of 530° to 605°C, in agreement with those inferred from petrologic evidence. These T and preliminary fluid inclusion data were used to predict oxygen isotope compositions of gangue quartz.

The results suggest that the gold-bearing fluids and the lead were supplied by rocks derived from the continental crust, in opposition to the data from many greenstone-hosted Archean gold lode deposits, which indicate a mantle source. This implies that metamorphic-hosted quartz-gold lodes do not necessarily derive metals and fluids from source beds within a greenstone sequence. (From the author's abstract)

Inclusions in quartz from gold lodes show Th 175-350°C, Tm ice 0 to -10°C, with a correlation suggesting mixing of two fluids. Th $CO_2$ and Tm clathrates yield 0.09 to 0.12 mole fraction $CO_2$. (E.R.)

CURTI, Enzo, LATTANZI, Pierfranco and BASTOGI, Marco, 1987, Fluid inclusion studies on the gold mineralizations of the Upper Valle Anzasca, northwestern Alps (Italy) (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 27-28. First author at Inst. Kristallographie u. Petrographie, ETH-Zentrum, Zürich, Switzerland.

The Au mineralizations of Upper Valle Anzasca are part of the Monte Rosa Au district, NW Alps, Italy. The mineralizations occur within polymetamorphic Paleozoic metasediments and metagranites of the Pennidic Monte Rosa Unit. Within the metasediments, the ore bodies consist of more or less concordant veins, whereas in the metagranites they occupy fractures and shear zones discordant with the foliation. Field evidence suggests however a common late-Alpine age for the emplacement of both types of veins.

The mineralogy of the ore bodies is dominated by quartz. Au is invariably associated with sulfides (pyrite, arsenopyrite, galena, sphalerite, chalcopyrite and sulfosalts).

Fluid inclusions in quartz from the mineralizations show some remarkably constant features: they are moderately saline brines containing, at room T, ~20 to 40% vol. of a low-density, rather pure $CO_2$ phase; they were probably homogeneous at the time of trapping. Small amounts of $CH_4$(?) may occur in some inclusions. Total Th occurs mostly in the gas phase or by near-critical phenomena at T mostly ~300°C-350°C; estimated Tt are ~400°-500°C at P of 1-2 kbar. A less common, presumably later type of $CO_2$-poor inclusions is interpreted as a later influx of cooler and less saline fluids.

Quartz from barren veins also contain $CO_2$-bearing inclusions, that however show lower apparent salinities, lower Th-$CO_2$ and lower total Th. Minor $N_2$ may be present.

Reconnaissance studies on fluid inclusions from other Au mineralizations (Val Sesia, Val Toppa) in the Monte Rosa district point to some significant differences with respect to Upper Valle Anzasca.

Combined with field evidence and available Pb- and O-isotope data, the fluid inclusion characters concur in defining a model of ore genesis in which the Au mineralizations of Upper Valle Anzasca were formed in the late stages of the Alpine orogeny by metamorphic fluids produced by devolatization reactions. The strict association between Au and sulfides suggests that Au was possibly transported as thiocomplexes. Possible precipitation mechanisms include cooling, dilution and decrease of the sulfur activity in the fluids.

Similar processes were probably active on a regional scale in the formation of the other Au deposits, but there is evidence that ore-forming hydrothermal systems separate in space and in time occurred in different areas of the district. (Authors' abstract)

DABITZIAS, S.G., 1985/86, Reaction of forsterite with $H_2O$-$CO_2$-0.5 M NaCl mixtures and the composition of the fluid phase at 250° and 310° and 1 kb pressure. Implications for the origin of Greek magnesite deposits: Annales Géol. des pays Helléniques, 1st Series, v. 33, p. 199-219. Author at I.G.M.E., Thessaloniki Br., Thessaloniki, Greece.

The reaction of forsterite with $H_2O$-$CO_2$-0.5 M NaCl mixtures to yield magnesite plus silica has been utilized in studying the solubility of magnesite and silica at 250° and 310°C, and 1 kb and for $CO_2$ up to 19 wt%. The experiments have demonstrated increase in magnesite solubility and decrease in silica solubility with decreasing T at constant $CO_2$. At 310°C and 1 kb, magnesite solubility reaches a maximum at ~4-6 wt% $CO_2$ and then decreases towards higher $CO_2$ concentrations. The appearance of a maximum followed by a minimum on the solubility curve of magnesite is very difficult to explain. A drastic decrease in silica solubility with increasing $CO_2$ concentration in the fluids was also demonstrated in this study. This decrease results because of the reduced activity of $H_2O$-$CO_2$ mixtures and because the solvation number n for aqueous silica is higher than 1.

Turning to the geological implications direct application of the results can be made on the origin of the cryptocrystalline magnesite veins in dunite, on the formation or thickening of quartz veins in the vicinity of and within carbonate rich rocks, and on the very small amounts of silica that can be transported or deposited by $CO_2$-rich hydrothermal fluids in comparison with $CO_2$-free fluids. It is unlikely that silica will be deposited from $CO_2$-rich hydrothermal fluids when either $CO_2$ escapes from the system or enters the gas phase in heterogeneous systems. (Author's abstract)

DAHAN, Noel and COUTY, Rene, 1987, Infrared microspectroscopy of hydrocarbon fluid inclusions in fluorite. Effect of heating under confining pressure (400°C-400 bars): C.R. Acad. Sci. Paris., v. 305, Ser. II, p. 687-689 (in French; English abstract).

Infrared microspectroscopy has been applied to study hydrocarbon fluid inclusions in fluorite (Zriba Guebli, Tunisia). This technique allows qualitative detection of $H_2O$, $CO_2$, $CH_4$ and saturated and unsaturated hydrocarbons. Heating under confining P (400°C-400 bars) induced a decrease of $CO_2$ and $CH_4$ frequencies. According to results of Gordon and Fabre, those shifts are produced by increasing P of $CO_2$ and $CH_4$ gases. (Authors' abstract)

See also next item. (E.R.)

DAHAN, N., COUTY, R. and SEIJAS, A., 1987, Small diamond anvil high-pressure cell for infrared spectroscopy of gas and liquid: Rev. Sci. Instrum., v. 58, no. 3, p. 412-414. First author at Lab. Géol., E.R. 224, E.N.S., 46 rue d'Ulm, 75005 Paris, France.

A small diamond anvil cell (DAC) for pressure (6 GPa) and temperature (90-500 K) infrared spectroscopy is described. The purpose of this equipment is to investigate phase diagrams of fluids. Infrared spectra of freon ($CHF_2Cl$ + $C_2ClF_3$) in the liquid and solid phases are given here to illustrate the capability of this apparatus. (Authors' abstract)

Of pertinence to studies of the gas phase in fluid inclusions (see previous item). (E.R.)

D'AMORE, Franco, FANCELLI, Ruggero and PANICHI, Costanzo, 1987, Stable isotope study of reinjection processes in the Larderello geothermal field: Geochimica Cosmo. Acta, v. 51, p. 857-867.

DANGIČ, Adam, 1985, Minor element distribution between galena and sphalerite as a geothermometer - Application to two lead-zinc areas in Yugoslavia: Econ. Geol., v. 80, p. 180-183. Author at Fac. Mining & Geol., Univ. Belgrade, Djusina 7, 11000 Belgrade, Yugoslavia.

The gn/sp thermometer values agree with previously published Th values on associated quartz. (E.R.)

DARIMONT, Anne, 1987, The fluid inclusions of the quartz veins of the Ardenne: Annales de la Soc. Géol. de Belgique, v. 109, p. 587-601, 1986 (published 1987) (in French; English abstract). Author at Lab. Géol. Appli., 45, Avenue des Tilleuls, B-4000 Liege, Belgium.

Microthermometry and Raman microprobe studies of fluid inclusions in quartz veins from the Ardenne anticlinal axis show them to fall in several systems: $H_2O$-NaCl-$CO_2$-$N_2$; $H_2O$-NaCl and $N_2$(-$CO_2$-$CH_4$). Heterogeneous $H_2O$-NaCl-$CO_2$-$N_2$ fluids are characteristic of metamorphic zones. Depositional P-T conditions ($P = 1.8$ kbar and $T = 400°C$) are determined by the crossing of aqueous and carbonic isochores. This agrees with a geothermal gradient of 50°C km, a high-T/low-P metamorphic domain. A homogeneous $H_2O$-NaCl-$N_2$-$CO_2$ fluid was recognized in non-metamorphic intermediate zones. Its composition is close to 96% $H_2O$ 2.8% $N_2$ and 1.2% $CO_2$. Aqueous fluids are ubiquitous, their densities vary from west to east. A nitrogen-rich (-$CO_2$-$CH_4$) fluid is observed in the Bastogne area; its isochores indicate a low-P environment. The origin of the volatile components is discussed with respect to their occurrence, abundance and relative proportions. (Modified from the author's abstract)

DARIMONT, A., BURKE, E.A.J. and TOURET, J.L.R., 1987, $N_2$-rich fluids in Devonian metasediments, Bastogne, Belgium (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 29-30. First author at Inst. Géol. Appl., 4000 Liège, Belgium.

Quartz segregations in Devonian metasediments (pelites, quartzites, carbonate rich sediments) may contain large (cm size) biotite related micas ("bastonite") with an abnormally low K content. Recent investigations have revealed a high $NH_4$ content (up to 4000 ppm, preliminary IR measurements), much higher than any other biotite analyzed so far. In the segregations, the abundant fluid inclusions belong to three categories:

1. Some "primary" (at least very early) oversaturated brines, with one or several isotropic solids (halites and other chlorides). These can nearly occupy the whole cavity (oversaturated fluid at the time of trapping).

2. An heterogeneous liquid/gaseous fluid, corresponding to the immiscible mixture of a high salinity aqueous (probably in equilibrium with the preceding NaCl bearing ones) and a gaseous, $CO_2$-rich fluid (typical molar composition: $CO_2$-90, $CH_4$-9, $N_2$-1). Trapping conditions can be estimated only qualitatively; they are compatible with peak metamorphic conditions ($P \sim 2$ kb, $T \sim 400°C$).

3. Much more abundant later fluids which are also heterogeneous, complicated gas/aqueous mixtures. They show several contrasting evolution trends:

i) For aqueous inclusions, strong decrease of the salinity, up to almost pure water (1 to 5 wt% NaCl).

ii) In the gas-rich ones, simultaneous increase of $N_2$ and $CH_4$ at the expense of $CO_2$. At $P = 0.5$ kb and an unknown T (±200°C), large quantities of pure $N_2$, containing only traces of $CH_4$ (about 2 moles %) and no $CO_2$, invades the system. They give spectacular trails of late secondary, purely gaseous inclusions. These are especially abundant in the vicinity of the bastonite crystals and without any doubt responsible for the peculiar chemistry of this strange mica.

The origin and evolution of fluids are discussed. It is speculated that the ultimate origin of $N_2$ could be found in now disappeared evaporites, initially associated to the Devonian sediments. (Authors' abstract)

DAVIDSON, D.W., DESANDO, M.A., GOUGH, S.R., HANDA, Y.P., RATCLIFFE, C.I., RIPMEESTER, J.A. and TSE, J.S., 1987, A clathrate hydrate of carbon monoxide: Nature, v. 328, p. 418-419. Authors at Div. Chem., Nat'l. Res. Council of Canada, Ottawa, Ontario K1A 0R9, Canada.

Since the mid-1950s it has been known that most simple clathrate hydrates belong to one of two cubic crystal forms known as type I and II. Only recently it was established that structure II hydrates are formed by small guests such as $O_2^-$, $N_2$, Kr and Ar as well as molecules larger than ~0.58 nm, with molecules of intermediate size forming type I hydrate. The existence of a hydrate of carbon monoxide, a molecule similar in size to $O_2$ and $N_2$, has been proposed since ~1960. This hydrate is thought to play an important role in comets and the outer planets in the Solar System. We have now prepared carbon monoxide hydrate, and demonstrate its clathrate hydrate nature from dielectric and $^{13}C$ NMR (nuclear magnetic resonance) measurements. Unexpectedly, X-ray powder diffraction shows that, unlike hydrates of $O_2$ and $N_2$, carbon monoxide has a type I cubic structure with a lattice parameter of 1.188 nm. (Authors' abstract)

Of pertinence to the interpretation of clathrates formed in fluid inclusions. (E.R.)

DAWSON, J.B., 1987, Fluid-rich interaction in coupled mantle-crust (abst.): Abstracts, NATO Advanced Research Workshop, Fluid movements, element transport, and the composition of the deep crust, Lindås, Norway, 18-24 May, 1987 (unpaginated).

DEINES, Peter, HARRIS, J.W. and GURNEY, J.J., 1987, Carbon isotopic composition, nitrogen content and inclusion composition of diamonds from the Roberts Victor kimberlite, South Africa: Evidence for $^{13}C$ depletion in the mantle: Geochimica Cosmo. Acta, v. 51, p 1227-1243.

DEJONGHE, L., BOULEGUE, J., DEMAIFFE, D. and LETOLLE, R., 1987, Stable (S, C, O) and radiogenic (Sr, Pb) isotope geochemistry of the Fransnian barite mineralization of Chaudfontaine (Belgium) (abst.): Terra Cognita, v. 7, no. 2-3, p. 227. Authors at Service Géol. de Belgique, Bruxelles, Belgium.

Low crystallization T (less than 50°C), are in agreement with fluid inclusion study. (From the authors' abstract)

DELANEY, J.R. and GOLDFARB, M.S., 1987, Two-phase separation in aqueous fluids near the boundaries of submarine axial magma chambers (abst.): EOS, v. 68, p. 1546.

DELANEY, J.R., MOGK, D.W. and MOTTL, M.J., 1987, Quartz-cemented breccias from the Mid-Atlantic Ridge: Samples of a high-salinity hydrothermal upflow zone: J. Geophys. Res., v. 92, no. B9, p. 9175-9192. First author at Sch. Oceanography, Univ. Washington, Seattle, WA.

Textural, mineralogical, chemical, and fluid inclusion studies on a suite of quartz-rich, sulfide-bearing greenstone breccias indicate that high-salinity, high fluid flow systems were recently active on the Mid-Atlantic Ridge south of the Kane Fracture Zone. These systems involved fluids with T close to 300°C and salinities almost 3 times that of seawater. Rounded, pebblelike fragments enclosed within a matrix of euhedral quartz crystals appear to have been cemented by quartz deposition from a moving fluid which attained velocities in excess of 1 m/s. Th and freezing point depression effects in fluid inclusions from texturally early and late quartz crystals indicate temporal evolution of fluid T and NaCl eq. salinities from 290°C and 10 wt % to 200°C and 4.7 wt % during alteration and cementation of the breccias. Highly variable cobalt concentrations in the evolving hydrothermal solutions are indicated by fine scale oscillatory zoning in euhedral pyrite within the breccias. A continuous supply of the high-salinity fluids may be generated either by supercritical two-phase separation at depths well below the level of inclusion entrapment or by retrograde dissolution of hydroxy chloride phases in the deeper portions of the hydrothermal system. Either model requires the initial T of the deeply circulating fluids to have been distinctly higher than 415°C and the fluid to have been cooled by conduction or by mixing with lower T seawater prior to entrapment within the inclusions. (Authors' abstract)

DELÉ-DUBOIS, M.-L. and SCHUBNEL, H.-J., 1987, Identification of inclusions in natural ruby or emerald and in synthetic minerals by Raman microspectrometry (abst.): Terra Cognita, v. 7, p. 14-15.

DEVINE, J.D., 1987, Possible mantle metasomatism beneath the Cameroon volcanic line (abst.): EOS, v. 68, p. 455. Author at Dept. Geol. Sci., Brown Univ., Providence, RI 02912.

Catastrophic release of $CO_2$ gas from Lake Nyos, a classic maar lake in NW Cameroon, in August 1986 resulted in the asphyxiation deaths of over 1,700 people. Gas and water geochemistry suggest a magmatic origin for the accumulated $CO_2$. Lack of typical eruption precursors such as geothermal, geochemical and seismic anomalies suggests that the $CO_2$ is derived by degassing of deep-seated, rather than near-surface, magma. Both crustal and mantle sources may make a contribution. Mineral grains in lherzolite xenoliths from Nyos tephra contain abundant $H_2O$- and $CO_2$-bearing fluid inclusions and some are cut by kaersutitic amphibole-bearing veinlets apparently unrelated to host magma, suggesting that previous episodes of metasomatism may have occurred along magma ascent pathways beneath Lake Nyos. Experimental studies of the system peridotite-$CO_2$-$H_2O$ have shown that degassing of magmatic $CO_2$ at great depth (>85 km) could be a consequence of near-solidus phase relations, and may contribute to, or even dominate, the flux of $CO_2$ observed at the surface. (Author's abstract)

DE VIVO, B., MAIORANI, A., PERNA, G. and TURI, B., 1987, Fluid inclusion and stable isotope studies of calcite, quartz and barite from karstic caves in the Masua mine, southwestern Sardinia, Italy: Chem. Erde, v. 46, p. 259-273. First author at Centro CNR per la Geocronol. la Geochim. delle Forma. Recenti, Bologna, Italy.

Very low Th (50-75°C), low salinities (0.5-2.7 wt.% NaCl eq.), and the C, O, and H isotopes in cave calcites suggest meteoric water deposition. Quartz inclusions are hotter (92°C), more saline (13.3-23 wt.% NaCl eq.), and have $^{18}O$ values suggesting Mississippi Valley-type ore fluids. (E.R.)

DICKSON, F.W. and RYTUBA, J.J., 1987, Transport, and deposition of gold and associated substances at the Carlin gold deposit, Nevada (abst.): Program with Abstracts, Symp.: Bulk Mineable Precious Metal Deposits of the Western United States, April 6-8, 1987, Geol. Soc. Nevada, p. 37. First author at Dept. Geol. Sci., Mackay Sch. Mines, Univ. Nevada.

Evidences support the following conclusions. Mineralizing fluids were originally meteoric (H isotopes), dilute (2-4.6 wt % NaCl eq., fl. incl.) during main stage and rose to about 17% (fl. incl.) during the acid-leach stage. Solutions contained major amounts of $SiO_2$, $FeS_2$, $BaSO_4$, hydrocarbons, $CO_2$, $H_2S$, and trace levels of gold suite elements, all of which occur in subjacent marine rocks. Isotopes in minerals of sulfide and sulfate sulfur, oxides, silicates, carbonates and lead are consistent with an original marine sedimentary source. Exotic mineral assemblages require unusual processes for concentrating, depositing and protecting from dissolution or oxidation. Slow replacive deposition of main stage minerals from 150-160°C (fl. incl.) yielded to rapid vertical flow up fissures and vein deposition from 200-300°C (fl. incl.). Boiling gave off water vapor, $CO_2$, and $H_2S$ to the aerated zone above the water table. Oxidation of $H_2S$ created acid that trickled downward to leach tops of ore bodies. (From the authors' abstract)

DILL, H. and CARL, C., 1987, Sr isotope variation in vein barites from the NE Bavarian Basement: Relevance for the source of elements and genesis of unconformity-related barite deposits: Mineral. & Petrol., v. 36, p. 27-39. Authors at Geol. Survey of Lower Saxony-Continental Deep Drilling Programme FRG (Management Group), Hannover, FRG.

The $^{87}Sr/^{86}Sr$ data point to a crustal derivation of ore-bearing fluids rather than to a homogeneous mantle source. (From the authors' abstract)

DILLES, John, 1987a Evolution of porphyry copper ore fluids during differentiation and crystallization of the Yerington batholith, western Nevada (abst.): GSA Abst. with Programs, v. 19, p. 372. Author at Geol. Dept., Oregon State Univ., Corvallis, OR 97331.

Petrologic studies of the Yerington batholith (YB) indicate that evolution of saline, Cu-rich, aqueous, ore fluids resulted from crystallization of hydrous andesite magma in the shallow crust under oxidized conditions. The YB is a 250 $km^2$, composite, Jurassic pluton, exposed in structural cross-section from <1 to 8 km paleodepth due to Cenozoic normal faulting and 90°W tilting. Quartz monzodiorite, quartz monzonite, and granite of the YB were emplaced within ~1 m.y. and were progressively smaller volume, more silicic (60, 66, & 68 wt.% $SiO_2$) and more deeply emplaced (tops at <1, 1.5, & 2.5-5 km). Major and trace element compositions and Sr- and O-isotope values ($^{87}Sr/^{86}Sr = 0.7040$, $\delta^{18}O = +6.8\%$) are similar to high-K andesites erupted through young continental crust. [sic]

Cpx, Biot, Mgt, and Ilm crystallized early and were joined by Hbl and Sph, indicating that magmas and high oxygen fugacity ($fO_2$ between Ni-NiO and Hm-Mgt buffers) and were hydrous (~4 wt.% $H_2O$). During differentiation and subsolidus cooling $fO_2$ increased as shown by the assemblage Mgt-(Mn)Ilm-Hm and by the low atomic Fe/Fe + Mg in Cpx (0.20-0.21), Biot (0.35-0.41), and Hbl (0.27-0.40). Atomic Cl/F in hydrous minerals is low and decreases with differentiation (apatite = 0.80-0.10). Magma solidification occurred at 1 kb at an inferred T ~750°C, but mineral compositions indicate subsolidus reequilibration at <500°C. Granite and cogenetic granite porphyry dikes, the YB's youngest phase, are associated spatially and temporally with porphyry Cu mineralization at 1-5 km paleodepth and contain 10 ppm Cu, a depletion of 50 ppm relative to the bulk YB.

The high $fO_2$, low Cl/F, low Cu, and extensive subsolidus reequilibration suggest that aqueous fluid separated from the solidifying magma and that Cl, Na, K, $Fe^{++}$, and Cu partitioned into the fluid. This fluid was the likely parent to ore fluids such as the high salinity fluid inclusions trapped in igneous and Cu-bearing, hydrothermal vein quartz. (Author's abstract)

DILLES, J.H., 1987b Petrology of the Yerington batholith, Nevada: Evidence for evolution of porphyry copper ore fluids: Econ. Geol., v. 82, p. 1750-1789. Author at Dept. Applied Earth Sci., Stanford Univ., Stanford, CA 94305.

Briefly quotes inclusion data of Dilles, 1984 (Fluid Inclusion Research, v. 17, p. 75-76). (E.R.) See also previous item. (E.R.)

DINGWELL, D.B., 1987, Melt viscosities in the system $NaAlSi_3O_8-H_2O-F_2O_{-1}$, in B.O. Mysen, ed., Magmatic Processes: Physicochemical Principles: Geochem. Soc. Spec. Pub. 1, p. 423-431.

DOBSON, P.F. and O'NEIL, J.R., 1987, Stable isotope compositions and water contents of boninite series volcanic rocks from Chichi-jima, Bonin Islands, Japan: Earth & Planet. Sci. Letters, v. 82, p. 75-86. First author at Div. Geol. & Planet. Sci., California Inst. of Tech., Pasadena, CA 91125, USA.

Measurements of stable isotope compositions and water contents of boninite series volcanic rocks from the island of Chichi-jima, Bonin Islands, Japan, confirm that a large amount (1.6-2.4 wt.%) of primary water was present in these unusual magmas. An enrichment of 0.6‰ in $^{18}O$ during differentiation is explained by crystallization of $^{18}O$-depleted mafic phases. Silicic glasses have elevated $\delta^{18}O$ values and relatively low $\delta D$ values indicating that they were modified by low-temperature alteration and hydration processes. Mafic glasses, on the other hand, have for the most part retained their primary isotopic signatures since Eocene time. Primary $\delta D$ values of -53 for boninite glasses are higher than those of MORB and suggest that the water was derived from subducted oceanic lithosphere. (Authors' abstract)

DONG, Yibao, BOTH, R.A., BARNES, R.G. and SUN, S.S., 1987, Regional stable isotope and fluid inclusion study of vein-type mineralization in the Broken Hill Block, New South Wales, Australia: Trans. Inst. Min. Metall. Section B, v. 96, p. B15-B30. First author at Chengdu College of Geol., Sichuan, PRC.

The stable isotope and fluid inclusion data that were obtained in the present study, when combined with field relationships and previous lead isotope studies, suggest that the strata-bound and vein-type deposits were derived by remobilization or leaching of components from the metasediments and metavolcanics of the Willyama Supergroup. (From the authors' abstract)

DORIA, A. and NORONHA, F., 1987, Fluid inclusion studies of scheelite deposit of Murçós, NE Portugal (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 137-138. Authors at Centro de Geol. da Univ. Porto, 4000 Porto, Portugal.

The W vein deposit of Murçós is spatially related to syntectonic Hercynian granitoids intruded in metasediments infra-Silurian in age, deformed by the Laza-Rebordelo ductile shear zone (N 130°E) associated with the last Hercynian deformation phase Fe (Westfalian in age) (Iglesias and Ribeior, 1981, Comun. Serv. Geol. Portugal, v. 76, 1, p. 85).

The scheelite-bearing veins are dominantly subhorizontal. The quartz, scheelite, tourmaline, potassic feldspar and other minerals are elongated. The strike of the lineation is parallel to the $F_3$ fold axis ($\underline{b}$ elongation) (Ribeiro and Pereira, 1982, Geonovas, v. 1, 3, 23). These minerals also present tension cracks in turn parallel to tension gashes filled by quartz sulphide mineralization N 45° - N 60°E (therefore perpendicular to elongation). The ensemble is crosscut by late barren quartz veins (N 20° - N 30°E).

Under the microscope the gray W-bearing quartz veins show two facies: clear deformed quartz (Quartz I) with S inclusions rimmed by recrystallized quartz (Quartz II), formed as a result of plastic deformation, with fluid inclusions located exclusively along grain boundaries which migrated during recrystallization. Thus it is not possible to analyze the W-bearing fluids.

The fluids contemporaneous with the shear ductile deformation were studied via fluid inclusions in Quartz I. They are aqueous-carbonaceous fluids (81 mole% $H_2O$; 13 mole% $CO_2$; 3 mole% NaCl) with a density d = 0.7416, at ~400 ± 50°C and 900 ± 100 bar. The fluids related to sulphide mineralization (galena + sphalerite + pyrite + chalcopyrite) were studied on Quartz

III: they are similar to those included in the quartz of the tension cracks. There was a drop of density d = 0.596 and $PCO_2$ and therefore a drop in $fO_2$ and an increase on the $CH_4$ content (86 mole% $H_2O$; 8 mole% $CO_2$; 3 mole% $CH_4$; 3 mole% NaCl) at ~400 ± 50°C and P <500 bar.

The late fluids, associated with barren veins are the most aqueous (97 mole% $H_2O$; 1 mole% $CO_2$; 2 mole% $CH_4$) with variable salinities, homogenizing in the liquid phase. (Authors' abstract)

DORYPHOROS, Catherine, 1985, A comparison of sandstone-hosted lead-zinc deposits using fluid inclusions: MS thesis, Stockholm Univ.; Medd. Stockholms Univ. Geol. Inst., no. 265, 119 pp.

Geological and mineralogical data from several sandstone-hosted lead-zinc deposits in Europe and North America show many similarities with the Laisvall ore deposit in Sweden. Important common features are sedimentological and paleogeographical mineralization controls.

The fluid inclusion evidence from cementing and detrital minerals from selected sandstone deposits resembles that of Laisvall. It is also similar to the microthermometric evidence from Mississippi Valley-type deposits.

Th indicate ore formation between 140° and 200°C from concentrated Na-Ca-Cl brines. Calcite and sphalerite precipitation are dependent on the densities and T of the ore-forming environment which probably resulted from mixing of the brine with a local groundwater solution. Variation in the local conditions may explain the differences in mineralogy and paragenesis between the different deposits.

The fluid inclusion morphology within the sand grains points to granitic source rocks for the sedimentary material of the sandstones. In spite of the complexity of the predepositional history displayed by the detrital grains, the microthermometric evidence is similar to that of the cementing minerals and emphasizes the role of these sandstones as natural aquifers and pathways for ore-forming solutions.

Fluid inclusion evidence from detrital quartz grains may constitute a potential tracer of sandstone-hosted lead-zinc deposits. (Author's abstract)

DOYLE, C.D. and NALDRETT, A.J., 1987, Ideal mixing of divalent cations in mafic magma. II. The solution of NiO and the partitioning of nickel between coexisting olivine and liquid: Geochimica Cosmo. Acta, v. 51, p. 213-219.

DROMGOOLE, E.L. and PASTERIS, J.D., 1987, Interpretation of the sulfide assemblages in a suite of xenoliths from Kilbourne Hole, New Mexico, in Geol. Soc. Am. Spec. Paper 215, Mantle metasomatism and alkaline magmatism, E.M. Morris and J.D. Pasteris, eds., p. 25-46. Authors at Dept. Earth & Planet. Sci., McDonnell Center for Space Sci., Washington Univ., Box 1169, St. Louis, MO 63130.

The sulfides in the Kilbourne Hole spinel lherzolites most likely result from partial retention, in the residual silicate rock, of an immiscible sulfide formed during mantle partial melting. (From the authors' abstract)

DU, Benchen, CHEN, Fugen, WU, Qingzhou and WANG, Dingxia, 1986, Geological characteristics of the Shijiawan molybdenum deposit in Luonan, Shaanxi: Geol. Shaanxi, v. 4, no. 2, p. 58-71 (in Chinese; English abstract).

The deposit has a genetic relation to the Shijiawan granite porphyry mass. The host rock alteration is obviously zoned, dominated by the potassic alteration zone in which most ore bodies occur. $\delta^{34}S$ in 13 pyrite samples is 3.8 - -2.4‰ (meteoritic type). Td of 50 quartz samples from ore-bearing veins range from 233-375°C and Th are 215.5-286.1°C; this indicates that this deposit formed in the mesothermal to epithermal range. (From the authors' abstract)

DUBÉ, B., GUHA, J. and ROCHELEAU, M., 1987, Alteration patterns related to gold mineralization and their relation to $CO_2/H_2O$ ratios: Min. & Petr., v. 37, p. 267-291. First author at Sci. de la Terre/Centre d'Étude sur les Ressources Min., Univ. Québec à Chicoutimi, Chicoutimi, Québec, Canada.

The hydrothermal alteration pattern is shown to be derived from a single fluid with a high initial $CO_2/H_2O$ ratio. At first, reducing reactions prevailed and, with progressive fluid-rock interaction, the $CO_2/H_2O$ ratio was lowered and oxidation reactions dominated. (From the authors' abstract)

DUBESSY, J., 1987, Vibrational spectroscopy of hydrothermal solutions: A review (abst.): Terra Cognita, v. 7, p. 15.

DUBESSY, Jean, BURNEAU, André and DHAMELINCOURT, Paul, 1987, Control parameters of gas analysis in fluid inclusions by micro Raman spectroscopy (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 33-34. Also in Terra cognita, v. 7, p. 15. First author at CREGU, GS CNRS-CREGU, BP 23, 54501 Vandoeuvre lès Nancy Cedex, France.

See same authors, Fluid Inclusion Research, v. 19, 1986. (E.R.)

DUBESSY, Jean and RAMBOZ, Claire, 1987a The history of organic nitrogen from early diagenesis to amphibolite facies: Mineralogical, chemical, mechanical and isotopic implications (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 31-32. First author at CREGU, GS CNRS-CREGU, BP 23, 54501 Vandoeuvre les Nancy Cedex, France.

Fluid inclusion analyses have shown that $N_2$ is a common fluid component in the crust. This paper is intended to show that far from being inert, nitrogen is involved in major mineralogical, chemical and mechanical processes. Nitrogen in diagenesis (S.L.). In early diagenesis, biodegradation of protein rich organic matter (O.M.) produces $NH_4^+$ in anoxic sedimentary environments. Ammonium can be stored into the interlayer space of clay minerals, in the lattice of feldspars, in sylvites and carnallites. Hydrogen, partly of organic origin, is necessarily stored with nitrogen in these minerals.

$N_2$ in salt diapirs. Two kinds of fluid chemistry, strictly related to the wall-rock minerals, can be distinguished: 1) $CH_4$-$N_2$-bearing fluids with little or no $CO_2$ are found in potash mines or halite of lacustrine origin mines where anhydrite is rare. 2) $CO_2$-$N_2$-bearing fluids with minor $CH_4$ are associated with marine anhydrite-halite deposits. This suggests that in marine halite deposits, organic $NH_4^+$ and $CH_4$ are oxidized [by two possible reactions]: (1) $CH_4 + SO_4^{--} + 2H^+ \rightarrow CO_2 + H_2S + 2H_2O$, or (2) $8NH_4^+ + 3SO_4^{--} \rightarrow 4N_2 + 3H_2S + 12H_2O + 2H^+$. Reaction (2) has a large $\Delta V(R)$. This increases fluid P in the impermeable water-poor halite and shale environment, therefore favoring hydraulic fracturing, salt and clay diapirism.

$N_2$ in metamorphic and geothermal environments. The occurrence of $N_2$-rich paleo-fluids in metamorphic and geothermal environments is now well established. $N_2$-bearing fluids associated with $NH_4^+$-silicates has been established only in the Dome de l'Agout, (Kreulen and Schuiling, 1982; GCA, v. 46, p. 193) and in the Jebilet Mountains, (unpub. data by Kreulen). The release of ammonium from micas to the fluid has also been shown to occur experimentally at 550°C-600°C (Hallam and Eugster, 1976 [no ref. given]). Calculation shows that $N_2$ is dominant as soon as $X(N_2) + X(NH_3) > 10^{-4}$ and/

or if $fO_2$ is > QFM (Dubessy, 1985; unpub. thesis, Nancy).

The release of $NH_4^+$ from minerals and its transformation to $N_2$ and $H_2$ have the following geochemical consequences: a) in thermal domes and metamorphic environments, $N_2$ must be considered to have been primarily of organic origin; b) the inert character of $N_2$ in metamorphism is not primary but results from redox reactions; c) fluids have low oxidation state: in the Jebilet, water-poor and $N_2$- and $CH_4$-rich fluids occur in graphite-bearing rocks indicating a low $fO_2$, compatible with the I-W buffer implied by the presence of Ti-bearing garnets (Ramboz and Bastoul, 1985; C. Rend. A.S., v. 301, p. 931); d) low $H_2O$ and $CO_2$ activities in $N_2$- and $CH_4$-rich fluids may enhance the devolatilization reactions to lower T; e) fluid circulation is enhanced, either as a result of gradient density in open systems, or as a result of ductile fracturing due to increase of fluid pressure in closed systems.

Hydrogen isotopic signature. Biogenic hydrogen is characterized by $\delta D < -100$ (Schoell, 1980; GCA, v. 44, p. 649). In the above mentioned environments, fluids and minerals with low $\delta D$, in particular waters (see reaction (2)), are expected to be found with $N_2$. Indeed, waters and minerals with $\delta D < -100$ have been reported in several $N_2$ producing environments, e.g., cap-rock deposits from Tunisia; Sn-W deposit of Panasqueira; $N_2$-rich granite from Ryoke Belt from Japan. (Authors' abstract)

DUBESSY, J. and RAMBOZ, C., 1987b, Devolatilization reactions in the C-O-H-N-S system: Consequences for fluid circulation and mass transfer in sedimentary, metamorphic and hydrothermal environments (abst.): Terra cognita, v. 7, no. 2-3, p. 128. Also in Abstracts, NATO Advanced Research Workshop, Fluid movements, element transport, and the composition of the deep crust, Lindås, Norway, 18-24 May, 1987 (unpaginated).

DUBESSY, Jean, RAMBOZ, Claire, NGUYEN-TRUNG, Chinh, CATHELINEAU, Michel, CHAROY, Bernard, CUNEY, Michel, LEROY, Jacques, POTY, Bernard and WEISBROD, Alain, 1987, Physical and chemical controls ($fO_2$, T, pH) of the opposite behavior of U and Sn-W as examplified by hydrothermal deposits in France and Great Britain, and solubility data: Bull. Mineral., v. 110, p. 261-281. First author at CREGU and GS C.N.R.S.-CREGU, B.P. 23, 54501 Vandoeuvre-les-Nancy Cedex, France.

The aim of this paper is to determine the physical and chemical parameters which control the opposite behavior of U and Sn-W between 300° and 500°C. In U deposits, $fO_2$ and $fS_2$ of mineralizing fluids are higher than values fixed by the pyrite-hematite-magnetite triple point, as shown by uraninite-hematite and/or pyrite mineral association. The stability of quartz-K feldspar-muscovite paragenesis in the wall-rocks of hydrothermal U deposits indicates weakly acid pH. By contrast, in the Sn-W occurrences from the French Southern Massif Central, the $fO_2$ of mineralizing fluids is between Ni-NiO and Q-F-M buffers as shown by $CO_2$-$CH_4$-$H_2O$-NaCl-bearing fluid inclusions. The pH of these fluids is weakly acid to weakly basic as shown by the stability of muscovite in presence or absence of quartz and/or feldspar. Sn-W mineralizing fluids from Cornwall are by contrast purely aqueous and acid, as indicated by the mineral assemblage muscovite-quartz which is typical of greisens.

Experimental data on $UO_2$, $SnO_2$, $FeWO_4$, $CaWO_4$ solubility and metal species in fluids show that $fO_2$ > H-M are required for U transport whereas $fO_2$ < Ni-NiO favors Sn transport. The fluid oxidation state has no direct influence on the transport and deposition of W. The $fO_2$ control on the hydrothermal transport properties of these three metals is related on the one hand to the fluid and rock composition, and on the other hand to the minimal 320°C T required for homogeneous equilibria in the C-O-H system to control the oxidation state at low values.

At high T, Sn, Fe and Ca chloride complexes are more stable than carbonate and phosphate U complexes; this is attributable to their structure and to the dielectric content of the fluid. The presence of dissolved gases at high concentration, which are produced by devolatilization reactions at high T, is emphasized since they lower the dielectric constant of the fluid which enhances the stability of chloride complexes. All these results show that T and $fO_2$ account for the opposite behavior of U and Sn-W in hydrothermal systems between 300° and 500°C. (Authors' abstract)

DU BRAY, E.A. and DUFFIELD, W.A., 1987, Compositions of feldspar phenocrysts and petrogenetic implications, Taylor Creek rhyolite, New Mexico (abst.): Geol. Soc. Am. Abst. with Programs, v. 19, p. 272. First author at U.S.G.S.-MS 905, Box 25046 D.F.C., Denver, CO 80225.

The compositions of sanidine and oligoclase phenocrysts have been determined for six rhyolite lavas. The rhyolite is locally crosscut by specularite- and cassiterite-bearing veins whose Sn we interpret as having evolved from the lavas themselves as they cooled, degassed, and devitrified. Two-feldspar geothermometry suggests 825-840°C equilibration at 1-2 kbar; these T are consistent with fluid inclusion Th as high as 700°C for specularite and 625°C for cassiterite in crosscutting veins. Such T imply volatile-poor magma (dissolved volatiles cause liquidus depression, which inhibits crystallization); the volatile-poor character of the magma may explain the absence of a more well developed (potentially mineralizing), magma-derived hydrothermal system in this otherwise fertile rhyolite. (From the authors' abstract)

DUFFIELD, W.A., 1987, Relations between cassiterite-bearing veins and rhyolite lavas, Black Range area, southwestern New Mexico (abst.): U.S. Geol. Survey Circular 995, p. 16-17.

Includes statement that "Other researchers report that fluid inclusions in cassiterite and associated vein minerals formed at 750-100°C ..." (E.R.)

DUFRESNE, M.B., 1987, Origin of gold in the White Channel sediments of the Klondike region, Yukon Territory: MS thesis, The University of Alberta.

See next item. (E.R.)

DUFRESNE, M.B., NESBITT, B.E., LONGSTAFFE, F.J. and MORISON, S.R., 1987, Plio-Pleistocene epithermal Au mineralization in the White Channel sediments of the Klondike district, Yukon (abst.): GAC-MAC, AGC-AMC Joint Ann. Mtg., Program with Absts., v. 12, p. 38. First author at Dept. Geol., Univ. Alberta, Edmonton, Alberta, T6G 2E3.

Placer Au was first discovered during 1896 in the Klondike district. Since then, exploration of mesothermal quartz veins in the Klondike Schist has failed to locate a source for the 10+ million oz of Au recovered from the Holocene creek gravels and the Plio-Pleistocene White Channel sediments. The field relationships and data collected from mineralogical, geochemical, fluid inclusion and oxygen isotope studies indicate that most of the Au mineralization in the White Channel sediments and footwall rocks was formed directly from Plio-Pleistocene epithermal processes. Through subsequent erosion of these units, significant amounts of epithermal Au was incorporated into the Holocene creek gravels.

The White Channel sediments are unconsolidated gravels and sands which exist on bedrock benches elevated above the Holocene creeks. Post-depositional hydrothermal alteration in the White Channel sediments is divided into 3 zones. Sediments in the uppermost zone (Bleached zone) have a bleached appearance, contain abundant secondary kaolinite and are depleted in Fe, Mg, Na and K relative to unaltered sediments. The lowest 2-4 m of gravel (Iron zone) are bright orange in color and contain secondary kaolinite, illite, smectite, Fe-hydroxides, hematite, adularia and gypsum. In this zone kaolinite, illite and the Fe-hydroxides are well-crystallized. Iron zone gravel also is enriched in the following elements with up to 26.16% $Fe_2O_3$, 0.73% $P_2O_3$, 490 ppm S, 15,900 ppm Ba, 1,560 ppm As, 45.5 ppm Sb and 110 ppm Co. The Klondike Schist underlying the White Channel sediments is pervasively altered (Footwall zone) and contains secondary minerals such as kaolinite, illite, illite/smectite, Fe-hydroxides and adularia. In the Footwall zone Fe, Mg, Ca, Na and K are depleted relative to unaltered bedrock. Quartz/chalcedony veins in the Footwall zone were emplaced during hydrothermal alteration. These veins contain vugs, banding, cockade, cockscomb and crustiform textures. Fluid inclusion studies indicate that the veins formed at ≈125°C from aqueous fluids that contain <2 wt.% eq. NaCl. The veins contain up to 1.86% MnO, 0.43% $P_2O_3$, 2,800 ppm S, 5,410 ppm Ba, 97 ppm As, 27.9 ppm Sb and 280 ppb Au. Quartz from these veins has an average $\delta^{18}O_{smow}$ of +4‰ indicating that the parent fluid had a $\delta^{18}O_{smow}$ of -15‰. The fluid was probably meteoric in origin. Au is disseminated in low grades and large tonnages throughout hydrothermally altered gravel and bedrock with a distribution that distinctly contrasts that of Au in unaltered White Channel gravel. (Authors' abstract)

DUKE, E.F. and GALBREATH, K.C., 1987, Graphite as a recorder of fluid flow in the mid-crust (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 648. Authors at Inst. for Study of Mineral Deposits, South Dakota Sch. Mines & Tech., Rapid City, SD 57701.

Graphite in wall-rock alteration zones adjacent to synmetamorphic quartz veins provides a record of migration of carbon-bearing fluids accompanying Early Proterozoic metamorphism and granitic intrusive activity in the Black Hills, South Dakota. In occurrences that have been examined in detail, wall rocks are quartz + biotite + plagioclase ± muscovite ± K-feldspar ± garnet schists of the staurolite and sillimanite zones. The veins are essentially pure quartz with traces of graphite, tourmaline, or sulfide and the principal alteration assemblages consist of tourmaline + quartz + graphite or quartz + graphite + pyrrhotite. Graphite locally makes up to >20 vol.% and tourmaline makes up >50 vol.% of samples of tourmaline-quartz-graphite assemblages. Visible alteration zones range from <10 cm adjacent to thin (~10 cm) veins to ~10 m adjacent to thick (~30 m) veins. Observed fluid inclusions in vein quartz are all secondary. Microthermometric measurements on samples from two occurrences indicate that fluids are predominantly $H_2O$-$CO_2$ mixtures with low to moderate salinities (8-77 mol% $CO_2$, 3-12 wt.% NaCl equiv.) although some inclusions contain significant quantities of an additional noncondensible gas (~15 mol% $CH_4$ equiv.). Within the precision of the measurements, such compositions approximate thermodynamic equilibrium with graphite in the C-O-H system at the inferred conditions of vein formation (~500°-600°C, 3-4 kbar). Calculated compositions and densities for some inclusions, however, imply that pressures may have been higher than previously estimated on the basis of present metamorphic assemblages in the area, perhaps reaching 5-6 kbar.

Available data do not allow us to distinguish between predominantly magmatic or predominantly metamorphic origins for the vein-forming fluids. The geologic setting of the occurrences, however, is consistent with multiple origins for fluid components. For example, carbon may have been derived from metamorphosed black shales whereas boron may have been contributed largely from nearby granitic intrusive bodies. (Authors' abstract)

DUNBAR, N.W., HERVIG, R. and TAYLOR, B.E., 1987, Volatile contents and degassing behavior of rhyolitic magmas from the Taupo Volcanic Zone, New Zealand (abst.): Int'l. Union of Geodesy & Geophys., XIX Gen. Assembly, Vancouver, Canada; Aug. 9-22, 1987; Abstracts, v. 2, p. 404. First author at NMIMT, Socorro, NM 87801.

The Taupo Volcanic Zone has produced at least 30 explosive rhyolitic eruptions during the last 50,000 yrs, from the Taupo and Okataina eruptive centers. In this study, preeruptive volatile content and retention of volatiles by quenched ejecta (obsidian) were investigated for 20 tephra units from these two centers.

Obsidian in other silicic systems has been shown to contain some fraction of preeruptive volatile contents of the parental magma. This allows reconstruction of degassing trends and extrapolation to initial volatile contents. Fragments of clear, grey to black obsidian in sampled tephra units contain variable amounts of $H_2O$ and Cl. Average $H_2O$ contents of bulk obsidian samples from single eruptive units range from 0.2 to 1.7 wt% $H_2O$. Individual obsidian fragments have $H_2O$ contents which vary up to ±1 wt% about the average $H_2O$ content of the bulk sample. During analysis, water is generally released from obsidian at 500°C, or above, suggesting that it is magmatic, not due to hydration. The average Cl contents of obsidian from individual tephra range from 0.12 to 0.16 wt% and roughly correlate with $H_2O$ contents. Delta D values of water in obsidian from several tephras show rough trends indicative of D and H fractionation between a vapor phase and magma. These data, together with water contents and degassing behavior indicate that obsidian retains some fraction of preeruptive volatiles and must have quenched from partially degassed magma at varying pressures, possibly along the walls of the conduit.

Melt inclusions in primary phenocrysts provide samples of chemically unaltered preeruptive magma from which magmatic volatiles can be determined. Electron microprobe analyses of Cl in melt inclusions range from 0.18 to 0.24 wt%. S contents are below 50 ppm. Ion microprobe determinations of $H_2O$ and F contents of melt inclusions in pyroxene from the 130 AD Taupo plinian eruption are 4.7 ± 0.5 wt% and 400 ± 50 ppm respectively. This water content is consistent with calculated solubilities of $H_2O$ in Taupo magma, but is higher than the estimate of 2.5 wt% inferred from the Cl content of glass inclusions and the observed Cl:$H_2O$ correlation in obsidian. Apparently, $H_2O$ and Cl degassing behavior decouples at higher $H_2O$ contents than those measured in obsidian. (Authors' abstract)

DUNBAR, N.W. and KYLE, P.R., 1987, Studies of magmatic volatiles using glass inclusions in crystals from the Taupo Volcanic Zone, New Zealand, and Mount Erebus, Antarctica (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Authors at New Mexico Inst. Mining & Tech., Socorro, NM 87801.

Glass inclusions in magmatic phenocrysts represent the closest available approximation of nondegassed magma, and study of these inclusions can yield information about pre-eruptive conditions in a magma chamber. Phonolite ejecta from Mount Erebus volcano and high silica rhyolitic tephra from the Taupo Volcanic Zone (TVZ) both contain phenocrysts with abundant pristine glass inclusions. Anorthoclase feldspar crystals from Mount Erebus contain negative crystal shape or irregular inclusions of brown glass which contain abundant shrinkage bubbles. Plagioclase, pyroxene, magnetite, and ilmenite phenocrysts from the TVZ tephra contain clear, blebby inclusions which generally lack shrinkage bubbles.

Microprobe analyses of the TVZ glass inclusions show that the major element chemistry similar to bulk compositions of the rhyolite tephra, and no chemical zonation is seen within inclusions. We believe that little or no post-entrapment crystallization occurred in the glass inclusions, and that they represent pre-eruptive, unaltered magma. Microprobe analyses of TVZ glass inclusions show Cl content of 0.18 to 0.24 wt% and S <0.02 wt%. Comparison of the post-eruptive Cl contents of tephra with Cl contents of glass inclusions yields an estimated output of 7.62 x $10^{12}$ grams of Cl for the Taupo Plinian eruption.

Ion microprobe analyses of glass inclusions from the Taupo Plinian eruption show 4.7 ± 1.0 wt% $H_2O$ (range from 3.4 to 5.4). This is one of the first direct determinations of pre-eruptive $H_2O$ contents of rhyolitic magmas. It is at the high end of estimates based on indirect methods. This value indicates that the Taupo Plinian magma was close to saturation at the time of eruption, which could account for the violence of the eruption.

It is difficult to see melting in glass inclusions from the TVZ because of the lack of shrinkage bubbles. The glass inclusions ususally decrepitate near 800°C, which is close to their entrapment T as inferred from Fe-Ti oxide geothermometry.

The major element chemistry of the Mount Erebus inclusions is only slightly different from the bulk chemistry, and there is no evidence of compositional zonation within inclusions, indicating that the inclusions represent pristine magma (Kyle, 1977). Glass inclusions in Mount Erebus tephra have Cl and S contents of 0.19 to 0.20 and 0.05 to 0.07 wt.% respectively. Matrix glass adhering to the crystals shows identical Cl and S contents, and the implications of this are not fully understood at this point. Melting and Th of glass inclusions average 950 and 1000°C respectively. The melting T agree with optical pyrometer T measurements of the magma [i.e., made at the time of eruption?]. (Authors' abstract)

DURASOVA, N.A., RYABCHIKOV, I.D. and BARSUKOV, V.L., 1986, Redox potential and behavior of tin in magmatic systems: Geologiya Rudn. Mestorozhd., v. 28, no 1, p. 5-11 (in Russian). First author at GEOKHI, Moscow, USSR.

The experimental data indicate that tin may be present in magmatic melts (basaltic and granitic ones) at two oxidation levels: $Sn^{2+}$ and $Sn^{4+}$ (T = 700-1200°C). The glass phase of hawaiite after run bears 0.70 wt.% of Sn as $SnO_2$ under $-\ell gfO_2$ 2.2-3.5 and the minerals in equilibrium bear $SnO_2$ as follows: plagioclase 0.01-0.07, magnetite 0.67-0.78, ilmenite 2.10-4.50; same under $-\ell gfO_2$ 6.0-11.8 for glass 1.02, for plagioclase 0.04-0.01. During hawaiite melt liquation the $SiO_2$-low globules (46.1 wt.% $SiO_2$) bear 0.9 wt.% $SnO_2$, the $SiO_2$-high matrix (70.0%) - 0.4% $SnO_2$. Coefficients of distribution of Sn between Cl-bearing acid water-rich phase and silicate melt range from 0.005 to 0.2 (granite) and from 0.0002 to 0.02 (basalt) at 750-1300°C, 1-1.5 kbar. Increase of $fO_2$ causes stronger partition of Sn to the water phase. (Abstract by A.K.)

ĎURIŠOVÁ, Jana, 1987a Diversity of fluids in the formation of ore assemblages in the Bohemian Massif (Czechoslovakia) (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 35-36. Author at Geol. Survey, Malostranské nám. 19, 118 21 Praha 1, Czechoslovakia.

Fluid inclusion data from various ore assemblages in the Czechoslovak part of the Bohemian Massif are reviewed. (...) Fluid inclusion studies were undertaken to distinguish ore assemblages on the basis of the nature of ore-bearing fluids. For the studies the samples from the main ore types were selected and tested by optical microthermometry using Chaixmeca apparatus.

The following styles of ore deposits were studied: a) Sn and W veins and greisen from the Saxo-Thuringian zone associated with Variscan plutonism (Cinovec, Horni Krupka). Two types of fluids were ascertained, the first one of high salinity (35-40% NaCl eq.) and the second one of low salinity (2.5-10% NaCl eq.) and of low density. NaCl predominates in both of them. The occurrence of both the types in the interval 500-350°C is characteristic with no mutual transitions. The boiling of solutions is common, the contents of $CO_2$ is low (<5 mol. %). b) Pb-Zn-Ag veins related to deep structures (Pribram district). The concentration of fluids varies between 10-25 NaCl eq. In addition to NaCl, some other chlorides ($CaCl_2$, $MgCl_2$) are present. T of deposition ranges from 250 to 100°C. No $CO_2$ was found. c) Fluorite-barite veins without an apparent relationship with magmatism. Low T (180-100°C) solutions with the high concentration of salts (15-30% NaCl eq.), $CaCl_2$ is markedly represented. In subrecent fluorites solutions of the $NaHCO_3$ type were found (T <100°C, salinity <5% NaCl eq.). d) Massive sulphides in metamorphosed Devonian (The Jeseniky Mts.). Ore assemblages were subjected to metamorphism. The fluids in the rock quartz are of $CO_2$-$CH_4$-$H_2O$ type. The high density of $CO_2$ is typical (500-960 kg/m$^3$) and it correlates with grade of metamorphism. The total salinity varied from 5 to 17% (NaCl predominates). With the decrease of metamorphism the proportion of $H_2O$ increased. e) Quartz veins with Au and scheelite in high metamorphosed crystalline of the Moldanubian. Quartz and apatite in the metamorphosed country rock contain inclusions with fluids of the $CO_2$-$CH_4$-$H_2O$ type with the average salinity of 5-10% NaCl eq. Scheelite and quartz from the vein type contain inclusions of low to moderate salinity (3-20% NaCl eq.) with occasional boiling (at 340-410°C). No $CO_2$ was found.

The diversity in the composition and T of fluids is indicative of different conditions of the ore-bearing processes in the Bohemian Massif.

The fluids related to Variscan plutonism were heterogenous at ore deposition, of very low or very high concentrations of salts and very low in $CO_2$. Those associated with regional and periplutonic metamorphism were high in $CO_2$ and $CH_4$ with increasing proportion of $H_2O$ during the decrease of metamorphism. The Post-Variscan vein types of mineralization were formed from the fluids of a more variegated composition. (Author's abstract)

ĎURIŠOVÁ, Jana, 1987a Fluid inclusions in minerals of the ore deposits of the Jeseniky Mts.: Vestn. Ustred. Ustavu Geol., v. 62, no. 2, p. 65-76 (in English). Author at Ustredni Ustav Geol., 118 21 Prague, Czechoslovakia.

The fluid inclusions in quartz (occurring as lenses and veinlets) in metamorphic rocks from 3 localities of the Jeseniky Mts. (the Zlaty Chlum and Sucha Rudna Au ore deposits and the Vidly polymetallic deposit, Czechoslovakia) were studied to determine formation conditions of mineral assemblages of the deposits. The inclusions are metamorphogenic and are of 2 types (liquid $CO_2$ and aqueous solution); under certain T-P conditions, the inclusions existed separate as 2 immiscible liquids. The d. of the $CO_2$ liquid increased from Sucha Rudna through Vidly to Zlaty Chlum, which confirmed the paragenetic association of the metamorphic facies. Results suggest that the P of the mineralizing solutions were 70-400 MPa; these solutions had a chloride composition with prevailing Na component and their total salinity was 5-17 wt. %. (C.A. 107: 239967k)

DUTTON, A.R. and ORR, E.D., 1986, Hydrogeology and hydrochemical facies of the San Andres formation in eastern New Mexico and the Texas Panhandle: Bureau of Econ. Geol. Report of Investigations No. 157, 58 pp.

Similarity between $\delta D$(-15‰ to -26‰) and $\delta^{18}O$ (+4‰ to +6.4‰) of

San Andres ground water in the Palo Duro Basin and $\delta D$ and $\delta^{18}O$ of fluid inclusions in halite beds suggests that brine in the carbonate rock could have originated during the Permian as evaporatively concentrated [and highly modified] seawater. (From the authors' abstract)

DUTTON, A.R., 1987, Origin of brine in the San Andres Formation, evaporite confining system, Texas Panhandle and eastern New Mexico: Geol. Soc. Am. Bull., v. 99, p. 103-112.

DYACHKOV, Sergei and McLELLAN, Eileen, 1987, Insight into the deformational and thermal history of the Stony Creek granite, Ct., through microstructural and fluid inclusion observations (abst.): EOS, v. 68, p. 443. First author at Peoples' Friendship Univ., Moscow, USSR.

We have conducted integrated field, microstructural, petrofabric and fluid inclusion analyses on a diapiric granite (Stony Creek, Ct.) to determine its thermal and deformational history. Petrofabric analysis shows that enclaves in the granite have a pronounced petrofabric (c + 1011* slip), very different from that of the country rocks (c + a slip); the enclosing granite has no c-axis fabric but shows limited evidence of c slip. The low strains in granite indicate limited post-crystallization deformation; observed fabrics (phase layering, bi-schlieren) are therefore magmatic in origin. Country rocks show a sub-horizontal girdle, compatible with field measurements of flattening strains in the aureole (? intrusion-related).

Fluid inclusion analyses together with petrologic and microstructural data show that P-T paths for both the granite and its country rocks were dominated by uplift during the early stages of granite crystallization (as expected for diapiric intrusion). Quartz veins formed in the country rock during granite crystallization are undeformed; deformation had therefore ceased by P ~5 kb and T ~600°C, i.e., very soon after solidification. Thermal equilibrium between granite and country rock was not reached until much later (P ~3 kb, T ~450°C). (Authors' abstract) [*Presumably 10$\bar{1}$1.]

DYMEK, R.F. and SCHIFFRIES, C.M., 1987, Calcic myrmekite: Possible evidence for the involvement of water during the evolution of andesine anorthosite from St-Urbain, Quebec: Canadian Mineral., v. 25, p. 291-319.

DYPVIK, H. and KONNERUP-MADSEN, J., 1987, Fluid inclusions and quartz cementation of Jurassic sandstones from offshore Norway (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 37. First author at Dept. Geol., Univ. Oslo, P.O. Box 1047, Blindern, N-0316, Oslo 3, Norway.

Fluid inclusions in quartz cement in Jurassic sandstones from the Haltenbanken area, offshore Norway, have been studied in order to obtain information on the T, P and types of fluids associated with quartz cementation. The cementation appears to be closely related to stylolitization processes in the sediments. The fluid inclusions studied occur within the quartz overgrowth or along "dust rims" of detrital quartz grains. The fluids are essentially aqueous solutions with salinities of 3-4 eq. wt% NaCl and densities of 0.96-0.97 $g/cm^3$.

In drill core samples from depths of 4300-4500 m Th to liquid occurs at 120° to 128°C, and trace contents of hydrocarbons (most probably methane) are indicated to be present in some inclusions. At a depth of about 3500 m Th to liquid was observed at 89° to 104°C.

The inclusion fluids, with salinities similar to those of marine waters, are considered to represent the pore fluids associated with quartz cementation of the sandstones. From burial history considerations of the

Haltenbanken area the fluid inclusion data indicate T of 140° to 170°C, depths of burial of 3500-4500 m, and an average geothermal gradient of about 40°C/km during quartz cementation. Such conditions were attained only at a late stage in the diagenetic evolution of the sediments in late Tertiary. (Authors' abstract)

DZHERBESHYAN, D.S., 1987, Petrogenetic features of the calc-alkaline series of the Aragats Volcano, Armenia: Geol. Zb.--Geol. Carpathica, v. 38, no. 2, p. 249-256 (in Russian).

DZYUBA, A.S., KVITKA, V.I. and ZU, Y.Y., 1986, Melting of crystal with inclusions in field of temperature gradient: Kristallografiya, v. 31, p. 1189-1192 (in Russian; translated in Sov. Phys. Crystallogr., v. 31, no. 6, p. 702-704, 1986). Authors at State Univ., Khar'kov, USSR.

The authors investigate the melting of a crystal with nonuniform distribution of impurity. They discover the formation of a boundary zone of inclusions of melt in the process of melting of the crystal in the field of a temperature gradient. They show that the width of this zone is uniquely determined by the phase diagram "main substance-impurity" and depends on the value of the externally imposed temperature gradient. (Authors' abstract)

EBADI, A., ZIEGENBEIN, D. and JOHANNES, W., 1987, Melt formation in granite system Qz-Ab-Or at a water activity <1 (abst.): Fortschritte der Mineralogie, Bd. 65, Bhf. 1, p. 41 (in German). Authors at Hannover, FRG.

It may be accepted that rock melts formed in deep continental crust are undersaturated with water, due to a deficiency of water or due to the presence of other volatiles, mainly $CO_2$. In any case, during melt formation the activity of water ($aH_2O$) is <1. Experimental data are available on formation of $H_2O$-saturated melts in the system Qz-Ab-Or-$H_2O$ (Tuttle and Bowen 1958, Geol. Soc. Am. Mem., 74, pt. 1; Luth et al., 1964, J. Geoph. Res., v. 69, p. 759) and in the system Qz-Ab-An-Or-$H_2O$ (Johannes 1984, Cont. Min. Pet., v. 86, p. 264). On melt formation under controlled water activity <1 in the alkali feldspar-granite system there are only calculations (Johannes 1985). The author made the first attempt to determine the solidus T in the system Qz-Ab-Or-$H_2O$-$CO_2$ at $aH_2O = 0.5$; the results fall in the range 750 to 800°C and the solidus line in the P-T plot is very steep [see Figure]. (Authors' abstract, translated by A.K.)

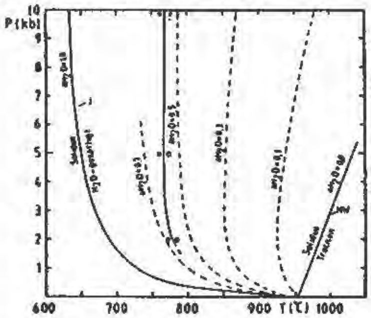


Figure. Solidus T in the system Qz-Ab-Or-$H_2O$ for $H_2O$ activities ($aH_2O$) equal 1.0, 0.7, 0.5, 0.3, 0.1 and 0.0. HW-Huang and Wyllie 1975, J. Petrol., v. 83, p. 737; J. Johannes 1984, Cont. Min. Pet., v. 86, p. 264; the dashed lines indicate the calculated curves made by J.R. Holloway (see Johannes 1985, in Migmatits, J.R. Ashward, ed., p. 36).

EDMOND, J.M., 1987, Hydrothermal fluxes in the oceanic geochemical budgets (abst.): EOS, v. 68, p. 1209.

EDMOND, J.M., VON DAMM, K.L. and BOWERS, T.S., 1987, The chemistry of submarine ore-forming solutions, in Marine Minerals, P.G. Teleki et al., eds., p. 339-347.

EGGLER, D.H., 1987a Discussion of recent papers on carbonated peridotite, bearing on mantle metasomatism and magmatism: An alternative: Earth & Planet. Sci. Letters, v. 82, p. 398-400.

EGGLER, D.H., 1987b Solubility of major and trace elements in mantle metasomatic fluids: Experimental constraints, in Mantle Metasomatism, Menzies, M.A. and Hawkesworth, C.J., eds., 1987, Academic Press, Inc., London, p. 21-41. Author at Geosci. Dept., The Pennsylvania State Univ., University Park, PA 16802.

Discusses the nature of mantle fluids as metasomatic agents and the results of experimental work on fluid chemistry and solubility. (H.E.B.)

EGGLESTON, T.L., 1987, The Taylor Creek district, New Mexico: Geology, petrology, and tin deposits: PhD dissertation, New Mexico Inst. Mining & Tech., 474 pp.

This dissertation covers the geology and petrology of these deposits in detail, and includes discussions of the fluid inclusions present in the vapor-phase crystallized rhyolites and tin mineralization which are summarized by Eggleston and Norman, 1987 (second item beyond). (E.R.)

EGGLESTON, T.L. and NORMAN, D.I., 1986, A summary of the geology, geochemistry, and tin occurrences in the Black Range, New Mexico: New Mexico Geol. Soc. Guidebook, 37th Field Conf., Truth or Consequences, p. 173-177. Authors at Dept. Geosci., New Mexico Inst. Mining & Tech., Socorro, NM 87801.

Fluid inclusion data mentioned briefly; see Eggleston and Norman, 1986, Fluid Inclusion Research, v. 19, p. 121, 1986. (E.R.)

EGGLESTON, T.L. and NORMAN, D.I., 1987, Glass-bearing inclusions in cassiterite, topaz, and quartz--Taylor Creek tin district, New Mexico (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Authors at New Mexico Inst. Mining & Tech., Socorro, NM 87801.

Tin occurrences in the Black Range of New Mexico consist of variable proportions of hematite and cassiterite in widely spaced veinlets near the carapace of high-silica rhyolite domes. The veinlets are typically a few meters long and high and as much as 10 cm wide. Quartz and topaz are locally present as gangue minerals. Two types of inclusions were observed in these minerals (except hematite). Type I inclusions, >50 um, are vapor dominated. Type II inclusions are typically <10 um and are multiphase, solid-vapor. Both types occur as P, PS and S inclusions. No phase changes were observed in Type I inclusions when heated to 600°C and cooled to -170°C. Type II inclusions consist of glass, 3 to 5 dms, and vapor at room T. One dm is an irregularly shaped opaque. Transparent dms include a cubic mineral, possibly halite, and 2 to 3 irregularly shaped, birefringent dms that may be other halides. The glass phase begins to melt at about 330°C and is completely molten at 350°C forming liquid-solid-vapor inclusions. The tranparent dms dissolve in the melt between 400° and 625°C indicating salinities of >75 eq. wt.% NaCl. Th to liquid occurs at 670° to 730°C. The glass quenches at 270° to 290°C. Large (>25 um) Type II exhibit somewhat different behavior. These inclusions are wholly crystalline at room T and begin to melt at about 340°C and are molten at about 350°C. On cooling, the major crystalline phase nucleates at about 370°C. Crystallization is complete by 350°C. A glass forms when these inclusions are cooled rapidly. In all cases, the vapor bubble is deformed by quenching or crystallization. The low melting point of the glass and crystalline phase suggests that the glass consists of halogen-alkali-metal compounds such as lithium tetraborate. Bulk gas analyses of gases from fluid inclusions yield $CO_2/H_2$ ratios of 0.1 to 0.3 with significant CO, He, $H_2$, and minor $H_2S$, $SO_2$, and organic gases. With exception of the organic gases which may be due to organic activity in the fumarolic system[sic], these gases are similar to those observed in presently active volcanos.

Mineralization is contemporaneous with the domes thus P on the system was ~1 bar. The oxygen isotopic composition of quartz associated with the mineralization is about +8 per mil (SMOW) and suggests a magmatic origin for the fluids.

The data indicates that tin mineralization was deposited from high T, magmatic fluids in a near surface, fumarolic environment in response to extreme thermal gradients. Type I inclusions are trapped supercritical fluid and Type II inclusions are condensates from those fluids. (Authors' abstract)

EGLINTON, T.I., CURTIS, C.D. and ROWLAND, S.J., 1987, Generation of water-soluble organic acids from kerogen during hydrous pyrolysis: Implications for porosity development: Min. Mag., v. 51, p. 495-503. First author at Organic Geochem. Unit, Dept. Geol., Drummond Bldg., Univ. Newcastle upon Tyne, Newcastle NE1 7RU.

Concentrations of organic acids ranging up to several thousand parts per million have previously been found in oil-field waters. These acids are of interest because of their potential to enhance porosity by the dissolution of carbonates and aluminosilicates. They are believed to be generated from organic geopolymers (kerogen) in the late-diagenetic-early-catagenetic stage of thermal maturation.

During the course of artificial maturation experiments in which kerogens of varying type were heated in the presence of water (so-called 'hydrous pyrolysis') and different minerals, the distribution and abundance of low molecular weight water-soluble acids were determined by gas chromatography and gas chromatography-mass spectrometry. Preliminary results suggest that significant quantities of mono- and di-carboxylic acids are produced during hdyrous pyrolysis. The amounts and types of acid appear to vary as a function of kerogen type, maturity and mineralogy. Implications of these findings regarding the development of secondary porosity are discussed. (Authors' abstract)

EILON, G., STARINSKY, A. and LANG, B., 1987a Heliothermal effects on the anhydrite-silica system: Data from fluid inclusions in quartz geodes, Upper Cretaceous, Israel (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 39-40. First author at The Hebrew Univ. of Jerusalem, Israel.

In Israel, quartz geodes occur mainly within a narrow stratigraphic interval in the Lower Cenomanian section, represented by marls, limestones and dolomites.

The geodes have a uniform spheroidal to slightly ellipsoidal shape, with cauliflower-like protrusions on the surface. Their diameters range from less than 1 cm up to 50 cm. Most of the quartz geodes are composed of the following concentric zones (from the exterior to the center): (a) an outer chalcedony rim occurring as thin irregular zone (< 1 cm) of fibrous, radial or plume-like chalcedony; (b) a drusy, anhedral to euhedral, milky quartz zone; (c) an inner zone of euhedral quartz crystals. In places, a central void is present.

Inclusions of prismatic anhydrite crystals (10 to 20 μm long), are characteristic of the two outer zones. Their abundance decreases sharply towards the center of the geode.

Three types of fluid inclusions are present within the quartz: 1. Rare, small (<15 μm), round or negative crystal forms of mono- or biphase inclusions (vapor volume 2-10%) which are considered to be primary; 2. Mono- and biphase inclusions with shapes and sizes similar to the included anhydrite crystals; and 3. Large (up to 70 μm) angular inclusions located at quartz-crystal junctions and commonly showing features of leakage. Types 2 and 3 are considered to be secondary.

Th of P (type 1) biphase fluid inclusions was 97.5 to 110.5°C. Tm [ice?] indicate solutions of normal sea water (in NaCl eq.) with several measurements indicating higher NaCl concentrations (up to 10%).

The quartz geodes are considered to have formed in the following stages:

A. Concretions of anhydrite (or gypsum) formed in small, inner basins where heliothermal processes resulted in a high salinity and T (>55°C) environment within a normal shallow marine platform.

B. As a result of the antithetic T-solubility relationship of silica versus anhydrite, the intermittent rise and fall of the T and salinities of the brines caused the dissolution of anhydrite and precipitation of silica as quartz or chalcedony.

The relatively high T recorded by the fluid inclusions indicate maximum T. The environment was characterized by rapid and extreme changes in salinities and T as a result of changes in external conditions such as wind and rain. Such drastic changes may explain the near-simultaneous formation of mono- and biphase fluid inclusions in the geodes.

C. The later return of normal sea conditions favored the dissolution of remnant (unsilicified) anhydrite concretions resulting in their absence for the present section. (Authors' abstract)

EILON, G., STARINSKY, A. and LANG, B., 1987b, Fluid inclusions in quartz geodes from the Judea-group (abst.): Israel Geol. Soc. Annual Meeting, 1987, p. 31. First author at Dept. Geol., Hebrew Univ.

See previous item. (E.R.)

EJIMA, Tatsuhiko, SATO, Yuzuru, YAMAMURA, Tsutomu, TAMAI, Kyoko, HASEBE, Maysayuki, BOHN, M.S. and JANZ, G.J., 1987, Viscosity of the eutectic $Li_2CO_3$-$Na_2CO_3$-$K_2CO_3$ melt: J. Chem. Eng. Data, v. 32, p. 180-182.

ELDERS, W.A. and SASS, J.H., 1987, An overview of the SSSDP (abst.): EOS, v. 68, p. 438. First author at IGPP, Univ. of California, Riverside, CA 92521.

An introduction to a program of papers on the SSSDP, including some pertinent fluid inclusion data. (E.R.)

ELMORE, R.D. and CRAWFORD, L.D., 1987, Origin of magnetizations in authigenic magnetite: Evidence for a relationship with hydrocarbons (abst.): EOS, v. 68, no. 16, p. 298. Authors at Sch. Geol. & Geophys., Univ. Oklahoma, Norman, OK 73019.

Paleomagnetic, rock magnetic, petrographic, and geochemical studies of hydrocarbon-saturated speleothems in the Ordovician Kindblade Formation in southern Oklahoma indicate there is a relationship between hydrocarbons and a chemical magnetization that resides in magnetite. The speleothems, which are composed of light and dark calcite bands, occur in caves of karst origin. Vertebrate fossils interbedded with the deposits indicate they are Permian in age. The dark bands contain primary hydrocarbon inclusions;

the hydrocarbons are not extensively biodegraded. The dark calcites possess over an order of magnitude stronger magnetization than the lighter bands which are too weak to yield stable decay during demagnetization. AF and thermal demagnetization of specimens of the dark bands reveals a Permian direction of magnetization (decl = 159, incl = 3, k = 29, α95 = 5, n = 29). The results of rock magnetic experiments, and the fact that most maximum unblocking temperatures are below 580°C, suggest that this dominant component resides in magnetite. In some specimens stable decay to 620°C indicates the presence of a weak component residing in hematite.

The presence of authigenic magnetite spheres in magnetic extracts of the dark calcites supports a chemical origin for the magnetization. Shallow burial depths probably eliminate the possibility of a thermoviscous origin. The occurrence of primary hydrocarbon inclusions suggests that hydrocarbons seeped into the caves during precipitation of the speleothems and were trapped in the calcite crystals. The relationship between intensity of magnetization and hydrocarbon abundance leads us to propose that chemical conditions created by the hydrocarbons caused precipitation of authigenic magnetite and acquisition of the associated chemical remanence. (Authors' abstract)

ELSENHEIMER, Don , VALLEY, J.W. and HANSEN, E.C., 1987, Petrology of granulite facies marbles and calc-silicate in Sri Lanka: Evidence for complex fluid histories (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 655. First author at Dept. Geol. & Geophys., Univ. Wisconsin, Madison, WI 53706.

The 15,000 km$^2$ granulite facies terrain of Sri Lanka is divided into the central Highland and Southwestern Series, and is composed of marbles and calc-silicates interbedded with pelitic and quartzo-feldspathic to mafic gneisses. At P = 6 kb, the crystallization of Di requires either slow cooling or an influx of a $CO_2$-rich fluid at T >650°C. Secondary fluid inclusion trails which cut Wo crystals to form Cc + Qtz support such an influx. In contrast, the original formation of Wo required infiltration of large quantities of $H_2O$-rich fluids. Therefore, a single, homogeneous fluid source cannot explain the protracted periods of peak and retrograde metamorphism demonstrated by these rocks. (From the authors' abstract)

ENGLAND, W.A., MACKENZIE, A.S., MANN, D.M. and QUIGLEY, T.M., 1987, The movement and entrapment of petroleum fluids in the subsurface: J. Geol. Soc., London, v. 144, p. 327-347.

ENGLISH, P.J., 1981, Gold-quartz veins in metasediments of the Yellowknife Supergroup, Northwest Territories: A fluid inclusion study: M.S. thesis, Univ. Alberta.

Samples from Au-quartz vein occurrences in the metasediments of the Yellowknife Supergroup, NWT, were studied using petrography, microthermometry, crushing and scanning electron microscopy.

P fluid inclusions indicate that the original mineralizing fluid had a salinity of about 5 wt% NaCl eq. and Th give a minimum Tf of 250-280°C. Th from veins within medium grade metasedimentary rocks are slightly but distinctly higher than those for the veins in low grade rocks. The mineralizing fluid was a $CO_2$-rich sodium chloride brine, with a trace amount of methane.

Published oxygen isotope data give a Tf of 360°C. This difference may be accounted for by a P correction for ~1 kbar (100 MPa). However the existence of 2 P inclusion populations, one $CO_2$-rich the other $H_2O$-rich, indicates that "boiling" (unmixing) may have occurred in which case no P correction is required.

The nature of the Au-transporting agent is not known; the hydrothermal fluid contained both chloride and sulphide components.

S inclusions provide information on a later stage hydrothermal fluid of moderate to high salinity (~10-30 wt. % NaCl eq.) and probably low T (mean Th ~140°C); minor Au remobilization occurred during this stage. This fluid was NaCl-rich and contained minor amounts of calcium, carbonate and sulphate.

This study suggests that petrography and microthermometry of fluid inclusions and oxygen isotope analysis of quartz are insufficient to distinguish auriferous quartz veins from barren quartz veins.

The data from this study do not conclusively support either a magmatic-hydrothermal or a metamorphogenic origin for the veins, but the author favors the latter. (From the author's abstract)

ENJOJI, M., 1987, Ancient hydrothermal activity around the Takatori tungsten mine, central Japan (abst.): Mining Geol., v. 37, no. 1, p. 75-76 (in Japanese).

ENJOJI, M. and KOMURO, K., 1987, Fluid inclusions in kuroko ores from the Ezuri mine (abst.): Mining Geol., v. 37, no. 1, p. 61 (in Japanese).

ERICKSON, C.L. and BODNAR, R.J., 1987, Determination of critical properties of aqueous solutions using synthetic fluid inclusions (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Authors at Dept. Geol. Sci., Virginia Polytech. Inst. & State Univ., Blacksburg, VA 24061.

Relatively few data are available on the critical properties of aqueous solutions, owing to the difficulty of obtaining this information using conventional experimental techniques. In particular, the location of the critical point must be inferred from external physical measurements because the system cannot be monitored optically at the high T and P involved. Synthetic fluid inclusions, however, provide a relatively simple and highly accurate technique for determining these parameters, because the inclusion, which contains a fluid of the critical density, is viewed through a microscope during heating. The Th, which is identical to the critical T of the fluid, is measured using a thermocouple, and critical behavior at Th is confirmed by monitoring the mode of homogenization optically. Furthermore, the P-T trend of the critical isochore is easily determined from these data because (1) isochores are defined by straight lines over relatively small intervals of T and P and (2) the end points of this line are defined by the known formation conditions of the inclusion and the measured critical point.

To test the applicability and accuracy of this technique, the critical point of pure $H_2O$ has been determined using synthetic fluid inclusions, and the results compared to the known critical point for pure $H_2O$ (374°C, 220 bars). Pure $H_2O$ synthetic fluid inclusions were trapped at 800°C and 1350 bars, and the homogenization mode and T of these inclusions determined using a heating-freezing stage. According to published PVT data for $H_2O$, inclusions formed at these conditions should contain $H_2O$ with a density equal to the critical density, and this was confirmed by the fact that the inclusions homogenized by critical behavior at 374.2 ± 0.2°C. The intersection of the critical isochore (obtained from published data) with this measured T defines a critical P of 220 ± 5 bars, and these tests verify that synthetic fluid inclusions may be used to determine the critical properties of aqueous fluids. Results of 5 wt.% NaCl fluids indicate that the critical point lies between ~410-430°C, and that the critical isochore lies above 700°C and 1200 bars. Results of 9 and 15 wt.% NaCl solutions establish critical T of 452°C and 517°C, respectively. (Authors' abstract)

ERLINGHAGEN, K.-P., 1987, Microthermometric studies of fluid inclusions of the siderite ore veins in the Siegerland-Wied district (abst.): Fortschritte der Mineralogie, Bd. 65, Bhf. 1, p. 44 (in German). Author at Inst. Geol. & Dynamics of Lithosphere, Univ. Göttingen, FRG.

The results of microthermometric studies of fluid inclusions in siderite, quartz, sphalerite, calcite, barite and ankerite (for paragenesis see Fenchel et al. 1985, Geol. Jb., Reihe D, v. 77, 520 pp., Hannover) indicate that the phases of hydrothermal mineralization in ore veins in the Siegerland-Wied district are connected with three systems of solutions, which are discernible by changes of T and composition of mineral-forming solutions. During the Variscan period of mineralization (initial phase through the main phase to galena stage of the sulfide phase), a magmatic-hydrothermal solution system ($NaCl-MgCl_2-H_2O \pm CO_2$) was active, showing an evolution toward higher salinities and lower T (...). At the end of the sulfide phase, the late-Variscan rejuvenation starts with calcite-I and barite-I. Low salinities and increasing T (Quartz-V 330°C) indicate a meteoric-hydrothermal solution system ($NaCl-H_2O$). The post-Variscan phases of mineralization developed from highly saline, deeply circulating waters from the country rock formations ($NaCl-CaCl_2-H_2O \pm KCl \pm MgCl_2$) at T <180°C. Cathodoluminescence studies of the hydrothermally formed quartz mineralization (Quartz I-VII) also support a multiple stage of mineral formation. (Author's abstract, translated by A.K.)

ERMANOVICS, Ingo, 1987, Saline groundwaters and brines in plutonic rocks of Precambrian shields (abst.): Abstracts, NATO Advanced Research Workshop, Fluid movements, element transport, and the composition of the deep crust, Lindås, Norway, 18-24 May, 1987 (unpaginated).

EUBANK, P.T., SCHELOSKE, J.J., HALL, K.R. and HOLSTE, J.C., 1987, Densities and mixture virial coefficients for wet natural gas mixtures: J. Chem. Eng. Data, v. 32, p. 230-233.

EUGSTER, H.P. and CARMICHAEL, I.S.E., eds., 1987, Thermodynamic modelling of geological materials: Minerals, fluids, melts: Mineralog. Soc. Am. Reviews in Mineralogy, v. 17, approx. 500 pp.

EWERS, G.R., 1987, Geochemical and structural controls of gold mineralization, northeast and northwest Queensland: Bur. Mineral Resources, Geology, and Geophysics [Australia] Yearbook, 1987, p. 79-80.

Includes fluid inclusion studies at Red Dome Au, Etheridge Goldfield, and Pajingo. (E.R.)

EXLEY, R.A., MATTEY, D.P. and PILLINGER, C.T., 1987, Low temperature carbon components in basaltic glasses - Reply to comment by H. Craig: Earth & Planet. Sci. Letters, v. 82, p. 387-390. Authors at Planet. Sci. Unit, Dept. Earth Sci., The Open Univ., Walton Hall, Milton Keynes MK7 6AA, UK.

See Craig, this volume. (E.R.)

FABRICIUS, Johannes 1987a Geochemical investigation of potassium-magnesium chloride mineralization of Zechsten 2 salt, Mors dome, Denmark: Danmarks Geol. Undersogelse, Ser. A, no. 19.

Solid-rich inclusions at 20°C of the $Na-K-Mg-Cl-H_2O$ system, found in euhedral quartz from the top of Zechstein 2 salt in the Mors dome, Denmark, were investigated microthermometrically.

The quartz crystals, all of the long prismatic, slender type, average length of 750 μm, are genetically closely connected to the intercalated clay in the deck halite Na2r.

The inclusions are faceted negative crystals, crystallographically oriented with the host quartz. Carnallite ($KMgCl_3 \cdot 6H_2O$) is the main dm, followed by tetrahydrate ($MgCl_2 \cdot 4H_2O$) and minor sylvite (KCl). Halite (NaCl) is found as grains in suspension in the trapped solutions. The trapped solutions represent melts of carnallite or tetrahydrate saturated with NaCl. The concentrations range from 167 mol $MgCl_2$ + 83 mol $K_2Cl_2$ + 3 mol $Na_2Cl_2$ per 1000 mol $H_2O$ to 250 mol $MgCl_2$ + 5 mol $K_2Cl_2$ + 0 mol $Na_2Cl_2$ per 1000 mol $H_2O$, corresponding to salinities from 52 to 62 wt.%. Tm measured, 170-185°C, and estimated P, 80-110 MPa, are minimum trapping values.

In a few cases highly irregular, "dry" grains of carnallite, containing dissolved high-P gas, were observed to have been trapped.

In this study it is shown that the melting T of carnallite in a closed space, where evaporation is prevented, depends on the prevailing P. It is also shown that high-P gas is dissolved in trapped grains of carnallite or halite, but not in the solution.

Finally, the results lead to the proposal of a model, related to time and space, of the metamorphism of an original carnallitic potash bed and subsequent K-Mg-Cl mineralization of the deck halite. The original paragenesis kieserite-halite-carnallite, sedimented in the deeper parts of the basin, was altered to the present kieseritic hard salt by means of progressive geothermal metamorphism from Upper Triassic to Lower Cretaceous. The hanging wall of the potash bed, the deck halite, was mineralized by the metamorphic solutions, squeezed out from the potash bed, possibly during the diapiric penetration phase in Upper Jurassic-Lower Cretaceous. (Authors' abstract)

See also Fabricius, 1984a,b (Fluid Inclusion Research, v. 17, 1984, p. 90, and v. 18, 1985, p. 112). (E.R.)

FABRICIUS, J., 1987b Natural Na-K-Mg-Cl solutions and solid derivatives trapped in euhedral quartz from Danish Zechstein salt: Chem. Geol., v. 61, no. 1/4, p. 95-112.

Full paper for abstract in Fluid Inclusion Research, v. 18, p. 91, 1985. (E.R.)

FABRICIUS, J. and ROSE-HANSEN, J., 1987, Pressure dependent melting of carnallite, $KMgCl_3 \cdot 6H_2O$, in a closed space (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 41. First author at Geol. Survey of Denmark, 31 Thoravej, DK-2400 Copenhagen NV.

The evaporite mineral carnallite, $KMgCl_3 \cdot 6H_2O$, melts incongruently at 167.5°C under atmospheric P in a closed space, where evaporation is prevented.

The incongruent melting results in a melt consisting of $MgCl_2 \cdot 6H_2O \cdot 0.25$ KCl plus solid KCl.

Fluid inclusions of the Na-K-Mg-Cl-$H_2O$ system with daughter carnallite, trapped in quartz crystals from Danish Zechstein 2 salt, were studied by means of microthermometry.

The liquid shrinkage vapor bubble disappears during heating at a lower temperature ($T_b$) than the melting/dissolving temperature ($T_m$) of the carnallite component.

The P built-up in the inclusion at $T_m$ is calculated from the equation $P = (T_m - T_b)dP/dT$ MPa, where dP/dT ranges from 1.04 MPa/°C to 1.08 MPa/°C, depending on the salinity and $T_m$, i.e., Th in fluid phase.

The P-dependent melting curve up to ~150 MPa can be expressed by the formula $T_m$ °C = 167.5°C + (dT/dP)P °C, where dT/dP = 0.1°C/MPa.

Small cores, 10 x 2.5 cm, of the salt mentioned above, containing disseminated subhedral single crystals of carnallite, were subjects for autoclave studies.

Thick sections (1 mm) of the autoclaved cores were examined under the microscope in order to observe the reaction of the grains of carnallite. The grains were compared with grains in thick sections from the same core before autoclaving.

Melted grains are easily identified: release of a small amount of solution; polycrystalline appearance; release of high P gas, dissolved in the original grain of carnallite. As a rule, also the mineral bischoffite, $MgCl_2 \cdot 6H_2O$, forms after melting of carnallite.

The mean dT/dP value is calculated to 0.10°C/MPa in the interval 0.08-0.12°C/MPa, with the uncertainties ±2°C and ±1 MPa. (Authors' abstract)

FACCHINELLI, A., GIGLI, P. and MASOTTI, A., 1986, New data and consideration on the pyrite-base metal sulfide deposit of Campiano, Grosseto (abst.): Rendiconti Soc. Ital. Mineral. Petrol., v. 41, p. 405 (in Italian). First author at Dipart. di Sci. della Terra, Univ. Torino, Torino, Italy.

Partitioning of Cd between sphalerite and galena and Th of two-phase fluid inclusions appear to indicate T of 300-350°C. (From the authors' abstract; translated by P. Lattanzi)

FAHLQUIST, Lynne and POPP, R.K., 1987, The effect of sodium chloride on nickel solubility in supercritical hydrothermal fluids (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 151. Authors at Dept. Geol., Texas A&M Univ., College Station, TX 77843.

The solubility of NiO was determined in both NaCl-free and NaCl-bearing systems at 550°-750°C and 2 kbar. The solubility of NiO increases significantly with increasing content of NaCl in the fluid. (From the authors' abstract)

FAILL, R.T., 1987, Tectonics and structural geology of the central Appalachians in Pennsylvania: Recent developments and future prospects (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 13. Author at Pennsylvania Geol. Survey, P.O. Box 2357, Harrisburg, PA 17120.

Sub-greenschist metamorphism has been recently delineated in the foreland by applications of coal reflectance, conodont alteration colors, fluid inclusions, fission tracks in apatites, and strontianite compositions. Perhaps the apparent deep burial of the Anthracite region indicated by this data reflects an Alleghanian overthrust of the Reading Prong nappes. (From the author's abstract)

FAIZIEV, A.R. and ISKANDAROV, F.Sh., 1987, The physico-chemical conditions of fluorite crystallization in carbonatites (on the example of Pamirs) (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 43-44. Authors at The Tadjik State Univ., Dushanbe, USSR.

The carbonatite mineralization type unites the rare earth-barite-fluoritic, the rare earth-sulphide-carbonate-fluoritic and the phlogopite-apatite-carbonate-fluoritic mineral types. Inclusions of solutions-melts with high density have been found in fluorites from carbonatites. We conclude that they crystallized in specific conditions, sharply differing from physico-chemical formation parameters of fluorite or other genetic types not only in the Pamirs, but and other regions of the Middle Asia.

The initial [i.e., primary?] inclusions in fluorite for the manifestations of rare earth-sulphide-carbonate-fluoritic type were found to be polyphase, crystal-gaseous-liquid ones. They are characterized by the abundance of dms (halides, carbonates, sulphates), up to 8-10 in one inclusion. Dms make up ~70-80 vol.%, aqueous solution - 15-20%, liquid $CO_2$ - 5-10% and gaseous phase up to 5%. Th was 620-700°C, and calculated Pt is

~2.2-3.0 kbar. The inclusion fluids have >70-75 wt.% of Na-K-Ca chlorides with considerable carbon dioxide.

The two kinds of initial inclusions occur in fluorites from rare earth-barite-hematite-fluoritic type: crystal-liquid and crystal-gaseous-liquid. Isotropic (1-2) and anisotropic (2-3) dms occupy <80 vol.%. The liquid phase make up to 15-25% plus L (15-25) and G (0-15). Th = 340-625°C and P = 1-4 kbar. The fluids contain 60-75 wt.% of chlorides of alkalies and alkaline-earths.

In the phlogopite-apatite-carbonate-fluoritic type the fluorite mineralization had been formed at lower T 520-550°C and P 1.05-1.65 kbar, from less concentrated (40-70 wt.%) fluids, mostly Cl-Ca. The initial inclusions are crystal-liquid, polyphase gaseous-liquid and essentially gaseous, composed of 30-60% gas, 30-50% solid and 25-30% liquid. In all inclusions solid dms are present (up to 6-7), with anisotropic ones dominant.

Therefore in carbonatites in the Pamirs the fluorite crystallization is assumed to be at high T 320-700°C an P 1-4 kbar, from highly-concentrated Cl-Na-K-Ca solutions, and randomly from solutions-melts, containing up to 75% of salts and more.

Bitumens have been found as fluid inclusions in fluorites from the Pamirs carbonatite, syngenetic to mineral-host. Its contents varies from 40 to 65 mg/kg (average 53 mg/kg) that more higher then in fluorites from the manifestations of other genetic types[sic]. (From the authors' abstract)

Note: This paper was not presented at the meeting. (E.R.)

FALLICK, A.E. and BARROS, J.G., 1987, A stable-isotope investigation into the origin of beryl and emerald from the Porangatu deposits, Goias State, Brazil: Chem. Geol. (Isotope Geosci. Sec.), v. 66, p. 293-300. First author at Isotope Geol. Unit, S.U.R.R.C., East Kilbride, Glasgow G75 0QU, Scotland.

The oxygen isotopic composition ($\delta^{18}O$ relative to SMOW) of a suite of 12 beryls and emeralds from the Porangatu emerald deposit, Brazil, is relatively constant at 11 ± 1‰. There is no clearly discernible trend with mineral color (and so chromophore content), which might indicate a systematic change in the physico-chemical conditions of the precipitating fluid. Water released from the minerals above 120°C ($H_2O^+$) has two components. Above 800°C a constant amount of water 2.0 ± 0.1 wt.% with a remarkably uniform hydrogen isotope composition δD = -39 ± 5‰ relative to SMOW is found; this is believed to be $H_2O$ trapped in the crystallographic channel of the mineral. In contrast, below 800°C the relatively small amount of water released - typically 0.3 wt.% - has a wide range in δD (-156 to -62‰) and is believed to represent fluid-inclusion water. Taking the channel water δD and silicate $\delta^{18}O$ as reflecting formation conditions an origin for beryl and emerald from magmatic or metamorphic fluid is inferred. The isotopic composition of the inclusion fluids is always depleted in D relative to this putative original formation fluid and may reflect a different origin, such as from hydrogen exchange with organic constituents or HF, or isotope fractionation associated with separation of a vapor phase. (Authors' abstract)

FAN, Yongxiang and ZHOU, Qunhui, 1987, On ore-forming geochemical characteristics and mechanism of gold ore deposit in Jiaojia, Shandong Province: Earth Sci., Jul., v. 12, no. 4, p. 414-424 (in Chinese; English abstract). Authors at Wuhan College of Geol., Wuhan 430074, PRC.

The authors consider that Au moves in the form of chloride or sulphur complexes, and the fluid is of $Ca^{2+}$-$HCO_3^-$ type, the T is 340-200°C, and the comparative reduction being weak acid[sic]. The ore-formation is characterized by a long-term evolution and multiple superposed enrichments. (From the authors' abstract)

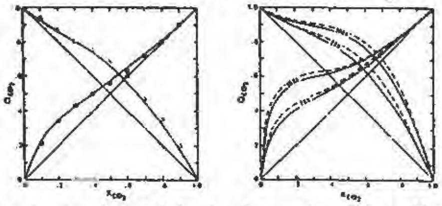
FARVER, J.R. and GILETTI, B.J., 1987, Oxygen diffusion in diopside and the timing of $^{18}O$ depletion in a hydrothermal circulation system, Cuillins Gabbro Complex Isle of Skye, Scotland (abst.): EOS, v. 68, p. 1528.

FAYOS, José, WATKIN, D.J. and PEREZ-MENDEZ, Mercedes, 1987, Crystal structure of the apatite-like compound $K_3Ca_2(SO_4)_3F$: Am. Mineral., v. 72, p. 209-212. Authors at Chem. Crystal. Lab., 9 Parks Rd., Oxford OX1 3PD, England.

Worth considering as a possible dm? (E.R.)

FEI, Y. and SAXENA, S.K., 1987, Fluid mixtures at crustal pressures and temperatures (abst.): EOS, v. 68, no. 16, p. 451. Authors at Dept. Geol., Brooklyn College, Brooklyn, NY 11210

Interaction energy parameters ($W_{ij}$) for polar-polar and polar-nonpolar mixtures of gases ($H_2$, $O_2$, $CO_2$, $H_2O$, CO and $CH_4$) have been calculated using the Kihara and Stockmayer potentials respectively. Using the mixing rules of averaging for dimensional properties and of geometric mean for potential parameters, $W_{ij}$ data are calculated for binary mixtures. The interaction parameters are used with the van Laar solution model and are found to reproduce the experimental binary mixing data well. The mixing model has been tested against experimental phase equilibrium data on solid-fluid reactions. Examples of some applications in the system Mg-Si-O-H, Fe-O and C-H-O are presented.



Figures show calculated activities in the $H_2O$-$CO_2$ fluid at 500°C and 2 kbar (the symbols represent experimental data), and at 400°C and 2 and 10 kbar (dashed lines from the HSMRK model). (Authors' abstract)

FEIN, J.B. and WALTHER, J.V., 1987, Calcite solubility in supercritical $CO_2$-$H_2O$ fluids: Geochimica Cosmo. Acta, v. 51, p. 1665-1673. Authors at Dept. Geol. Sci., Northwestern Univ., Evanston, IL 60201, USA.

An extraction-quench apparatus was used to measure calcite solubilities in supercritical $CO_2$-$H_2O$ mixtures. Experiments were conducted at 1 kbar and 2 kbar, between 240°C and 620°C, and from $X(CO_2) = .02$ to $X(CO_2) = .15$ in order to determine the solubility behavior as a function of P, T, and $CO_2$ content. The results indicate that calcite solubilities under these conditions behave similarly to previously investigated calcite solubilities at lower P and T. (From the authors' abstract)

FELDMAN, M.D. and KNAUTH, L.P., 1987, Paleoatmospheric gases in brine inclusions in halite (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 661. Authors at Dept. Geol., Arizona State Univ., Tempe, AZ 85287.

24 samples of bedded salt from the Permian San Andres Formation, Palo Duro Basin, Texas, contain from 0.6 to 13 $cm^3$ STP of trapped gas per kilogram of salt. The gas is composed primarily of $CO_2$, $N_2$, $O_2$, in order of decreasing abundance. Methane is abundant in only one specimen. $CO_2$ is greater than two orders of magnitude more abundant in the salts than in the modern atmosphere, suggesting that the gases do not represent contamination by modern air introduced during storage or handling. The large relative abundance of $CO_2$ in the gas is consistent with the disproportion-

ately large solubility of $CO_2$ in water relative to other atmospheric gases, an indication that the gases are dissolved in brine inclusions.

The $CO_2$ content of the salt is variable but high, comprising from 60 to 97% of the total gas. $\delta^{13}C$ values of the $CO_2$ range from -9 to -2‰ suggesting that the $CO_2$ was not derived by decomposition of organic matter in the salt.

Because of our analytical technique, we cannot rule out the possibility that some of the $CO_2$ is derived from trace amounts of carbonate minerals in the salt. On a plot of $CO_2$ content versus $N_2 + O_2$ at $CO_2/(N_2 + O_2) = 1.8$. This line passes through the origin of the diagram. Data lying on or near the minimum are interpreted as uncontaminated paleoatmospheric gases.

Both petrographic and stable isotope data suggest that the brine inclusions in these salts contain well preserved Permian-age evaporite fluids. With further improvements it may be possible to use the composition of dissolved paleoatmospheric gases in brine inclusions as a means of directly measuring the composition of the ancient atmosphere, thereby placing constraints on proposed models for atmospheric evolution. (Authors' abstract)

FENG, Shuzhuang, 1987, Multistage and patterns of gold enrichment in the paleovolcanic hydrothermal gold deposit in Zhong-Ao, Zhejiang Province: Earth Sci., Jul., v. 12, no. 4, p. 397-404 (in Chinese; English abstract). Author at Wuhan College of Geol., Wuhan 430074, PRC.

The ore deposit occurs in Proterozoic epimetamorphic rocks, and is obviously controlled by faults. Mineralization is multistage, and enriched mainly in hydrothermal epoch, with superimposed Au enrichment. The multistage and patterns of Au enrichment are significant for searching for Au ore-shoots. The deposit belongs to the paleovolcanic epithermal type. (Author's abstract)

FERGUSON, J., 1987, A possible role for light hydrocarbons in Pb/Zn mineral exploration: Min. Mag., v. 51, p. 527-533.

FERRY, J.M., 1987, Metamorphic hydrology at 13-km depth and 400-550°C: Am. Mineral., v. 72, p. 39-58.

FILLMANN, K. and BANERJEE, A., 1987, Emeralds - chemical composition, inclusions, structure (abst.): Fortschritte der Mineralogie, Bd. 65, Bhf. 1, p. 48 (in German). Authors at Univ. Mainz, FRG.

The mica-bearing, especially phlogopite-bearing emeralds from Brasilian, African, Austrian and Russian deposits were studied. (...) Phlogopite/biotite was found as crystal inclusions in all specimens, which at least partly are trapped syngenetically by growth of the emeralds. Moreover crystal inclusions of amphibole, muscovite, margarite, chlorite, talc, feldspar [i.e., alkali feldspar? A.K.], plagioclase, carbonate, quartz, apatite and ores were found (identification by electron microprobe). Microscope studies of orientation of these inclusions suggest the syntectonic growth of emeralds in the parent rocks. (From the authors' abstract, translated by A.K.)

FISHER, R.S. and HOVORKA, S.D., 1987, Relations between bromide content and depositional processes in bedded halite, Permian San Andres formation, Palo Duro Basin, Texas: Carbonates & Evaporites, v. 2, no. 1, p. 67-82. Authors at Bureau Econ. Geol., The Univ. Texas at Austin, University Station, Box X, Austin, TX 78713-7508.

Geochemical data, stratigraphic mapping, and textural relations with bedded halite in the Permian San Andres Formation, Palo Duro Basin, Texas Panhandle, were integrated to determine environments of deposition and alteration and to evaluate influences on the amount of bromide in halite.

Four factors control the bromide concentration of bedded halite. First, samples that contain large amounts of mudstone have anomalously high bromide concentrations, reflecting bromide in cements or intergranular fluids. Second, highly irregular bromide-versus-depth profiles record continual alteration of parent brine and interruptions of halite precipitation in a broad, shallow brine pool. General vertical trends in bromide content record large-scale lateral migrations of depositional environments over time that result in varying proportions of first-cycle marine, second-cycle marine, and second-cycle meteoric evaporite brine. Third, lateral variations in the bromide content of correlative samples from different geographic positions in the basin reflect the amount of primary marine halite, recycled marine halite, and recycled meteoric halite in the evaporite environment. Finally, similar bromide concentrations in texturally distinct samples indicate that most halite precipitated in a marine-dominated evaporite environment in which alteration occurred syndepositionally. Patterns in the bromide content of halite samples augment interpretations based on detailed statigraphic mapping and provide sedimentologic information that is not available from other data sources. (Authors' abstract)

Of pertinence to the interpretation of the many Br analyses of fluid inclusions from halite. (E.R.)

FLUET, D.W., 1986, Genesis of the Deer Trail Zn-Pb-Ag vein deposit, Washington, U.S.A.: MS thesis, The University of Alberta.

See next item. (E.R.)

FLUET, D.W., CHANGKAKOTI, A., MORTON, R.D., GRAY, J. and KROUSE, H.R., 1987, The genesis of the Deer Trail Zn-Pb-Ag vein deposits, northeast Washington, U.S.A.: Evidence from fluid-inclusion and stable-isotope studies: Can. J. Earth Sci., v. 24, p. 1715-1726. First author at Dept. Geol., Univ. Alberta, Edmonton, Alta., Canada T6G 2E3.

The Zn-Pb-Ag-bearing vein deposits of the Deer Trail mine, northeastern Washington, U.S.A., are hosted by Beltian metasediments that have been intruded by the Jurassic-Cretaceous Loon Lake granitoid batholith.

Vein infilling took place in three stages: pre-ore, ore, and post-ore. Fluid inclusion studies revealed Th and salinities of ~300°C and 6.5-8.5 wt.% NaCl eq., respectively, for the pre-ore stage; 250-150°C and 4-7.5 wt.% NaCl eq. for the ore stage; and <150°C and 3 wt.% NaCl eq. for the post-ore stage. The calculated $\delta^{18}O$ values of the hydrothermal fluids and $\delta D$ values of fluid inclusion waters were +8 to +11‰ (SMOW) and -128 to 134‰ (SMOW), respectively, for the pre-ore stage; 0 to 10‰ and -89 to -143‰ for the ore stage; and 0 to -5‰ and -139‰ for the post-ore stage. The $\delta^{34}S(\Sigma S)$ of the hydrothermal fluids was ~+10‰ (CDT).

The results provide insight into the evolution of a geothermal system dominated by meteoric waters and driven thermally by the cooling batholith. The chemical and isotopic compositions of the veins were influenced by chemical reactions and isotope exchange of the hydrothermal fluids with the Precambrian metasedimentary rocks. (Authors' abstract)

FOLEY, N.K., BARTON, P.B., BETHKE, P.M. and DOE, B.R., 1987, The isotopic composition of ore lead of the Creede mining district and vicinity, San Juan Mountains, Colo. (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 275.

FOLEY, N.K., BETHKE, P.M. and RYE, R.O., 1987, Pseudosecondary fluid inclusions in shallow ore-forming environments: Clues to interpreting a dynamic pressure-temperature regime (abst.): American Current Research on Fluid

Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Authors at U.S. Geol. Survey, National Center, MS 959, Reston, VA 22092.

PS inclusions commonly are assumed to contain the same fluid as P inclusions because they form during the growth of crystals and, therefore, often are lumped with P inclusions when interpreting fluid inclusion data. In fact, this assumption may be wrong in many cases (particularly for shallow ore deposits) and may lead to the loss of much potential information. Our work shows that PS inclusions in quartz can yield important information on the dynamic P-T regime of shallow ore bodies because quartz is susceptible to thermal cracking in near-surface environments. Detailed study of PS inclusions can be used to identify the role of ground water in shallow ore bodies and, when combined with data from P inclusions, may help to elucidate the role of different fluids in such processes as alteration, mixing, conduction, and boiling.

The study of Foley and others (1982, GSA Abs., v. 14, no. 7) is a good example of the use of PS inclusions to understand the changing P-T conditions in a near-surface ore environment. In the Creede district, Colo., they identified ground water that was trapped in PS inclusions in healed microfractures in quartz. Striking contrasts in textures, salinity, and isotopic composition between PS and P inclusions enabled them to verify the existence of fresh ground water overlying the deeply circulating ore-forming fluid. The PS inclusions recorded a different event than did the P inclusions and, because of this, proved to be important to the interpretation of the hydrology of the Creede system. Bethke and others (1973, GSA Abs., v. 5, no. 7) previously had shown that the ore fluids were largely meteoric in character and Steven and Eaton (1975, E.G., v. 70) had suggested that ascending and descending waters possibly had mixed in the vicinity of the ore zone. Hayba (1984, GSA Abs., v. 16, no. 6) and Robinson and Norman (1984, E.G., v. 79) quantified this interpretation by using enthalpy-salinity trends for P inclusion data. The PS inclusion data demonstrate the existence of overlying ground water and document changes in the hydrologic regime that allowed abrupt incursions of overlying ground waters into the ore zone. The incursions are interpreted to have resulted from the rapid downward displacement of the interface between the ore-forming brine and the overlying fresh ground water.

Another example illustrating the effect of thermal cracking of quartz in a regime involving a hot convecting fluid recharged by cooler surficial water has been proposed by Bargar and others (1985, Geology, v. 14), for the Lower Geyser Basin, Yellowstone National Park, suggested that cracking of quartz was occasioned by lowering of the water table due to glacial decline and the resultant incursion of cooler waters into deeper levels. Subsequent healing trapped highly dilute solutions in PS inclusions.

The range of conditions under which quartz will crack as a result of thermal shock and the conditions under which the fractures reheal has been explored in laboratory experiments. Studies of synthesized fluid-inclusion textures, following Sterner and Bodnar (1984, GCA, v. 49), together with Creede inclusion data, suggest that healing of the crystals and trapping of the low-salinity fluids was fairly rapid in the range 190-270°C. Continuing studies of the textures of rehealed quartz are underway to evaluate possible changes in inclusion character that are recorded by multiple generations of fluid inclusions in a shallow P-T ore environment. (Authors' abstract)

**FORBES, P., LANDAIS, P., PAGEL, M., and MEYER, A., 1987, Thermal evolution of the Guezouman formation in the Akouta uranium deposit (Niger) (abst.): Terra cognita, v.7, p.343. Authors at CREGU,**

Vandoeuvre-lès-Nancy, France.

Fluid inclusions from the Akouta U deposit have been studied in pre-ore stage minerals, as quartz overgrowths or barite, and in ore stage minerals, as dolomite or sphalerite. The data obtained (Tm and Th respectively) on barite ≈ -6°C, ≈ 80°C; sphalerite ≈ -7°C, ≈ 110°C; ≈ -15°C, ≈ 140°C; ≈ -20°C, ≈ 95°C; and dolomite, ≈ -20°C, ≈ 120°C can be explained by a sedimentary basin brines circulation which has a significant role in the ore formation. However the Th obtained in pre-ore quartz overgrowths are not consistent with the inferred depth of burial.

These T are related to a low-T hydrothermalism associated with tectonic events. Td of the ore stage fluid inclusions indicate that this hydrothermalism is a pre-ore stage event. A comparison with the organic matter maturation suggests that it is a short duration pulse.

The spatial variations of T have been evaluated by studying fluid inclusions in quartz overgrowths and dolomite sampled eastward from the deposit to the sedimentary basin edges. A decrease in T and salinity is shown for the pulse (Tm ≈ -0.5°C, Th ≈ 145°C, in quartz overgrowths from 20 km eastward) and the ore stage fluids (Tm ≈ -10°C, Th ≈ 105°C, in dolomite from 20 km eastward).

A thermal evolution is proposed for the ore host-formation in the deposit area and in the barren East zones, according to data obtained from organic matter. (From the authors' abstract)

FÖRSTER, H.-J., 1986, Micas as indicators of the fugacities of some volatile components in magmatic-hydrothermal systems: The Variscan postkinematic granites of the Erzgebirge Mts., G.D.R.: Geol. Zbornik-Geol. Carpathica, v. 37, no. 6, p. 667-679. Author at Central Inst. Physics of Earth, Acad. Sci. G.D.R., 1500 Potsdam, Telegrafenberg, GDR.

The paper deals with the composition of the fluid phase in terms of the fugacities of oxygen and the fugacity ratios of halogen acids (HF, HCl) to water in the time of crystallization of the Variscan postkinematic Older (OG) and Younger granites (YG) of the Erzgebirge Mts.

The data calculated on the basis of the chemical composition of tri-octahedral micas indicate that these two granitic complexes crystallized under a distinct fluid regime, especially with regard to $fO_2$ and relative HF fugacity. This partly explains the different element associations in the granite-related ore deposits. (From the author's abstract)

FOURNIER, R.O., 1985, Silica minerals as indicators of conditions during gold deposition: USGS Bull. 1646, p.15-26.

FOURNIER, R.O., 1987a Nonequilibrium three-phase flow during testing of the Salton Sea Scientific Drill Hole - Implications regarding interpretation of fluid inclusions in natural hydrothermal systems (abst.): EOS, v. 68, p. 1537. Author at USGS, Menlo Park, CA 94025.

During flow testing of the Salton Sea Scientific Drill Hole, a brine containing about 25 wt. % total dissolved solids was produced from a reservoir at about 305°C. Pressure (P) and temperature (T) were measured near a series of sampling ports located along a horizontal flowline equipped with orifice plates to reduce the P and T in increments between the ports. The P and T at each port except one, the first port, were appropriate for the salinity of the particular brine that was in equilibrium with steam at that point along the flow path. At the first port, which was closest to the wellhead, the P (3.27 MPa) and T (235°C) were appropriate for equilibrium between dilute liquid water and steam, but the P was too great for brine to flash at the measured T. As P decreases and flashing progresses with T decreasing from 305° to about 240°C, the enthalpy of the steam fraction must increase. Evidently, at some point, the enthalpy of the steam increased by condensation of a small amount of pure water that did not readily mix with the denser brine. Where horizontal flow as occurring within the surface piping, a thin layer of boiling, dilute water came to float on top of much denser brine. As long as this dilute water phase persisted, P and T were appropriate for flashing of pure water. Similar nonequilibrium three-phase flow might be induced in natural hydrothermal systems where saline waters are present and boiling occurs above 240°C. Consequently, highly saline and dilute liquid fluid inclusions might be simultaneously trapped without the need for alternating hydrologic conditions of changing sources of fluids. (Author's abstract)

FOURNIER, R.O., 1987b Conceptual models of brine evolution in magmatic-hydrothermal systems: U.S. Geol. Survey Prof. Paper 1350, p. 1487-1506.

The depth of intrusion of a magmatic body is important in regard to brine evolution and to the type and intensity of hydrothermal alteration that is likely to be associated with that intrusion. At a depth of intrusion of 6-7 km, and in the absence of evaporite deposits somewhere in the section, nonmagmatic water is not likely to be converted to brine unless there are special circumstances, such as repeated magmatic intrusions and repeated fracturing of very hot rock. In contrast, brine is very likely to form from nonmagmatic water where the depth of intrusion comes within about 3-4 km of the surface, and dilute water is heated to above about 400-450°C.

When pore-fluid pressures are controlled by hydrostatic conditions, magmatic waters will evolve to highly saline brines at depths less than about 10-12 km, irrespective of the initial concentrations of salt and water dissolved in the magma. Dilute hydrothermal fluids of meteoric origin and mixtures of meteoric water and condensed magmatic gas (steam) are likely to form convection systems that float upon the more saline and probably hotter magmatic fluid. Double-diffusive convection is likely to result from the temperature and salinity gradients.

Quasi-plastic flow and mineral deposition generally prevent flow of water at hydrostatic pressure through rock at temperatures above 350-450°C. However, where there are steep thermal gradients and a relatively rapid rate of change of stress, such as where magma is rapidly injected from a deep environment into a more shallow environment, brittle deformation of rocks may occur at temperatures in excess of 450°C. Ground water at hydrostatic pressure may flow into and through these fractures and become heated to very high temperatures, possibly flashing in great part to steam with the simultaneous development of a small mass of brine. This situation should persist for only a relatively short time before quasi-plastic flow and mineral deposition limit additional fluid circulation to temperatures below 350-450°C.

A generalized model is presented for the evolution of a hydrothermal system within an oceanic volcano, such as at Hawaii, in which a slowly rising magma reservoir maintains a depth of about 3-4 km beneath the summit as the volcanic edifice builds upon the sea floor. Significant amounts of highly saline brine are likely to be generated from sea water when the magma reservoir rises to within about 4-5 km of sea level. After a volcanic island forms, fresh water may enter the top of the hydrothermal system and float upon the brine. Sulfides are likely to deposit below sea level within the chloride-rich brine portion of the system, but these deposits are not likely to be exposed during subsequent erosion. With continued growth of the volcano above sea level, temperatures and pressures within the hydrothermal system become appropriate for complete evaporation of pore waters adjacent to the rising magma chamber. Sodium sulfate- and sodium carbonate-rich brines form above sea level where steam condenses and sulfur- and carbon-rich gases react with the country rock.

What is generally thought of as supercritical behavior of a fluid (no phase change upon heating or cooling) occurs only at pressures greater than the hypercritical pressure, a pressure great enough to ensure that the gas phase will retain all the salt that was initially dissolved in the liquid phase at a lower temperature. At hydrostatic conditions the hypercritical point for a dilute water containing about 2,000 mg/kg total dissolved solids would be at about 700°C at a depth of 4.6 km, and for sea water it would be at about 900°C at a depth of 12.9 km. (Author's abstract)

FOWLER, A.D., JENSEN, L.S. and PELOQUIN, S.A., 1987, Varioles in Archean basalts: Products of spherulitic crystallization: Canadian Mineral., v. 25, p. 275-289. First author at Dept. Geol., The Univ. Ottawa, 770 King Edward St., Ottawa, Ontario K1N 6N5, Canada.

Petrography and geochemistry indicate that the globular structures (varioles) of numerous Archean basalts of the Abitibi Greenstone Belt result from spherulitic crystallization. The distribution of rare earths between the varioles and their mesostases is incompatible with the hypothesis that these rocks represent quenched immiscible liquids. (From the authors' abstract)

FRANCE-LANORD, C., SHEPPARD, S.M.F. and LeFORT, P., 1987, C-O-H isotopic evidence for migration of fluids during the Himalayan reverse metamorphism (abst.): Terra Cognita, v. 7, no. 2-3, p. 136. Authors at Center de Recherches Pétrogr. & Géoch., Vandoeuvre-lès-Nancy, France.

Isotopic compositions of fluid inclusions imply that fluids are (1) heterogeneous for δD, $\delta^{13}C$ and $\delta^{18}O$ (quartz pods) and (2) under partial control of country rock. $CO_2$ content of fluid inclusions increases from low (0%) to high grade zone (40% mol.). Apart from δD variations related to biotite content, isotopic evolutions and fluid compositions are not consistent with in situ devolatilization reactions and a single homogeneous fluid. Interaction of an exotic $CO_2$-rich fluid, with high deuterium content and $\delta^{13}C$ values around -6‰, is proposed. This is probably generated during decarbonatation and oxidation of graphite reactions. (From the authors' abstract)

FRANCIS, K.A. and ATKINSON, W.S., Jr., 1987, Geology and ore deposits of the Caribou mine, Boulder County, Colorado (abst.): Geol. Soc. Am. Abst. with Programs, v. 19, p. 276. Authors at Dept. Geol., Univ. Colorado, Campus Box 250, Boulder, CO 80309.

The Caribou mine, located in the Colorado Front Range, has produced approximately 5 million ounces of silver. The mine is hosted by the Caribou stock, a composite Tertiary intrusion.

Four distinct periods of mineralization have been recognized. The first assemblage is quartz, specular hematite and pyrite. The second, the main stage mineralization, consisted of quartz, dolomite, sphalerite, galena and chalcopyrite. The third period, the precious metal phase, deposited polybasite, chalcopyrite, stromeyerite and jalpaite. Supergene enrichment deposited chalcocite, native silver, chalcopyrite and covellite.

Alteration is zoned outward from the veins, from sericite to kaolinite and montmorillonite. Silicification decreases outward and dolomite is a component of all alteration assemblages. Adularia alteration occurs locally. The altered zones are generally less than 2 meters in width.

Fluid inclusions in samples from the surface to the lowest level suggest minor, localized boiling. All observations were made on primary inclusions in quartz. Homogenization temperatures and salinities increase from 250°C (3 wt. % NaCl) at the surface to 290°C (13 wt. % NaCl) on the 1230-foot level. This represents a minimum paleodepth of 630 meters.

Study of mineral assemblages, FeS content in sphalerite and alteration suggest movement of ore-forming fluids from the pyrite-hematite join to lower $fS_2$, indicated by 3 mole % FeS in sphalerite and the deposition of main stage minerals. Subsequently, increased $fS_2$ permitted precipitation of polybasite, stromeyerite and jalpaite. The deposit has characteristics consistent with models of epithermal deposits developed by Hayba et al. (1985) and Buchanan (1981). (Authors' abstract)

FRANCK, E.U., 1987, Fluids at high pressures and temperatures: Pure & Appl. Chem., v. 59, no. 1, p. 25-34. Author at Inst. Phys. Chem., Univ. Karlsruhe, Kaiserstrasse 12, D7500 Karlsruhe, FRG.

With high P, supercritical fluids can be studied over a very wide range of denisty. Fluids with strongly interacting polar molecules - for example water - are of particular interest. Results for several thermophysical properties are discussed. Density, dielectric constant and self-ionization of water have been determined or predicted to 1000°C. Beyond 20 GPa very hot water appears to become a dense ionic fluid. Dense, supercritical gases are increasingly applied as solvents. P-T-composition diagrams and critical curves to 400°C and 200 MPa have been determined for binary systems of water with helium, argon, xenon, nitrogen, oxygen, methane, carbon dioxide, benzene and others. An equation of state based on a defined molecular interaction model permits computation of such phase diagrams with polar partners and at high T. Extension to ternary systems is possible. Of geochemical interest are the ternary systems water-carbon dioxide-sodium chloride and water-methane-sodium chloride. Within the dense, supercritical aqueous mixtures, oxidation reactions are possible. Steadily burning "hydrothermal flames" have been produced at P to 100 MPa by introducing a slow flow of oxygen into supercritical dense water-methane fluids with excess water at 400°C and above. (Author's abstract)

FRANTZ, J.D., MAO, H.K., ZHANG, Y.G., WU, Y., THOMPSON, A.C., UNDERWOOD, J.H. and GIAUQUE, R.D., 1987, Analysis of fluid inclusions by X-ray fluorescence using synchrotron radiation (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 667. First author at Geophys. Lab., 2801 Upton St., NW, Washington, DC 20008.

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 Beam Line at the National Synchrotron Light Source at Brookhaven National Laboratory was 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 5 to 10 μm 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. The sensitivity of the technique for zinc, the heaviest element analyzed was on the order of a few ppm or less for a 15 µm x 25 µm inclusion lying 80 µm below the surface of the quartz. For an inclusion at a depth of 20 µm, the sensitivity for calcium was found to be approximately 50 ppm. Accurate determination of the number of picograms contained within the inclusions 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. (Authors' abstract)

FRAPE, S.K. and FRITZ, P., 1987, Geochemical trends for groundwaters from the Canadian Shield, in Saline water and gases in crystalline rocks, eds., Fritz, P. and Frape, S.K.: Geol. Assoc. Canada Special Paper 33, 1987, p. 19-38.

FREISLEBEN, B.M., 1983, Fluid inclusion studies in tourmalinized zones of the Kipaila pegmatite, Katanga, Zaire: Thesis for diploma in Geology, Univ. St. Andrews.

Fluid inclusion studies were carried out on quartz from tourmalinized zones and a central quartz zone in the Kipaila granite pegmatite, Katanga, Zaire. Microthermometric measurements show a certain increase of salinity, accompanied by increasing $CO_2$-contents and decreasing average Th from the minor tourmalinized zones in the inner parts of the pegmatite (average Th = 316°C), to the intensely tourmalinized contact with the country rock (average Th = 218°C). Two coexisting groups of inclusions with contrasting average salinities (6.5 eq.% NaCl and >23.3 eq.% NaCl) may be explained as an unmixing of the fluid caused by "effervescence" of $CO_2$. The fluid inclusions in the quartz zone have the highest $CO_2$-concentrations, the lowest Th and the greatest variation in degrees of filling, and salinities. These inclusions in the central quartz zone indicate a final stage of "effervescence." This suggests that the quartz zone developed at a later stage than the tourmalinization process in the evolution of the pegmatite. (Author's abstract)

FRENTZEL-BEYME, K. and BEHR, H.H., 1987, SEM investigations on core material of the preliminary drillings of the continental deep drilling program of the Federal Republic of Germany (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 139. Authors at Inst. für Geol. & Dynamik der Lithosphäre, Goldschmidtstr. 3, D-3400 Göttingen.

Paleo-fluid-systems in lower and middle crustal rock were characterized and classified in the course of first investigations by SEM and SEM-supported methods.

SEM-supported cathodoluminescence and back-scattered electron images are more suited than any other methods to provide further information on deformation and fluid movements in the course of tectono-metamorphic processes.

In addition, microthermometric investigations on selected samples were carried out to correlate fluid chemistry as available from microthermometric data with SEM results. (Authors' abstract)

FREY, M., ed., 1987a Low temperature metamorphism: Chapman & Hall Publ., New York, 351 pp.

This book covers transformations of mineral and organic material in the T range of 150-200 to 350-400°C. (H.E.B.)

FREY, Martin, 1987b The reaction-isograd kaolinite + quartz = pyrophyllite + $H_2O$, Helvetic Alps, Switzerland: Schweiz. Mineral. Petrogr. Mitt., v. 67, p. 1-11. Author at Min.-Petrogr. Inst. der Univ., Bernoullistrase 30, CH-4056 Basel.

The reaction-isograd kaolinite + quartz = pyrophyllite + $H_2O$ has been mapped in the Helvetic Alps, Switzerland, over a distance of about 200 km. Metamorphic conditions at the reaction-isograd were estimated from vitrinite reflectance and fluid inclusion data to be 1.3-2.1 kbar and 240-270°C at a water activity of 0.6-0.8. Textural evidence obtained with a scanning electron microscope suggests that pyrophyllite grew through a dissolution-precipitation process. (Author's abstract)

FREY, M., 1987c, Metamorphic map of the central Alps (abst.): Terra Cognita, v. 7, no. 2-3, p. 91. Author at Min.-Petrogr. Inst., Univ. Basel, Switzerland.

See previous item. (E.R.)

FREZZOTTI, M.L., DE VIVO, B., LIMA, A. and TRIGILA, R., 1987, Peridotite nodules from Oahu island (Hawaii): Fluid inclusion and chemical studies (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 45-46. First author at Dip. Sci. della Terra, Via delle Cerchia 3, 53100 Siena.

Abundant fluid inclusions are present in peridotite nodules in nepheline basalts from Pali (Kolau Range) and Salt Lake Crater, Oahu (Hawaii). Their study has been carried out in order to characterize both fluid composition and history of ascent of nodules. Fluid inclusions have been examined by microthermometry using a CHAIXMECA heating and freezing stage; S.E.M. and microprobe analyses have been performed in nodule constituent minerals.

Practically all nodules (11 samples) are spinel lherzolites - only one is an harzburgite - characterized by medium grain size (1-5 mm) and a four-phase assemblage: olivine (ol, 50 to 60 vol.%, Fo ~88), orthopyroxene (opx, 20 to 40 vol.%, En ~90), clinopyroxene (cpx, 10 to 15 vol.%, Wo 45-47 En 48 Fs 5-7) and spinel (1 to 5 vol.%, Cr/(Cr + Al) = 0.09-0.20). In orthopyroxene and clinopyroxene spinel exolution lamellae are often present due probably to a change in T and/or P. Application of different geothermometers based on the equilibration pair cpx/opx suggest values ranging from 900 to 1100°C.

Fluid inclusions have been found predominantly in opx and cpx and subordinately in ol. Microthermometric experiments suggest that the fluid inclusions contain essentially pure $CO_2$ (Tm ranging from -55 to -57.2°C). Most of the inclusions occur along healed fractures (secondary) and are often associated with different proportions of silicate glass; some contain a dark globule (probably a sulfide). They represent two or three coexisting immiscible fluid phases - silicate melt, sulfide melt, and dense supercritical $CO_2$. A few fluid inclusions, not associated with glass, are very likely P; they generally are bigger in size and show clear decrepitation phenomena. 250 Th of vapor (V) and liquid (L) $CO_2$ were measured and range from -40 to +30°C (95% Th $L + V \rightarrow L$; 5% Th $L + V \rightarrow V$) yielding $CO_2$ densities from 1.11 to 0.35 g/cm$^3$. The higher density values are given by small inclusions associated with the presumed P ones.

Assuming Tt of 1000°C the corresponding Pt for a pure $CO_2$ system would be in the interval from 1.1 and 10.2 Kb. With an hydrostatic P (from a liquid lava column with average density $\rho = 2.8$ g/cm$^3$) the inclusions would have been trapped at depth from 37 to 4 Km.

The $CO_2$ fluid inclusions give evidence that the lherzolite xenolites originate in the mantle and represent accidental fragments randomly sampled by their host nepheline basalt magma. The different distribution of $CO_2$ densities represent various fracturing episodes during ascent. (Authors' abstract)

FRIEDMAN, G.M., 1987a Deep-burial diagenesis: Its implications for vertical movements of the crust, uplift of the lithosphere and isostatic unroofing - A review: Sedimentary Geol., v. 50, p. 67-94. Author at Dept. Geol., Brooklyn College of the City Univ. New York, Brooklyn, NY 11210, USA.

Various techniques of study of strata exposed at the surface in undeformed areas of the Appalachian Basin and Ozark Dome, imply that these strata have been heated to temperatures that suggest a former great depth of burial. The data reveal that the strata have been much more deeply buried than previously thought. If such former deep burial has taken place, then subsequent uplift and erosion must also have taken place to bring these formerly deeply buried strata to the present land surface. Unexpectedly large amounts of uplift and erosion, ranging from 4.3 to 7 km, have re-exposed these formerly deeply buried rocks. (From the author's abstract)

Fluid inclusion data on dolomite, sphalerite, fluorite, and calcite from these sediments, both new and quoted from the literature, are one of the main evidences for the concept. (E.R.)

FRIEDMAN, G.M., 1987b, Deep-burial diagenesis: Its implications for vertical movements of the crust, uplift of the lithosphere and isostatic unroofing - A Review: Sed. Geol., v. 54, p. 165-167. Author at Dept. Geol., Brooklyn College-City Univ. New York, Brooklyn, NY 11210.

An addendum to the previous item. (E.R.)

FRIEDMAN, G.M., 1987c, Vertical movements of the crust: Case histories from the northern Appalachian Basin: Geology, v. 15, p. 1130-1133. Author at Dept. Geol., Brooklyn College-City Univ. New York, Brooklyn, NY 11210.

Evidence of former deep burial of Ordovician to Devonian strata of the northern Appalachian Basin has been obtained from various techniques of study, including fluid inclusion Th, $\delta^{18}O$, and vitrinite reflectance. Diagenetic minerals indicate paleotemperatures of 100-200°C. Maximum depths of burial were calculated from the estimated paleotemperatures; a gradient of 26°C/km was assumed. Silurian strata of the basin are interpreted to have reached maximum burial depths of 5.0 km; Devonian strata in the Catskill Mountains had former burial depths of ~6.5 km; Lower Ordovician carbonate sequences were buried to >7 km; Middle Ordovician strata had paleodepths of ~5 km; and Devonian carbonate strata had paleodepths from 4.5 to 65 km. If these strata were buried deeper than previously thought, unexpectedly large amounts of uplift and erosion, ranging from 4.3 to 7 km, must also have taken place to bring these strata to the present land surface. The occurrence of such large-scale vertical movements of the crust and lithosphere must be recognized in paleogeographic reconstructions. Such drastic changes represent isostatic unroofing, with widespread implications for paleogeography of a kind unrecognized at present. (Author's abstract)

FRIEDMAN, J.D. and MUTSCHLER, F.E., 1987, New geophysical, geochemical, and geological investigations of northern Appalachian zinc-lead sulfide deposits of New York State (abst.): U.S. Geol. Survey Circular 995, p. 21-22.

Reports unpublished inclusion data of J.S. Wilbur of 150-265°C for the Shawangunk district. (E.R.)

FRIEND, C.R.L., 1987, The morphology of granulite-amphibolite facies transitions: The importance of fluid movements (abst.): Abstracts, NATO Advanced Research Workshop, Fluid movements, element transport, and the composition of the deep crust, Lindås, Norway, 18-24 May, 1987 (unpaginated).

FRITZ, Bertrand, CLAUER, Norbert and KAM, Marie, 1987, Strontium isotopic data and geochemical calculations as indicators for the origin of saline waters in crystalline rocks, in Saline water and gases in crystalline rocks, eds., Fritz, P. and Frape, S.K.: Geol. Assoc. Canada Special Paper 33, 1987, p. 121-126. Authors at Center Sédimen. & Géoch. de la Surface (CNRS), 1, rue Blessig, 67084 Strasbourg-Cedex, France.

Groundwaters collected at deep levels in the granitic body of Stripa in central Sweden, are of a saline type. Their origin is still matter of debate with two major theories: the primary waters might either be of marine origin, or they might have been very diluted and could have leached progressively the fluid inclusions of some minerals of the plutonic massif.

Rb-Sr data on a rock and minerals from granitic body, on fracture coatings and on waters, as well as geochemical calculations on these waters allow a somewhat different hypothesis for the origin of their salinity, which is based on a long-term rock-water interaction in the fractures of the granite. Our results clearly discard a marine origin for the primary waters, but they do not definitely address the alternative possibility which is a leaching of fluid inclusions. (Authors' abstract)

FRITZ, P. and FONTES, J.Ch., eds., 1986, Handbook of environmental isotope geochemistry, Vol. 2, The terrestrial environment, B: Elsevier, 558 pp.

Contains 12 chapters, by various authors, some of which may be pertinent to fluid inclusion studies, e.g., in speleothems, carbonates, and relations to deep basin brines. (E.R.)

FRITZ, P., FRAPE, S.K. and MILES, M., 1987, Methane in the crystalline rocks of the Canadian Shield, in Saline water and gases in crystalline rocks, eds., Fritz, P. and Frape, S.K.: Geol. Assoc. Canada Special Paper 33, 1987, p. 211-223. Authors at Dept. Earth Sci., Univ. Waterloo, Waterloo, Ontario, Canada N2L 3G1.

$CH_4$ in association with minor amounts of higher hydrocarbons, $N_2$, He, Ar and H discharge from numerous boreholes in mines across the Canadian Shield. Isotopic analyses on methane, ethane and aqueous carbonate dissolved in associated salt waters and brines show that these hydrocarbons have most likely an abiotic origin. It is remarkable that each mining district releases methane with uniform $^{13}C$ and $^{2}H$ contents which are not readily related to a specific carbon source or generating mechanism.

The isotope data provide evidence which suggests that the methane and associated hydrocarbons did not form in a high T environment. Instead, especially H isotope data point towards kinetic and low or intermediate T processes. Further support for this interpretation is found in the free H associated with some occurrences. It is very strongly depleted in D as is characteristic for H gas generated in other areas through the reduction or radiolytic decomposition of water at low, near surface T.

Geochemical and isotopic data show that these methanes are not active participants in geochemical reactions which affect water chemistries and the generation of brines. However, their formation in crystalline rock environments does not occur and, therefore, contributions to commerical hydrocarbon reservoirs cannot be excluded. (Authors' abstract)

FRITZ, S.J., HINZ, D.W. and GROSSMAN, E.L., 1987, Hyperfiltration-induced fractionation of carbon isotopes: Geochimica Cosmo. Acta, v. 51, p 1121-1134.

FROST, B.R. and FROST, C.D., 1987, $CO_2$, melts and granulite metamorphism: Nature, v. 327, p. 503-506. Authors at Dept. Geol. & Geopys., Univ. Wyoming, Laramie, WY 82071, USA.

The discovery that granulites contain $CO_2$-rich fluid inclusions while amphibolites in the same terrane contain $H_2O$-rich or mixed $CO_2$-$H_2O$ inclusions has led to a debate over the processes that produce granulite metamorphism. One theory maintains that granulites form as the result of a massive influx of $CO_2$ from lower crustal or mantle sources. Such an influx could be responsible for the marked depletion many granulite terranes show in large-ion lithophile elements. Others, however, maintain that granulite-facies metamorphism is a necessary complement of crustal melting. Recently, Lamb and Valley have argued that granulite metamorphism may be a product of any one of three processes: $CO_2$-streaming, partial melting, or recrystallization of originally dry rocks. Here we suggest that these processes need not be independent and that they all may be related to the passage of melts through the crust. (Authors' abstract)

FROST, B.R., FROST, C.D. and TOURET, Jacques, 1987, Synmetamorphic magmas as a source for fluids and heat in granulite metamorphism (abst.): Abstracts, NATO Advanced Research Workshop, Fluid movements, element transport, and the composition of the deep crust, Lindås, Norway, 18-24 May, 1987 (unpaginated).

FUKUNAGA, K., MATSUDA, J., ITO, K., NAGAO, K. and MIYAMOTO, M., 1987, Chemical vapor deposition of diamonds from $CH_4$-$H_2$ gas mixture and the origin of diamonds in meteorites (abst.): Meteoritics, v. 22, p. 381-382.

FYFE, W.S., 1986, The transport and deposition of gold, in Clark, L.A., ed., Gold in the Western Shield: The Canadian Inst. Mining & Metal., Special Vol. 38, p. 156-167. Author at Dept. Geol., Univ. Western Ontario, London, Canada N6A 5B7.

Au is mobilized and precipitated in a wide variety of environments ranging from those of weathering and biological phenomena, to pluton emplacement to deep metamorphism. But it appears that pervasive leaching of large rock volumes followed by the focussed discharge of typically low salinity fluids is frequently involved. There are great gaps in our knowledge, particularly with respect to Au in very high T fluids generated at near Moho depths. But such fluids may play an important part in Archaean pluton associated lode Au deposits where ultra high T fluids, rich in $CO_2$-CO-COS, may be associated with magma underplating and crustal assimilation processes (sag subduction) associated with very dense ultramafic magmas. Other environments with great potential include those of major thrust faults and strike slip faults where large quantities of fluids are mobilized. (Author's abstract)

FYFE, W.S., 1987, Tectonics, fluids and ore deposits: Mobilization and remobilization: Ore Geol. Reviews, v. 2, p. 21-36.

FYFE, W.S., RIBEIRO, A. and BARRIGA, F.J.A.S., 1987, On tectonic fluidization and injection through the lithosphere (abst.): Abstracts, NATO Advanced Research Workshop, Fluid movements, element transport, and the composition of the deep crust, Lindås, Norway, 18-24 May, 1987 (unpaginated).

GAFFEY, S.J., 1987, Aqueous fluid inclusions in carbonate skeletal material (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Author at Geol. Dept., Rensselaer Polytech. Inst., Troy, NY 12181.

Aqueous fluid inclusions occur in all types of carbonate skeletal material. Generally too small to be detected by standard petrographic techniques, they can only be seen using TEM. However, their presence can easily be detected using visible and near infrared (VNIR) reflectance spectroscopy (0.6-2.5 um). Although calibration work is still under way, this method promises to provide a rapid, inexpensive technique for detecting and monitoring aqueous fluid inclusions too small to be studied using standard petrographic techniques, as well as larger inclusions.

VNIR spectroscopy can be used to distinguish OH from $H_2O$ and water present in aqueous fluid inclusions can be distinguished from $H_2O$ bound in a mineral phase.

Absorptions due to the carbonate radical also occur in this region, and the intensities of water bands relative to intensities of carbonate bands in the same spectrum are sensitive indicators of the amount of water present. [Ed. note: This paper not presented at meeting.] (From the author's abstract)

GALABURDA, Y.A. and KVASNITSA, V.N., 1987, Inclusions of oil and hydrocarbons in hydrothermal quartz of Donets Basin coals: Mineralogicheskiy Zhurnal, v. 9, no. 2, p. 77-79. (in Russian; English summary)

GAMBLE, B.M., 1987, Gold veins of the Seward Peninsula, Alaska (Extended abst.): U.S. Geol. Survey Circular 995, p. 23.

Gold-bearing veins of the Seward Peninsula, AK, occur along high-angle faults in the Nome Group metamorphic rocks. The veins can be divided into two types - low and high sulfide. The low-sulfide type is more common and generally contains less than 3 percent arsenopyrite and (or) pyrite; galena, sphalerite, and scheelite occur locally. Quartz is the dominant gangue mineral, but plagioclase (albite-oligoclase) and (or) carbonate minerals (calcite, dolomite, ankerite) locally make up as much as 50 percent of the veins. Minor amounts of chlorite, sericite, and clay minerals also may be present. The high-sulfide veins contain 20-80 percent stibnite and minor amounts of pyrite and arsenopyrite. Quartz is the dominant gangue mineral, but some sericite, calcite, and clay minerals are usually present. The veins at Big Hurrah (58 km northeast of Nome) are the largest on the Seward Peninsula. They range from 0.5 to 4 m wide, and as many as four veins are present in a single fault zone. Fluid inclusions in vein quartz from Big Hurrah contain $CO_2$ and $CH_4$ (Read, 1985, [Fluid Inclusion Research, v. 18, 1985, p. 335-336]). A pressure estimate of 0.8 kbar, and T estimates ranging from 300 to 400°C indicate emplacement after peak blueschist facies metamorphic conditions in Late Jurassic to Early Cretaceous time. Quartz from several veins on the Seward Peninsula yield $\delta O^{18}$ isotope values that range from +10.2 to +19.2 (Gamble and others, 1985, Fluid Inclusion Research, v. 18, p. 128, 1985); these values are consistent with a metamorphic origin for the veins.

Results obtained so far represent part of an ongoing study. Future work includes (1) obtaining additional measurements of fluid-inclusion compositis and Th, (2) K-Ar age determinations of suitable phases from several veins, (3) identification by X-ray of unknown phases, (4) assay of mineral separates, and (5) obtaining additional $\delta O^{18}$ isotope data. (From the author's abstract)

GAMMONS, C.H. and BARNES, H.L., 1987, Stability of silver-bisulfide complexes under hydrothermal conditions: Applications to metal transport in geothermal systems (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 671. Authors at Ore Deposits Res. Sec., The Pennsylvania State Univ., University Park, PA 16802.

The solubility of argentite/acanthite ($Ag_2S$) in near-neutral solutions buffered by $H_2S(aq)$ and $HS^-$ was measured in the T range 25° to 300°C using a standard "Barnes-type" rocking autoclave. Total dissolved sulfide in the experiments ranged from 0.2 to 2.0 molal. By varying the relative amounts of $H_2S$ and $HS^-$ between runs, the dominant solubility-controlling reaction under these conditions has been determined:

$$1/2Ag_2S + 1/2H_2S + HS^- = Ag(HS)_2^- \qquad (1)$$

Preliminary results indicate that log K for this reaction increases linearly from -3.59 ± 0.1 (25°C) to -1.78 ± 0.2 (300°C). The linear T-dependence is typical of aqueous reactions written with balanced like charges.

Using thermodynamic data available in the literature for other complexes of silver (e.g., chloride, hydroxide), it can be shown that $Ag(HS)_2^-$ dominates over a wide range in physio-chemical conditions relevant to many natural hydrothermal systems. For example, using analytical data for the BR22 geothermal well at Broadlands, New Zealand (Brown, 1986), and log K (260°C) for reaction 1 = -2.05 (this study), silver solubilities on the order of several ppb can be expected from the $Ag(HS)_2^-$ species. This is somewhat lower than Brown's empirical estimate of 8 ppb total Ag for the BR22 aquifer fluid, but is more than one order of magnitude greater than the calculated solubility assuming chloride complexing alone. (Authors' abstract)

GAMO, Toshitaka, ISHIBASHI, J.-I and SAKAI, Hitoshi, 1987, Methane anomalies in seawater above the Loihi submarine summit area, Hawaii: Geochimica Cosmo. Acta, v. 51, p. 2857-2864.

GARDE, A.A., 1987, Retrogression and fluid movement across a granulite-amphibolite facies boundary in late Archaean Nuk gneisses, Fiskefjord, southern West Greenland (abst.): Abstracts, NATO Advanced Research Workshop, Fluid movements, element transport, and the composition of the deep crust, Lindås, Norway, 18-24 May, 1987 (unpaginated).

GASPAR, O., BOWLES, J.F.W. and SHEPHERD, T.J., 1987, Silver mineralization at the Vale das Gatas tungsten mine, Portugal: Mineral. Mag., v. 51, p. 305-310. First author at Lab. Direccão-Geral de Geol. e Minas, 4465 S. Mamede de Infesta, Portugal.

The Vale das Gatas W (wolframite) mine is situated at the contact between Hercynian granite and Cambrian-Precambrian crystalline schists. Fluid inclusions in wolframite-bearing quartz show simple, two-phase liquid/vapor systems which homogenize into the liquid phase at a mean Th of 225 ± 6°C and salinity measurements suggest the inclusions contain about 6 wt.% NaCl eq. $CO_2$ liquid is absent, as are vapor-rich inclusions. (E.R.)

GATTER, István, 1986, The study of fluid inclusions in quartz crystals and its application to the study of archeological materials: Int'l. conf. on prehistoric flint mining and lithic raw material identification in the Carpathian Basin, Budapest-Sümeg, 20-22 May, 1986, p. 149-153. Author at Eötvös Loránd Univ. Sci., Dept. Min., Muzeum Krt. 4/A, H-1088 Budapest, Hungary.

A mainly theoretical discussion of the possibility of using fluid inclusions, e.g., in quartz crystals, to aid in archeology. (E.R.)

GATTER, I., 1987a Fluid inclusion studies in the polymetallic ores of Gyöngyösoroszi (north Hungary) - Spatial and temporal evolution of ore-forming fluids: Chem. Geol., v. 61, no. 1/4, p. 169-181.

Full paper for abstract in Fluid Inclusion Research, v. 18, p. 130-131, 1985. (E.R.)

GATTER, István, 1987, Fluid inclusion studies of pre-ore quartz veinlets from Matra Mts. (N-hungary) and its ore-genetical evaluation (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 47-48. Author at Mineral. Dept. Eötvös Loránd Univ., Budapest, Muzeum krt. 4/a II-1088, Hungary.

A complex fluid inclusion study of quartz crystals from veinlets in the area of polymetallic (± Au-Ag) mineralization situated in the Neogene intermediate volcanic complex of the Mátra Mts. (N-Hungary) has been undertaken. The crystals grew at the edge of the ore field, and at the margin of the individual ore bearing veins as well. The country rock has been altered by sericitization, argillization and silicification processes. The crystals are faceted by simple forms, as m($10\bar{1}0$), r($10\bar{1}1$), z($01\bar{1}1$), M($30\bar{3}1$), e($50\bar{5}1$), $\nu(220\overline{22}7)$. Syntaxial overgrowth (scepter form) and distortion phenomena often occurred as well.

The types of inclusions are as follows: a.) solid crystallites (s), b.) high density single-phase (l), c.) low density single-phase (vapor/gas)-(v), d.) two-phase (l + v), e.) three-phase (v + l + s) with trapped crystallites, f.) two-phase (l1 + l2 + v) with two immiscible (presumably CH) fluids.

Microthermometric data: Th = 210-250°C (160-380°C) Te = -2 to -10°C (subordinately -25 to -40°C), Tm ice = 0.5 to -1.5°C (-0.5 to -5°C). Salinity = 0.35-2.05 NaCl eq. wt. %. Density of the fluids is 0.82-0.85 $g/cm^3$ (assuming $NaCl-H_2O$ system). Boiling is a frequent phenomena and the estimated thickness of a cover varies between 100-450 m. The bulk of the fluid composition can be modelled on the basis of cryoscopic data using the $NaCl-NaHCO_3-H_2O \pm CO_2$ system, but some of the specimens (or a part of a specimen) had been trapped from a $NaCl-CaCl_2-H_2O$ type fluid. The (c) type of inclusions, containing besides vapor, low density $CO_2$ and/or $CH_4$, were determined by means of phase transition and Raman spectrometric data.

Temporal change of fluid character can be traced by the zonal structure of crystals. The cooling trends are common, sometimes we could observe $Cl^-$ rich fluids along the veins in the younger parts of the crystals.

The formation of the quartz can be attributed to separation of phase condensates of magmatic fluids which were mixed in the boiling zone with heated meteoric water as observed in recent geothermal fields. The fluids which were trapped in the crystals differ from the ore-bearing Na-Ca-Cl type fluids. This fact permits distinguishing ore-bearing vein outcrops from silicified country rocks in the course of field exploration. (Author's abstract)

GATTER, István and MOLNÁR, Ferenc, 1987, Periodic growth history of grown-up quartz from Újhuta (Tokaj Mountains, NE-Hungary) by the fluid inclusion study (poster) (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 141-142. Authors at Mineral. Dept. of Eötvös Loránd Univ Budapest, Muzeum krt. 4/a, H-1088, Hungary.

The grown-up quartz crystals with three growing period (scepter quartzes with syntaxial overgrowth) came from a Neogene propylitic pyroxene-andesite and rhyolitic tuff. The observed inclusion types are as follows:

1. P and PS inclusions: two-phase (L + V), sometimes with different L/V ratios; one-phase, low density (V) (only in the first and the second growth stage); and calcite crystallites (observed only in the second and the third period).
2. One-phase (L) and two-phase (L + V) S inclusions. The common presence of the two-phase inclusions (with different L/V ratios) and of gas inclusions in the first and the second growth period of quartz crystals refer to the boiling of the hydrothermal fluid. On the basis of cryoscopic

data the chemical composition of the fluid inclusions can be modelled by $NaCl-NaHCO_3-H_2O-CO_2$ system. The cotectic T is between -19°C and -2°C, and it increases from the first to the third growth period. This fact refers to the increase of the bicarbonate-ion content of the solution in the course of the quartz growth. The concentration is generally low (Tm ice = -0.4°C to -1.2°C; c = 0.7-2.22 NaCl eq. wt.%), and those values did not change along the crystal growth direction. The first growth stage developed between 220°C and 250°C, and 35-50 bars, and the second stage developed between 180°C and 230°C, and 20-40 bars which account for the boiling and presence of $CO_2$. The T of the third growth period (on the basis of the distribution of the Th, without P correction) was between 160°C and 220°C.

The increasing tendency of the cotectic T and the decreasing tendency of the Th point out mixing of an originally $Cl^-$ type hydrothermal, and a near-surface $HCO_3^-$ type fluid.

Conclusion: the boiling and the near-surface groundwater influx into the hydrothermal system caused the periodic quartz crystal growth. (Authors' abstract)

GE, Chaohua and HAN, Fa, 1986, Submarine volcanic hydrothermal sedimentary origin of the Daboshan iron and polymetallic sulfide deposit: Mineral Deposits, v. 5, no. 1, p. 11-12 (in Chinese; English abstract). Authors at Inst. Mineral Deposits, Chinese Acad. Geol. Sci.

The Dabaoshan deposit, a large Fe and polymetallic sulfide deposit is in northern Guangdong.

Tf of the syngenetic massive ores is determined at about 150°. The T obtained by geothermometry [by fluid inclusions?] for the late reformed ores range from 290 to 320°C, quite close to those of the altered rocks.

The $\delta^{18}O$ SMOW values of equilibrium water for syngenetic sedimentary ore average -2.25 ± 0.99‰, which are rather similar to those for the Kuroko-type deposits, implying its volcanic-sedimentary origin. The $\delta^{18}O$ values of siderite in quartz-siderite ore average 18.47 ± 0.43‰, and $\delta^{13}C$‰ PDB range from -2.55 to -5.80 when no influence of organism exists. The $\delta^{13}C$ values are similar to those of Red Sea hot brine (averaging -4.5‰). The Pb isotope ratios of the Dabaoshan ores are extremely stable: $^{206}Pb/^{204}Pb$ = 18.6303 ± 0.0314, $^{207}Pb/^{204}Pb$ = 15.6809 ± 0.0250 and $^{208}Pb/^{204}Pb$ = 38.8226 ± 0.0809. (From the authors' abstract)

GEISLER-CUSSEY, Dominique, 1986, Sedimentological and geochemical approach of the mechanisms generating recent and ancient evaporitic formations: Solar salt works in Camargue and in eastern Spain, Mediterranean Messinian, and Triassic of Lorraine: Memoire 48, Sciences de la Terre, 268 pp. (in French; English abstract).

The geochemical approach permits establishing the representativeness, towards the mother brines, of the fluids trapped in P inclusions of halite crystals and the positive correlation between increasing salinity and rise in Sr content in gypsum and Br content in halite.

In fossil deposits, the behavior of Sr is observed in Messinian Mediterranean gypsum crystals which show more or less constant values for a given gypsum facies. Br geochemistry is studied in Lower Keuper of Lorraine where the saliferous levels, of marine origin, show at the sequential scale a cyclic evolution of salinity, except in cases of early diagenesis. At last, in the Middle Muschelkalk series of Lorraine, the sequences reflect elementary changes in the depositional environment, especially salinity changes which show a cyclic evolution for the whole series. (From the author's abstract)

GELBLAT, R.H., 1987, Use of fluid inclusions in determining fluids present during deformation, Kelowna detachment, southern British Columbia (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Author at Dept. Geol., Bryn Mawr College, Bryn Mawr, PA 19010.

This study reports on petrographic, fluid inclusion, and oxygen isotope investigations of samples from a homogeneous granodiorite which has been strongly sheared on one side. Three fluids have interacted with this body; a $CO_2$-rich fluid, a low-salinity aqueous fluid, and a meteoric aqueous fluid. The amount of fluid present varies across the body. The sheared portions of the granodiorite contain a greater abundance of muscovite and aqueous fluid inclusion-rich pegmatites indicating a concentration of aqueous fluid in the shear zone. Since the muscovite and pegmatites in the shear zone are also sheared, it appears that an aqueous fluid was present during ductile deformation.

Fluid inclusion studies were undertaken to determine the composition of the syndeformational aqueous fluid and to attempt to determine P and T conditions during deformation. Two fluids were identified; a $CO_2$-rich fluid and a low-salinity (0.76-2.6 wt.% NaCl equiv.) aqueous fluid. Isochores for aqueous fluid inclusions fall into two groups, a high density group and a low density group. Since the salinity of the two groups is the same, I interpret the low density inclusions are representing re-entrapment of the same aqueous fluid as represented by the high density inclusions. The greater abundance of low density inclusions in the sheared rocks and the consistency of composition may indicate that the high density fluid inclusions were destroyed during shearing and that the same fluid was retrapped during shearing and uplift.

The granodiorite does not contain appropriate mineral assemblages to tightly constrain P-T conditions during shearing. P-T conditions for the pegmatites are best constrained by the wet granite melting curve as an upper thermal boundary and atmospheric P as a lower P boundary. This results in entrapment conditions of 200°-650°C and up to 6 Kbars for the high density inclusions. For the low density, possibly syndeformational, aqueous inclusions entrapment occurred between 300°-650°C and at P up to 3 Kbars.

Preliminary oxygen isotope data from the granodiorite and the pegmatites shows that the feldspars have been reset by exchange with a meteoric fluid while quartz has not. This implies a meteoric fluid T between 150° and 300°C. Since the isochore lines for the low density fluid inclusions show that 300°C corresponds to atmospheric P, and it is unlikely that entrapment was at the surface, the low density aqueous fluid trapped as inclusions is not meteoric. (Author's abstract)

GEORGE, Brigitte, 1987, Behavior in nature of uranium in volcanic rocks and an experimental approach: PhD dissert., Univ. Nancy I/CREGU (in French; English abstract).

The behavior of U in various volcanic rocks result from the existence of various events which occur successively or not in the same place: fertile source-rock, preconcentration stages, hydrothermal and/or supergene mobilization and good traps. The preconcentration stage (vapor phase crystallization in Mexico, zeolitization in Latium, Italy), concentrates the previously disseminated U and thus favors its concentration during the following events. The hydrothermal mobilization of U is directly related to the alteration grade and the volume of the fertile rock which is concerned. (From the author's abstract)

GERAGHTY, E.P., CARTEN, R.B. and WALKER, B.M., 1987, Northern Rio Grande rift tectonics: Tilting of Urad-Henderson and Climax porphyry molybdenum deposits (abst.): Geol. Soc. Am. Abst. with Programs, v. 19, p. 277. Authors at Climax Molybdenum Co., AMAX Inc., Henderson Mine, P.O. Box 68, Empire, CO 80438.

Asymmetric orientation of dikes, veins, stocks, and attendant Mo mineralization and hydrothermal alteration indicate that Red Mountain (Urad-Henderson Mo deposits) and Climax intrusive-hydrothermal systems are tilted 25° southeast and 37° southwest, respectively. Evidence suggests tilting resulted from displacement on planar normal faults associated with the northern Rio Grande rift system: Woods Creek fault at Red Mountain and West fault at Climax (830 m and 760 m estimated dip-slip displacement, respectively). Woods Creek and West faults are part of sets of subparallel faults that are downdropped to the west and northeast, respectively. Both systems formed during incipient rift development (Climax system to the south was initiated slightly earlier, 33 m.y., than the more northerly Red Mountain system, 29 m.y.) and are associated with voluminous high-silica rhyolite stocks and dikes and scarce lamprophyre dikes. Trends of youngest major normal faults at both deposits are nearly perpendicular to early fault sets. This change in trend probably is related to a switch in positions of $\sigma_2$ versus $\sigma_3$, $\sigma_1$ remaining essentially vertical. Well-developed radial structural patterns about Red Mountain system indicate the absence of a well-defined regional tectonic overprint.

Reconstruction of Oligocene-age paleotopography using estimated post-mineralization fault displacements near Red Mountain suggests a minimum depth of emplacement of 1.6 km (Pc 41 MPa) and 2.8-3.1 km (Pc 72-80 MPa) for the apices of principal mineralizing stocks in Urad and Henderson deposits, respectively. These minimum depths are corroborated by homogenization pressures (78 MPa) for fluid inclusions from distal portions of moderately dipping open-space veins in the Henderson deposit. Depths of emplacement for Climax system remain unchanged, 2.3-3.2 km, and are similar to the new estimates for Red Mountain system. (Authors' abstract)

GERLACH, T.M., 1987, How oceanic ridge and intraplate volcanos degas (abst.): Hawaii Symp. on How Volcanoes Work, Abst. Volume, Hilo, Hawaii, Hawaiian Volcano Observatory, p. 89.

GERLER, J., 1987a Trace elements in hydrothermal quartzes and their relation to the amount and salinity of fluid inclusions (abst.): Fortschritte der Mineralogie, Bd. 65, Bhf. 1, p. 56 (in German).

Hydrothermal quartz from a) vein-type post-Variscan mineralization with barite, fluorite, galena and sphalerite (e.g., veins in Upper Harz) and b) quartz segregations from the Paleozoic metamorphism (e.g., quartz lenses from the geothermal boreholes in Oberpfalz and Schwarzwald) were analyzed by nondestructive neutron-activation. The two groups of quartz have distinctly different concentrations of trace elements. For the post-Variscan quartzes the high contents of Al, Na, Ca, Sr, Cl and Br, and especially Ga, Ge, As and Sb are typical. The contents of Al, Na, Ca, Sr, Cl and Br display a positive correlation with the amount of fluid inclusion water determined coulometrically. From this correlation one may conclude that all Cl and Br and most Na, Ca and Sr come from fluid inclusions. Ga, Ge, As and Sb do not display any correlation of the above type and due to the absence of mineral phases which would bear these elements (electron microprobe studies), these may be present in the quartz crystal lattice.

Metamorphic quartzes typically bear K, Rb, Cs, Fe and Mn, however, without correlation with fluid inclusion content. The determinations of salinity of parent solutions and Th suggest that the trace element contents in quartz depend in high degree on the composition of these solutions. (Author's abstract, translated by A.K.) See also next item. (E.R.)

GERLER, J., 1987b Neutron activation analysis of trace elements in quartz (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 143. Author at Inst. für Geol. & Dynamik der Lithosphäre der Univ. Göttingen, Goldschmidtstr. 3, D-3400 Göttingen, FRG.

Up to now little work has been done on trace elements in quartz, although this mineral is nearly ubiquitous in vein deposits and is likely to preserve the original chemistry of ore solutions due to its high resistance to weathering.

Quartz samples from post-Variscan vein mineralizations with fluorite, barite, calcite, and Pb-Zn in the Federal Republic of Germany and quartz segregations of the Palaeozoic metamorphism have been analyzed nondestructively by neutron activation analyses (NAA). It can be shown that the trace elements in quartz are strongly dependent on the composition of the mineralizing solutions and that T and P are of minor significance.

The post-Variscan vein quartzes which contain highly saline fluid inclusions are independent of the tectonic setting and the chemistry of the country rocks characterized by high concentrations of Ga, Ge, As, Sb, Cl, Br, Ca, Sr, and U. In contrast, the trace element content of the Variscan quartz segregations is variable and depends on water-rock reactions between the fluid phase and the country rocks.

Analyses of trace elements in quartz can be used as a prospecting tool in the exploration of mineral deposits. (Author's abstract) See also previous item. (E.R.)

GERRETSEN, Jurriaan, MCLAREN, Alex and PATERSON, Mervyn, 1987, Evolution of water inclusions in wet synthetic quartz as a function of temperature and pressure (abst.): EOS, v. 68, p. 1453. First author at Res. Sch. Earth Sci., Australina Nat'l. Univ.

To obtain some more information on the role of water inclusions in quartz plasticity, measurements in the TEM of the size distribution of inclusions in 'wet' synthetic quartz (670 H/$10^6$Si) were made after heat-treatment at various T and P. Correlation of the observed trends with light scattering indicates that the TEM observations over small volumes are representative of the bulk. Two types of water-related inclusions are distinguished; (1) clusters: spheroid-like precipitates with a high internal P, characterized by a butterfly shaped strain contrast in appropriately oriented TEM sections, and (2) bubbles: approximately spherical inclusions which do not show such evidence of an excess internal P. The starting material contains mainly clusters with a mean diameter of 33 nm.

In practical counting of the inclusions from micrographs, clusters which do not have a suitable orientation or size to show strain contrast are initially counted as "bubbles," so that the count of "clusters" is an underestimate of the clusters (on average, in a single micrograph only 25% of the clusters show a distinct strain field). In heat-treatment the number of <60 nm "bubbles" decreases, at a rate which is higher at lower P and higher T. Larger sized, >60 nm "bubbles" (maximum size 135 nm at 873 K and 200 nm at 1173 K), some with associated prismatic dislocation loops appear during heat-treatment and increase in number with time. The "cluster" population follows a similar pattern to that of <60 nm bubbles. The ratio of "cluster" to "bubbles" decreases with increasing time and decreasing P. At 873 K and low P the eventual average size for all <60 nm inclusions decreases towards 23 nm but at 1.5 GPa it remains near to the original 33 nm, wheras at 1173 K the average size of the <60 nm inclusions changes to 23 nm, independent of P.

The variation of the inclusion size distribution with time, T and P suggests two stages in the coarsening process. At first high P inclusions readily nucleate a dislocation if above a critical size (which is smaller for low P and high T). At the same time clusters below a critical size grow at a rate which appears to be higher at lower T until the critical size for that particular P difference is exceeded when a dislocation loop is again nucleated. (Authors' abstract)

GERSTNER, M.R., BOWMAN, J.R. and PASTERIS, J.D., 1987a P-T-X-$\bar{V}$ characterization of methane-bearing fluids from the MacTung scheelite skarn deposit, Yukon-Northwest Territories, Canada (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). First author at Dept. Geol. & Geophys., Univ. Utah, Salt Lake City, UT 84112.

Skarn development at MacTung has produced both anhydrous and hydrous skarn assemblages: 1) pyroxene (Px) + quartz (Qz) + scheelite (Sch) + pyrrhotite (Po) ± garnet (Gn) ± wollastonite (Wo); 2) amphibole (Amp) + epidote (Ep) + Qz + calcite (Cc) + Sch + Po ± biotite (Bi) ± plagioclase (Pg). Microthermometry and Raman spectroscopy analyses of P fluid inclusions in Px, Gn, and Qz from anhydrous skarn and Qz from hydrous skarn yield the following characteristics: 1) presence of $CH_4$-bearing fluids, with traces of $H_2S$ and $N_2$ and undetectable $CO_2$, in all facies and stages of skarn development; 2) homogenization of a methane-rich liquid and vapor in the presence of ice and clathrate between -80° and -110°C; 3) low salinities (max. 6 equiv. wt. % NaCl from final ice melting); 4) mean clathrate melting T of 10°C in Px and 17°C in hydrous skarn and; 5) mean methane-water Th of 340°C in Px and 360°C in Qz. The mole fraction of $H_2S$ in the vapor must increase from ~0.03 in anhydrous skarn to >0.12 in hydrous skarn, with concommitant decrease in vapor molar volume (based on clathrate melting) of 500 $cm^3$/mole to 120 $cm^3$/mole. Values of $x(CH_4)$ are based on estimates of vol. % vapor (~25% in inclusions in all three phases) and range from 0.005 to 0.02 in Px and 0.01 to 0.04 in Qz and Gn. Isochores, although sensitive to estimates in $\bar{V}$ (bulk), indicate fluid P remained high (>2.0 Kb) throughout development of both anhydrous and hydrous skarn. Both anhydrous skarn and initial hydrous skarn formed at similar T (450 ± 25°C) and P, which suggests simultaneous development of both skarn facies. This inference is consistent with the systematic zonation of hydrous and anhydrous calc-silicate skarn assemblages about quartz veins within interbedded hornfels observed by Dick and Hodgson (1982). Textural evidence of anhydrous skarn replacement by hydrous skarn therefore indicates a progressively expanding anhydrous-hydrous boundary, not later, exclusively retrograde development of hydrous skarn at lower T and P. (Authors' abstract)

GERSTNER, M.R., BOWMAN, J.R. and PASTERIS, J.D., 1987b P-T-X-V characterization of methane-bearing fluids from the MacTung scheelite skarn deposit, Yukon-Northwest Territories, Canada (abst.): Eos, v. 68, no. 7, p. 101. See also previous item. (E.R.)

GHENT, E.D., 1987a Pressure-temperature-time (P-T-t) paths in metamorphism - An introduction to the symposium (abst.): GAC-MAC, AGC-AMC Joint Ann. Mtg., Program with Absts., v. 12, p. 45. Author at Dept. Geol. & Geophys., Univ. Calgary, Calgary, Alberta T2N 1N4.

To quantitatively characterize the P-T-t paths of metamorphism, it is necessary to consider non-equilibrium features of the metamorphic rocks. For the commonly postulated P-T "clockwise" path the initial heating and burial portion of the path is probably best constrained by studying the early formed metamorphic inclusions in porphyroblasts which have been preserved metastably during the remainder of the P-T cycle. Chemical zoning within minerals such as garnet can be used with the compositions of inclusions and of matrix minerals to calculate changes in mineral chemistry as a function of changing P and T, e.g., using the method of Spear and Selverstone (1983). It is unlikely, however, that the reaction assemblage was present during the entire crystallization history of the zoned porphyroblast. In addition, many porphyroblasts show resorption and marginal retrograde zoning and/or reaction textures which complicates the picture. Estimation of closure temperatures for Fe-Mg exchange (Dodson model) is also possible. Because of the lag in temperature increase relative to changes in pressure, it is difficult to estimate the maximum pressure in the P-T path. In principle, more accurate estimates of P maximum may be obtained from rocks that were never heated above these closure temperatures. Estimation of P-T-t points on the uplift and cooling parts of the cycle can be made by techniques such as closure temperatures for isotopic ages, e.g., K-Ar, and preservation of fluid inclusions. It is difficult, however, to relate the time of trapping of fluid inclusions to the isotopic closure temperature. (Author's abstract)

GHENT, E.D., 1987b Tremolite and $H_2O$ activity attending metamorphism of hornblende-plagioclase-garnet assemblages (abst.): EOS, v. 68, p. 1528.

GHENT, E.D., BLACK, P.M., BROTHERS, R.N. and STOUT, M.Z., 1987, Eclogites and associated albite-epidote-garnet paragneisses between Yambe and Cape Colnett, New Caledonia: J. Petrology, v. 28, p. 627-643. First author at Dept. Geol. & Geophys., Univ. Calgary, Calgary, Alberta T2N 1N4, Canada.

Fe-Mg exchange thermometry between omphacite and garnet suggests T between 520 and 600°C. Omphacite + quartz (mol % jadeite = 37-43) does not coexist stably with albite suggesting minimum P near 12 kb at 550°C. Remnants of more jadeite-rich pyroxenes in paragneisses ($jd_{50-60}$) suggest even higher P. The stable coexistence of chloritoid-almandine-quartz in paragneisses suggests relative $H_2O$-rich fluids were in equilibrium with this assemblage. The widespread stable occurrence of sphene suggests relative low $f(CO_2)$ during metamorphism. Late stage healed fractures in quartz contain $H_2O$-rich fluid inclusions with relatively low density isochores. Limited geochronologic data combined with these petrologic data suggest a fairly rapid initial rate of uplift followed by a much slower rate of uplift. (From the authors' abstract)

GIAMELLO, M., GUASPARRI, G., RICCOBONO, F. and SABATINI, G., 1987, Mo-mineralizations associated to Hercynian intrusive magmatism of Sardinia. Preliminary results of fluid inclusions study: Atti Acc. Fisiocritici Siena, ser. XV, v. 6, p. 63-70 (in Italian; English abstract). Authors at Inst. Min. e Pet., Fac. di Sci. Mat., Fisi. e Natur., Univ. di Siena, Italy.

Fluid inclusions from quartz veins of Mo-mineralizations, bound to the Hercynian batholith of Sardinia, are two-phase. Disseminated Mo-mineralizations, associated wtih phyllic alteration show both liquid-rich and gas-rich inclusions. [The inclusions are too small to be certain about a third phase.] Three-phase are certainly present in the Perdu Cara cassiterite quartz vein. Microthermometric data show definitely different Th values for the two types of Mo-mineralization. (From the authors' abstract)

GIBSON, P.C., 1987, Geology of the Buckskin mine, Douglas County, Nevada (abst.): Program with Abstracts, Symp.: Bulk Mineable Precious Metal Deposits of the Western United States, April 6-8, 1987, Geol. Soc. Nevada, p. 63. Author at Mackay Sch. Mines, Univ. Nevada-Reno.

Fluid inclusion data indicate the presence of at least two distinct hydrothermal fluids. One fluid was a high salinity, high T fluid which was probably boiling, and is characterized by inclusions with a small vapor bubble and one or more dms or vapor-dominated inclusions with or without dms. The other fluid was less saline and cooler, and is characterized by inclusions with a small vapor bubble and no dms.

Hudson (Ph.D. diss., University of Nevada, Reno, 1983) described the region surrounding the Buckskin mine as the upper part of a porphyry Cu deposit on the basis of alteration, fluid inclusions and copper mineralization. The Buckskin vein is possibly related to this porphyry system. Evidence for this association includes the relatively high copper content of the vein and the high temperature and salinity fluids observed. The presence of two distinct types of fluids is also commonly observed in porphyry Cu deposits. (From the author's abstract)

GIGGENBACH, W.F., 1987, Redox processes governing the chemistry of fumarolic gas discharges from White Island, New Zealand: Applied Geochem., v. 2, p. 143-161. Author at Chem. Div., DSIR, Petone, NZ.

On the basis of a systematic thermodynamic evaluation of some 250 gas analyses for 100 to 800°C fumaroles on White Island, New Zealand, the gas discharges were found to be made up of two source components: (1) a primary "magmatic" component high in $SO_2$, rising rapidly and directly from the underlying magma; and (2) a secondary "hydrothermal" component rising slowly from a two-phase, saline brine-vapor envelope surrounding the magmatic system. Relative rates of equilibration for individual species decrease from $H_2$, to CO, to $CH_4$ and $NH_3$. The two "slow" species, $CH_4$ and $NH_3$, are formed at depth within the hydrothermal zones where redox conditions are governed by the Fe(II)-Fe(III) buffer of the rock system; redox conditions within the rapidly rising magmatic component are governed by the $SO_2$-$H_2S$ buffer, but only the "fast" system $H_2$-$H_2O$ is able to respond. Both systems are bridged by CO-$CO_2$. The overall redox process corresponds to the more or less successful conversion of initially oxidized ($SO_2$, $CO_2$), high temperature magmatic gases to their reduced counterparts ($H_2S$, $CH_4$), which are stable in the presence of lower temperature rock. The highly acid and oxidizing conditions within the hydrothermal zones give rise to intensive fluid-rock interaction, the dissolution of cationic rock components, and the formation of highly mineralized brines, that are potential source fluids for volcanic-hosted precious metal deposits. (Author's abstract)

GILLET, P. and MALEZIEUX, J.-M., 1987, A sapphire anvil cell adapted for Raman microprobes (abst.): Terra Cognita, v. 7, p. 16.

GILMER, A.L., 1987, The geology and genesis of the Sierra de Santa Maria metalliferous deposits, Velardeña, Durango, Mexico: MS thesis from Univ. Texas at El Paso, 264 pp.

Pb-Zn-Ag mineralization is spacially and temporally associated with a 33 million year old quartz latite porphyry stock and associated quartz latite porphyry and rhyolite dikes.

Sulfide mineralization occurs as skarn-replacement, carbonate-replacement, disseminated, breccia, and epithermal fissure-vein ore. The mesothermal ore zones are divided and named on the basis of the dominant sulfide peculiar to their respective assemblages. They are a) pyrrhotite ore zone (skarn-replacement ore), b) arsenopyrite ore zone (disseminated ore in quartz latite porphyry), and c) pyrite ore zone (carbonate-replacement ore). The two other ore zones in the sierra are the epithermal ore zone (fissure-vein ore) and breccia ore zone (quartz latite porphyry breccia ore).

A variety of alteration assemblages are recognized. These are, in order of occurrence, pre-sulfide stage prograde skarn, potassic and propylitic, sulfide stage retrograde skarn, late sulfide stage phyllic, and post-sulfide argillic alteration. All but the argillic (probably supergene) are attributed to hypogene hydrothermal activity.

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.

S isotope analyses of the sulfides (0‰) and host Mesozoic sedimentary rocks (-7.3 to 3‰) suggest that the S was derived from a juvenile, magmatic source. No $\delta^{34}S$ compositional variations were observed either paragenetically or spatially.

Pb/Zn ratios in the Santa Maria mine indicate that fracture intersections with the Santa Maria dike were the major hydrothermal fluid pathways. This is further supported by higher Bi/Sb ratios in galena within the central portions of the hydrothermal fluid paths than along the distal fringes.

Finally, the variation in sulfide mineralogy between mesothermal ore zones is attributed to zonation, apparently controlled by increasing fossil sulfur and oxygen fugacities as the hydrothermal fluid migrated away from the stock. This effect was probably due to increasing small-scale meteoric groundwater interaction with magmatically derived hydrothermal fluids distally from the stock. (From the author's abstract)

GILMER, A.L. and HARDER, V.M., 1987a Dating of hydrothermal events and implications upon fluid evolution via fluorite fission track dating, biotite K-Ar dating and fluid inclusion analyses within the Santa Maria dome, Velardena, Dgo. Mexico (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Authors at Univ. Texas at El Paso, El Paso, TX.

The hydrothermal events in the Sierra de Santa Maria in Velardena, Durango, Mexico, lend themselves to be dated via fluid inclusion Th plotted against empirically derived convective cooling curves. These curves are constrained in age by a K/Ar biotite date of the genetically related igneous rocks at 33 m.y. and a gangue fluorite fission track date of 24 m.y. The blocking T of the two techniques serve to constrain the T of the curve at ~350°C and 108°C for K/Ar of biotite and fission track of fluorite respectively.

Usage of this technique depends upon 1) the occurrence of a single magmatic event or the occurrence of numerous magmatic events within a tightly constrained time period; 2) a reasonable estimation of the pre-intrusion heatflow, i.e., pre-intrusion T of host rock; 3) depth of burial of the intrusion at original time of emplacement; 4) size of intrusion; and 5) erosional rates during cooling. The last criterion is more or less important, depending upon original depth of emplacement. These criteria can be approximated to within reason by field observations, fluid inclusion data, and fission track dates.

The Sierra de Santa Maria is a structural dome; the core being a hypabyssal quartz latite porphyry stock about 3 km in diameter. The stock was emplaced at a depth of no more than 1 km, as constrained by stratigraphic reconstructions as well as fluid inclusion data. As such, erosional rates are not as critical in importance as they would be in deeply buried igneous rocks with rapid erosion. Evidence of boiling in S inclusions is used as a P indicator, implying overburden during the secondary events. By observing the above constraints upon the Sierra de Santa Maria, and utilizing T and compositional information from fluid inclusion analyses, the hydrothermal events are dated and hydrothermal fluid evolution in time is documented. (Authors' abstract) See following items. (E.R.)

GILMER, A.L. and HARDER, V.M., 1987b Temporally constraining hydrothermal events in igneous-related ore deposits with an example from Velardena, Mex. (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 676-677.

GILMER, A.L., PORTER, E.W. and CLARK, K.F., 1987, Hydrothermal fluid characteristics of the Sierra de Santa Maria Pb-Zn-Ag deposits, Velardena, Durango, Mexico (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Authors at Univ. Texas at El Paso, El Paso, TX.

The Sierra de Santa Maria in the Velardena mining district, Durango, Mexico, has within it a number of carbonate-hosted Pb-Zn-Ag deposits, the type for which Northern Mexico is famous. On and within the northeastern flank of the sierra, Po-Py-Sph-Cpy (Gal-Sb, Bi, Ag sulfosalts) mineralization in a gangue of white fluorite, quartz, and calcite exist within massive replacement pods inside a skarn zone adjacent to a quartz latite porphyry stock and around the lower portions of one major and several minor hypabyssal rhyolite dikes. The upper portion of the major rhyolite dike exhibits a silver-rich Py-Gal-Sph assemblage with a gangue of white fluorite, calcite and quartz within massive sulfide replacement bodies developed in the carbonate along the rhyolite-limestone interface. Disseminated and stockwork mineralization occurs within a number of small quartz latite porphyry and rhyolite "fingers" in the northeastern flank of the sierra as well. These ores exhibit an Asp-Gal-Sb sulfosalt (Sph-Ag sulfosalt) assemblage in a gangue of lavender fluorite. The southwestern portion of the sierra contains epithermal fissure-veins and veinlets exhibiting a Gal-Sph-Py (Ag, Sb sulfosalts) assemblage in a green fluorite gangue.[3]

Because of the variety of ore assemblages found in and on the northeastern flank of the Sierra de Santa Maria, it was commonly believed that several mineralizing events took place. Fluid inclusion analysis of P inclusions from the fluorites indicate that a single fluid of an average composition of 27 wt. % KCl and 30 wt. % NaCl was responsible for all the mineralization exhibited within the northeastern flank of the dome. The fluid inclusions also did not exhibit a significant T variation between the different deposits, indicating that changes in the chemistry of the fluid, rather than T, may have been important in precipitating the variety of sulfide assemblages in these deposits.

Fluid inclusions from the epithermal deposits on the southwestern flank of the sierra exhibit an average salinity of 18 wt. % NaCl equiv. and an average Th of 220°C. These deposits may or may not be related to the replacement deposits found on the northeastern flank of the dome. (Authors' abstract) See previous items. (E.R)

GILZEAN, M.N. and BRIMHALL, G.H., 1987, Nature of deep hydrothermal system near Red Mountain, Colorado (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 278.

GIORDANO, T.H. and DRUMMOND. S.E., 1987, Zinc acetate complexing in hydrothermal solutions (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 677.

GISLASON, S.R. and EUGSTER, H.P., 1987a, Meteoric water-basalt interactions. I: A laboratory study: Geochimica Cosmo. Acta, v. 51, p. 2827-2840.

GISLASON, S.R. and EUGSTER, H.P., 1987b, Meteoric water-basalt interactions. II: A field study in N.E. Iceland: Geochimica Cosmo. Acta, v. 51, p. 2841-2855.

GIULIANI, G., 1985, The Xihuashan tungsten deposit (South Jiangxi, China): Mineral. Deposita, v. 20, p. 107-115 (in French; English abstract). Author at 1, Rue Jean-Jaurès, 54300 Lunéville, France.

Includes some discussion (presumably from fluid inclusion work) of the probable composition of the fluids, and of immiscibility in the system $CO_2$-$CH_4$-$N_2$-NaCl-$H_2O$. (E.R.)

GIULIANI, Gaston, 1987a Fluid inclusion study from Xihuashan tungsten deposit in the South-Jiangxi Province (China): Int'l. Symp. on Granites and Associated Mineralizations, Salvador, Bahia, Brazil, Jan. 21-31, 1987, Extended Abstracts, p. 235-239. Author at ORSTOM-Caixa Postal 4021, Alameda da Barra Salvador-Bahia, Brazil.

Fluid inclusions in quartz veins from the Xihuashan W deposit contain aqueous and $CO_2$-bearing inclusions which homogenize in the liquid or vapor phase between +150°C and 420°C, with salinities of 1 to 10 wt%, eq. NaCl. The different peaks of Th and Tm ice record a number of discontinuous events during a continuous hydrothermal evolution of the system during cooling. The earlier fluids are of two kinds: - low density and salinity, $CO_2$-bearing aqueous solutions circulating at $<$ 420°C, - low salinity (2 to 3 wt% eq. NaCl) aqueous solutions, lacking of $CO_2$, circulating at 280°C to 400°C that correspond to a specific hydrothermal fracturing event; limited unmixing occurs at 380°C, 200 to 100 bar, probably in response to a sudden P drop.

The fluids related to the idiomorphic drusy quartz are typical $CO_2$-bearing aqueous solutions with low salinity (2.5 wt% eq. NaCl) and low to moderate Th (180°C to 340°C). (From the author's Conclusions)

GIULIANI, G., 1987b, The cassiterite zoning from the Sokhret Allal deposit (Zaër Granite, Central Morocco): Chemical composition and associated fluid phases: Mineral. Depostia, v. 22, p. 253-261 (in French; English abstract). Author at ORSTOM, Inst. Francais de Rech. Sci. pour le Dével. en Coop., Antenne de Salvador CP 4021, Alameda da Barra 40.000, Salvador da Bahia, Brazil.

The chemical composition of a zoned cassiterite from the W-Sn deposit of Sokhret Allal (Zaër granite, Central Morocco) has been analyzed with an electron microprobe. The mineral zoning is related to variable Fe, Ti, and Nb contents: the darker zone are enriched in Ti and Fe whereas lighter zones are purer. Fluid inclusions contemporaneous with cassiterite deposition are P, and the fluids are aqueous with a composition of 97-99 mol% $H_2O$ and 3-1 mol% eq. NaCl (T = 270-330°C) and were trapped in the liquid-stability field. The contribution of these data to the central Morocco W-Sn metallogenesis is discussed. (Author's abstract) See next item.

GIULIANI, G. and WEISBROD, A., 1986, Vein Sn-W mineralization of the Zaer massif, central Morocco (abst.): Colloque européen: gisements de tungstène: métallogénie, exploration, minéralogie, Toulouse, 12-14 May 1986, p. 91-92 (in French). First author at CRPG, P.B. 20, 54501 Vandoeuvre-lés-Nancy, France.

Sn and W vein mineralization occurs at three sites in altered 279 ±11 Ma two-mica granites intruding Ordovician-Devonian metasediments in the Zaer massif. At Ferme Paquis, quartz veins bear cassiterite, scheelite, molybdenite and subordinate bismuth. At Sokret Allal, the paragenetic sequence is: Oxides I: quartz, muscovite, rutile, cassiterite, wolframite; Oxides II: quartz, adularia, apatite, wolframite; Oxides III: quartz, rutile, cassiterite, scheelite, pyrite; Sulfides: quartz, arsenopyrite, pyrite, chalcopyrite, sphalerite. Sn-bearing greisen is weakly developed in vein walls. At Koudiat Chbeika, veins consist of barren quartz, quartz + scheelite + arsenopyrite, and quartz + wolframite + scheelite + sulfides. Fluid inclusions in the Sokret Allal veins indicate the following evolution of fluid character: 1. Low-density, low-salinity aqueous fluid containing 12-17% $CO_2$, 3-5% $N_2$, 0.5-1% $CH_4$; minimum T 340-400°C; Tt probably 400-500°C; P 400-800 bars. 2. Low-salinity aqueous fluids of higher density, 5-9% $CO_2$, 1-1.5% $N_2$, 0.1-0.4% $CH_4$; minimum T 310-360°C; Tt probably 350-400°C. 3. Aqueous fluids, minimum T 240-320°C, Tt probably 250-330°C. 4. Aqueous fluids, 5-10 wt % NaCl, minimum T 290-330°C. 5. Aqueous fluids, 5-10 wt % NaCl, minimum T 190-270°C. Tt values are similar to minimum T in 4 and 5. During stages 1 to 3, $CH_2/N_2/CO_2$ ratios remained constant, but $CH_4$ + $N_2$ + $CO_2/H_2O$ diminished with falling T. Deposition of W and Sn resulted from mixing of hot, reducing fluid-bearing C-species with cooler, slow-salinity aqueous fluid. (Summary by C.J. Eastoe) See previous item.

GIZE, A.P. and BARNES, H.L., 1987, The organic geochemistry of two Mississippi Valley-type lead-zinc deposits: Econ. Geol., v. 82, p. 457-470. Authors at Ore Deposits Res. Sec., The Pennsylvania State Univ., University Park, PA 16802.

The organic matter associated with two Mississippi Valley-type deposits (Gays River, Nova Scotia, and Shullsburg, southwestern Wisconsin) has been characterized by petrographic, isotopic, spectrophotometric, gas chromatographic, and mass spectral methods. Comparisons were made of distributions of organic species identified from unmineralized and mineralized samples. The primary variations in the distributions of organic species isolated from the two deposits reflect variations in host-rock paleoecology, facies, and geologic age. Secondary effects were microbial degradation, thermal maturation, and mineralization. The genetic model tested in this study presumed that mineralizing brines evolved from sedimentary basins and migrated to the ore host rocks. (From the authors' abstract)

GLASMACHER, U. and FRIEDRICH, G., 1987, Metallogenesis of the gold-silver occurrences in Yukon-Tanana Terrain (Yukon Territory, Canada) (abst.): Fortschritte der Mineralogie, Bd. 65, Bhf. 1, p. 59 (in German). Authors at Rheinisch-Westfälische Technische Hochschule, Aachen, FRG.

The Yukon-Tanana area consist of Precambrian to Paleozoic metasediments, metavolcanites and orthogneisses. At the Cretaceous/Tertiary border calc-alkaline magmatism in a subduction zone developed, altering from andesitic to dacitic lavas and pyroclastic sediments. Next the hydothermal system

Table. Conditions of formation of various mineral parageneses

| Mineral paragenesis | Th, °C | NaCl equiv., wt. % | pH | log $aS_2$ | log $aO_2$ | m(Na + K), mole/l |
|---|---|---|---|---|---|---|
| 1. Mineralization in the metamorphic basement | | | | | | |
| Arsenopyrite-Au-pyrite-quartz | 305 | 7.3 | 4-5 | -10 to -11 | | 1.3 |
| Galena-sphalerite-pyrite-chalcopyrite-siderite-ankerite-quartz | 245 | | 7-8 | -13 to -14 | -40 to -41 | |
| Pyrite-pyrrhotite-mackinawite-chalcopyrite-bismuth-quartz | 265 | 19.5 | 4-5 | -12 to -13 | -40 to -41 | 3.3 |
| Arsenopyrite-Au-galena-tetrahedrite-pyrite-quartz | 200 | 10.8 | 5-6 | | -42 to -48 | 1.8 |
| Freibergite-chalcopyrite-quartz | 145 | 13.5 | 5-6 | | | 2.3 |
| 2. Mineralization in volcanic rocks | | | | | | |
| Pyrite-arsenopyrite-Au-quartz | 270 | 9.3 | 4-5 | -9 to -13 | -36 to -40 | 1.6 |
| Galena-sphalerite-pyrite-arsenopyrite-freibergite-polybasite-siderite-ankerite-quartz | | | >7 | | | |

developed in this complex, which caused the origin of Au and Ag mineralization and very intensive alteration of the wall rocks. Native Au occurs exclusively in paragenesis with arsenopyrite and pyrite. Ag appears in Au-Ag alloys, as mathildite, freibergite, polybasite, in galena and in tetrahedrite. Microthermometric studies indicated the formation temperatures [sic] 200-305°C and salinity 7.3-10.8 wt. % NaCl eq. for Au and 145-200°C and 10.8-13.5 wt. % NaCl eq. for freibergite and polybasite.

On the above basis one may determine that Au was transported as hydrogen sulfide complexes and Ag as chloride complexes. Calc-alkline volcanic rocks, stratabound lenses of galena, pyrrhotite and pyrite in metamorphic basement, and metasediments might be a source of the precious metals. The average contents equal 28 ppb Au and 54 ppb Ag in volcanic rocks, 1 ppm Au and 48 ppm Ag in sulfide lenses and 5 ppb Au and 840 ppb Ag in metasediments. (Authors' abstract, translated by A.K.)

GLASSLEY, William, 1987, Mineral stability and element mobilitiy in fluid-bearing systems under deep crustal conditions (abst.): Abstracts, NATO Advanced Research Workshop, Fluid movements, element transport, and the composition of the deep crust, Lindås, Norway, 18-24 May, 1987 (unpaginated).

GLYUK, D.S. and SHINAKIN, 1986, The role of liquid-immiscibility differentiation in the pegmatite process: Geokhimiya, no. 4, p. 445-457 (in Russian; translated in Geoch. Int'l., v. 23, no. 7, p. 38-49, 1987). Authors at Inst. Geochem., Siberian Div., Acad. Sci. USSR, Irkutsk, USSR.

Experiment shows that liquid immiscibility occurs in a granite system on account of alkali metals, fluorine, water, phosphorus, boron, $CO_2$, and various other components. These accumulate in the residual liquid and may cause immiscibility. These phenomena are particularly characteristic of the pegmatite process, since granitic pegmatites are formed from liquids rich in volatiles and fluxing components (alkalis). Immiscibility requires conditions favorable to the accumulation of excess components: prolonged temperature stability and plastic deformation in the country rocks during differentiation. The immiscibility may occur in one or several stages, which can give rise to pegmatite bodies of complicated structure with distinct zones of contrasting composition. (Authors' abstract)

GOELLNICHT, N.M., 1987, Constraints on the timing and source of gold mineralization at Main Dome, Telfer, Western Australia: B.S. thesis, Dept. Geol., The Univ. Western Australia, Nedlands (unpub.), 78 pp.

Telfer, in the Paterson Province, is the largest single producing Au mine in Western Australia. Stratiform to stratabound Au-Cu mineralization, in quartz-sulphide reefs, is hosted by a Middle Proterozoic, fine-grained turbidite sequence. Most models postulate a modified syngenetic origin, and emphasize the continuous, stratiform nature of the auriferous Middle Vale Reef (MVR) and its internal sedimentary structures. This study, of the controls and timing of primary mineralization, is based on recent drilling of the hypogene ore at Main Dome, and has important implications for an epigenetic model.

Textural and geochemical studies indicate that within the MVR, most of the sulphides are epigenetic, and replace calcareous mudstones and siltstones, which locally contain some carbonaceous material. The Pb isotopic composition of pyrites in discordant veins and the MVR are atypical of Precambrian syngenetic mineralization, and are isotopically indistinguishable from galena in nearby granitoid-related skarn deposits. The data are best explained by mixing of Pb from a granitic source, with Pb from the host rock (or basinal brines) at the time of granitoid emplacement (738±20 Ma).

Fluid inclusions in vein- and MVR-quartz are highly saline (up to 54 wt.% NaCl eq.) and have moderate to high Th (225°C-441°C). They comprise a complex mixture of salts dominated by NaCl with variable proportions of $CO_2$, and are characteristic of trapping of immiscible fluids. Maximum trapping T are greater than 430°C at fluid P of ~ 2 kb. P mineralizing fluids are probably of a deep-seated magmatic origin, and have mixed with cooler, low-salinity formation waters and/or have reacted with host-rock carbonate.

The composition of the ore fluid, temperature of ore deposition, and pyrite geochemistry are similar to those of porphyry Cu and Sn-W-Mo deposits, and the temporal relationship with granitoid plutons indicate that mineralization fluids at Telfer may be of magmatic origin.

Telfer is interpreted as an epigenetic vein-hosted replacement deposit in which Au mineralization is controlled by both structure and composition of the host rocks. Hot, saline magmatic fluids which have mixed with cooler, low-salinity meteoric or formation waters, have introduced Cu and Au during regional deformation. (From the author's abstract)

GOLD, T., 1987, The origin of terrestrial helium, its association with hydrocarbons, and the interpretation of its isotopic composition (abst.): Applied Geochem., v. 2, p. 133-134.

GOLD, T. and HELD, T., 1987, Helium-nitrogen-methane systematics in natural gases of Texas and Kansas: J. Petr. Geol., v. 10, no. 4, p. 415-424. First author at Cornell Univ., Ithaca, NY, USA.

The data place constraints on the origin of the three gases, and suggest that they all derive from sources deeper than the sedimentary layer. (From the authors' abstract)

GOLDFARB, R.J., LEACH, D.L., LIGHT, T.D., PATERSON, C.J., PICKTHORN, L.B. and PICKTHORN, W.J., 1987, The Juneau gold belt: A Mother Lode-type system in southeastern Alaska (abst.): Geol. Soc. Am. Abst. with Programs, v. 19, p. 382. First author at USGS, Box 25046, DFC, Denver, CO 80225.

Deposits of the Juneau gold belt have yielded 75% of Alaska's lode gold and stretch for 200 km along the western flank of the Cretaceous to Eocene Coast Range batholith. Gold-bearing quartz veins are confined to a 6-km-wide zone of black slate, phyllite, greenstone, and diorite exposed along the Coast Range megalineament. Intense carbonatization, sulfidization, and silicification characterize wall rock alteration in many of the deposits.

Fluid inclusion studies indicate that $CO_2$-$H_2O$-NaCl fluids were trapped at depths of at least 5 km, sometimes from a boiling system. Stable isotope analyses indicate relatively heavy ore-forming fluids and are inconsistent with any type of system dominated by deeply circulating meteoric water. A K-Ar age of 55.3 ± 2.1 Ma for the Alaska-Juneau deposit and the fact that gold-bearing veins crosscut regional metamorphic fabric are evidence that mineralization postdates nearby late Cretaceous and Paleocene igneous activity. Eocene igneous bodies, though unmetamorphosed, are not exposed within 15 km of the gold belt.

Our data support a model in which deep-seated, ore-forming fluids were produced during prograde metamorphism of underthrusted crust associated with rapid, early Tertiary convergence in southeastern Alaska. These fluids may have been expelled rapidly upward, along major shear zones, into retrograding regions of the metamorphosed pile. Alternatively, the fluids may have been trapped along impermeable boundaries until thermal expansion of the fluids and/or rapid regional uplift dilated the major crustal flaws and focused fluid flow to higher crustal levels. The geologic setting, fluid inclusion data, and common alteration assemblages resemble those of the California Mother Lode deposits. (Authors' abstract)

GOLDSMITH, J.R., 1987, Al/Si interdiffusion in albite: Effect of pressure and the role of hydrogen: Contrib. Mineral. Petrol., v. 95, p. 311-321. Author at Dept. Geophys. Sci., The Univ. Chicago, 5734 S. Ellis Ave., Chicago, IL 60637, USA.

See Goldsmith, 1986, Fluid Inclusion Research, v. 19, p. 154-155. (E.R.)

GOLDSTEIN, R.H., 1987, Extent of reequilibration of fluid inclusions during burial diagenesis (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Author at Univ. Kansas, Dept. Geol., 120 Lindley Hall, Lawrence, KS 66045.

Recent studies have clearly shown that some fluid inclusions in calcite, trapped at low T, tend to reequilibrate during the heating of deeper burial. In an inclusion population, many variables control reequilibration, so some inclusions may remain unaltered, and others may reequilibrate by wall-stretching with no leakage or reequilibrate by leakage and opening to burial pore fluids before resealing. On a plot of Th versus Tm ice, such a population might show two convergent lines, one describing unchanging Tm ice and variable Th and the other describing decreasing Tm ice (increasing salinity) with increasing Th. Both lines would converge on the point of lowest Th and highest Tm ice (lowest salinity). The first line would be caused by stretching of the unaltered fluid inclusions and the second line would be caused by reequilibration resulting from the opening and resealing of fluid inclusions during the general increase in salinity and T accompanying burial. The point of convergence is representative of the original Th and Tm ice of the unaltered population of fluid inclusions. Deep burial calcite cements from the Pennsylvanian Holder Formation show such convergent trends. Therefore, the original conditions of cement growth can be interpreted from a reequilibrated population of fluid inclusions. The fluid inclusions indicate cement growth at about 100°C from an ~9 wt. % NaCl equiv. fluid. Application of convergent reequilibration trends should be limited to analysis of P fluid inclusions within a single compositional cement zone and would be most effective for cements that precipitated at ~50°C or higher, the fluid inclusions of which reequilibrated during the increasing salinities and T of deeper burial. (Author's abstract)

GONZALEZ, C.M. and McKIBBEN, M.A., 1987, Thermal history of vein mineralization in CSDP corehole VC-2A, Sulphur Springs, Valles Caldera, New Mexico (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 679. Authors at Dept. Earth Sci., Univ. California, Riverside, CA 92521.

CSDP corehole VC-2A penetrated 528 m of altered intracaldera tuffs and volcaniclastic rocks in the western ring-fracture zone of the Valles Caldera at Sulphur Springs, New Mexico. Because of the existence of acid sulfate springs and isotopically-light fumarole steam, the part of the geothermal system penetrated by VC-2A is now thought to be vapor-dominated (Goff et al., 1985, JV&GR).

Veins and vugs containing quartz, molybdenite, pyrite, fluorite, calcite and rhodocrosite occur in the upper 170 m of VC-2A. Textures of the mineralization require formation from a liquid phase, implying that this part of the geothermal system was at one time liquid-dominated. We have made a detailed study of fluid inclusions in quartz and fluorite in order to assess the thermal history of the geothermal system.

More than 95% of the inclusions were liquid-dominated with uniform L/V ratios. A few inclusions were either empty or had leaked; they exhibited no phase changes upon freezing or heating. Tm ice ranged from -0.7 to +0.6°C, with positive values occurring in inclusions that either failed to nucleate a bubble after freezing or exhibited possible clathrate melting. The negative values indicate that trapped fluids contain NaCl equiv. salinities of no more than 1.2 wt.%. No significant differences in salinity were observed between inclusions in quartz and fluorite.

Significant differences in Th were noted between quartz and fluorite. Th in quartz ranged from 157 to 238°C, with the higher values occurring at depths of 30 and 134 m. T in fluorite were lower, ranging from 150 to 199°C at 59 and 164 m. Texturally, fluorite appears to be younger than quartz, implying a cooling trend during mineralization. If downhole T logs are accurate, the upper system has cooled by as much as 150°C since quartz-fluorite mineralization from liquid-dominated fluids. (Authors' abstract)

GRAHAM, D.W., JENKINS, W.J., KURZ, M.D. and BATIZA, Rodey, 1987, Helium isotope disequilibrium and geochronology of glassy submarine basalts: Nature, v. 326, p. 384-386. First author at Dept. Chem., Woods Hole Oceanographic Inst., Woods Hole, MA 02543, USA.

We show that isotope disequilibrium in the $^3$He/$^4$He ratio between helium trapped in vesicles and that dissolved in the glass phase of some young seamount basalts can be used to determine (U + Th)/He ages for the basalts. We use the $^3$He/$^4$He in vesicles (extracted by crushing in vacuo) to correct the dissolved phase He (by fusion of the remaining powder) for the inherited component, and compute the radiogenic helium concentration. (From the authors' abstract)

GRAMBLING, J.A., 1987, Ilmenite inclusions in garnet: Monitors of simultaneous changes in pressure, temperature and fluid composition during the progressive metamorphism of graphite-bearing rocks (abst.): Abstracts, NATO Advanced Research Workshop, Fluid movements, element transport, and the composition of the deep crust, Lindås, Norway, 18-24 May, 1987 (unpaginated).

GRANT, G.L., 1987, Fluid evolution in the Pb-Zn-Ag deposits of the San Francisco Del Oro/Santa Barbara hydrothermal system based on mineralogic, metal zonation and fluid inclusion studies: MS thesis, Univ. Arizona, Tucson.

Mid-Tertiary polymetallic quartz-sulfide vein deposits of the San Francisco Del Oro/Santa Barbara district are hosted by the Cretaceous Parral shale. Significant production has come from vein ores and from several vein related massive sulfide replacement bodies.

Early massive sulfide-rich veins are cut by veins rich in calc-silicates, quartz, and late sulfides. This group is cut by two stages of post-ore quartz-fluorite-calcite veins with minor sulfides.

Stage 1 veins are characterized by massive sphalerite, galena and quartz, with weak alteration halos of epidote, axinite, chlorite, quartz and minor andradite. Stage 1 vein quartz was precipitated from 250°C to 320°C solutions with salinities ranging from 2 to 14 wt. % NaCl eq. Vein related replacement bodies were also formed during this stage of hydrothermal activity. Stage 2 veins are characterized by an abundance of skarn minerals within the veins, a change in sulfide mineralogy to 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 on late Stage 2 quartz range from 180°C to 300°C and salinities range from 1 to 14 wt. % NaCl eq. Stage 3 and 4 veins are characterized by quartz, calcite, and fluorite. These veins were formed by 220°C to 260°C fluids with salinities ranging from 1 to 3 wt. % NaCl eq.

Ore-bearing fluids varied widely from 180°C to 320°C and chloride concentration (<1 to 14 wt. % NaCl eq.) in a given stage. Boiling was not an important mechanism for ore deposition.

There are systematic decreases in the ratios of Cu/Pb (from 0.80 to <0.10), Cu/Zn (from 0.38 to 0.01), and in Zn/Pb (from 3.2 to 0.5) to the north, indicating that fluids may have emanated from the south. The deposits were probably emplaced during several episodes, representing the superposition of at least two distinct hydrothermal systems. The systems may correspond with an andesitic magmatic event Ca. 32 Ma. ago, and a rhyolitic magmatic event Ca. 26 Ma. ago. (Author's abstract, edited by C.J. Eastoe)

GRANT, N.K. and CHALOKWU, C.I., 1987, The abundance, composition and distribution of S in the trapped liquid of the Partridge River intrusion, Duluth Complex (abst.): Geol. Soc. Amer. Abstracts with Programs, v. 19, no. 4, p. 201. First author at Geol. Dept., Miami Univ., Oxford, OH 45056.

The troctolitic and gabbroic rocks contain a compositionally uniform trapped liquid which is similar to ferro-diorites associated with the anorthosites of the Nain Province.

The high S zones [in the trapped liquid] may have involved the formation of an immiscible sulphide liquid, but the absence of S-depleted trapped liquid elsewhere suggests sulphide immiscibility was established prior to the emplacement of the Partridge River Intrusion. (From the authors' abstract)

GRATZ, J.F. and MISRA, K.C., 1987, Fluid inclusion study of the Gordonsville zinc deposit, central Tennessee: Econ. Geol., v. 82, p. 1790-1804. First author at U.S. Environ. Protection Agency, 26 Federal Plaza, New York, NY 10278.

A complementary paragenetic and fluid inclusion investigation of the carbonate-hosted Gordonsville Zn deposit was undertaken to trace thermal and chemical evolution of the mineralizing fluid. The following paragenetic sequence was established from field and petrographic study: white (early) calcite-sphalerite-galena-fluorite--white to lavender (main stage) calcite-barite--clear to amber (late stage) calcite. Sphalerite occurs in three textural varieties: disseminated (yellowish brown), massive (reddish brown), and vug fill (dark brown). The disseminated sphalerite, with somewhat lower Fe and Cd contents, may represent an earlier stage of mineralization, but its fluid inclusion characteristics are similar to the other two.

Th and [Tm ice] of two-phase (liquid + vapor) inclusions show a pronounced change in the nature of mineralizing fluids between early-stage and late-stage minerals. The early-stage minerals (early calcite through main-stage calcite) precipitated from moderately hot (97°-133°C) and highly saline Na-Ca-Mg-Cl fluids (salinity 21-23 eq wt % NaCl). Variations in Th of the early-stage minerals probably reflect periodic influx of basinal fluids of similar salinities. However, the lack of correlation between Th and [Tm] suggests, but does not prove, that fluid mixing was not the cause of precipitation of these minerals. The fluid inclusion data for sphalerite are consistent with its emplacement from a single solution carrying both Zn and S, although the model remains untested without a knowledge of the pH of the Gordonsville ore fluid.

The late-stage minerals (barite and late-stage calcite) precipitated from a fluid of somewhat lower T (96°-122°C) but markedly lower salinity (7-9 eq wt % NaCl), suggesting an influx of a more dilute fluid, probably heated meteoric water, at the end of main-stage calcite deposition. (Authors' abstract)

GRAY, J., CHANGKAKOTI, A. and MORTON, R.D., 1987, Simultaneous extraction of hydrogen and oxygen from fluid inclusion waters for isotopic analysis (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). First author at Dept. Physics, Univ. Alberta, Edmonton, AB Canada T6G 2J1.

Oxygen and hydrogen isotope ratio variations have been used extensively in the study of ore bodies. While a number of workers have measured $^{18}O/^{16}O$ (Rye and O'Neil, Ec. Geol., 63, 232, 1968) and D/H ratios (Ohmoto and Rye, Ec. Geol., 69, 947, 1974) in fluid inclusion waters very few reports of both $^{18}O/^{16}O$ and D/H measurements on the same sample have been reported. (Knauth and Beeunas, GCA, 50, 419, 1986, recently reported such a study on fluid inclusions in halites where large water samples were available and conventional techniques could be applied.) The primary reason for this is small sample size (often 1-5 mg of water).

The normal procedure where both D/H and $^{18}O/^{16}O$ data are not available is to measure D/H ratios of the extracted ore fluid and to subsequently calculate the $^{18}O/^{16}O$ composition of the fluid from the measured $^{18}O/^{16}O$ composition of the host mineral. This is often done using T obtained by microthermometry on the inclusions of the host mineral and the appropriate mineral-water fractionation equation. However there are inherent errors in the T obtained by microthermometry and furthermore the mineral-water fractionation equations normally assume pure water, whereas hydrothermal fluids are frequently saline brines. Thus there may be discrepancies between the calculated $\delta^{18}O$ of the included water and the true value obtained directly from the included water (Rye and O'Neil 1968; Truesdell, EPSL, 23, 398, 1974).

A technique described by Gray et al. (Int. J. App. Radiat. Isot., 35, 525, 1984) is being applied to fluid inclusion waters. In this approach water samples (2-10 mg) are pyrolysed with carbon in a nickel reaction vessel. The hydrogen produced in the reaction $H_2O+C \rightleftarrows CO+H_2$ diffuses through the nickel walls where it is collected. The reaction thus goes to completion leaving CO (and $CO_2$) in the reaction vessel. In this way the hydrogen and oxygen components are separated and isotopic analysis for $\delta^{18}O$ and $\delta D$ may then be carried out.

Initial results for the method applied to standard waters have been obtained and comparison with results obtained using conventional methods show excellent agreement. The technique is being applied to non-oxygen-bearing minerals from a number of ore deposits and to a number of oxygen-bearing minerals to evaluate oxygen exchange effects. Results from these investigations will be presented. (Authors' abstract)

GRAZIANI, Girgio, GÜBELIN, Edward and MARTINI, Maurizio, 1987, The Lennix synthetic emerald: Gems & Gemol., v. 23, p. 140-147. First author at Univ. Rome, Italy.

Presents color plates of fluid and solid inclusions characteristic of these synthetic emeralds. (H.E.B.)

GREELEY, Ronald, 1987, Release of juvenile water on Mars: Estimated amounts and timing associated with volcanism: Science, v. 236, p. 1653-1654.

GREEN, D.H., FALLOON, T.J. and TAYLOR, W.R., 1987, Mantle-derived magmas--roles of variable source peridotite and variable C-H-O fluid compositions, in B.O. Mysen, ed., Magmatic Processes: Physicochemical Principles: Geochem. Soc. Spec. Pub. 1, p. 139-154.

GREEN, H.W., TINGLE, T.N. and FINNERTY, A.A., 1987, Diffusion of carbon in olivine at high pressure: Speciation and the effect of hydrogen (abst.): EOS, v. 68, p. 417. Authors at Dept. Geol., Univ. California, Davis, CA 95616.

Previous experiments to measure the solubility and diffusivity of carbon in San Carlos olivine at 3.0 GPa using $CO_2$ and $CO_2$-$H_2O$ fluids pointed out that either the presence of elemental carbon and/or hydroxyl species catalyze the incorporation of carbon. The solubility of C in olivine annealed at 3.0 GPa and 1200°C in $CO_2$-$H_2O$ was determined to be 100 wt. ppm C with a diffusivity of $\ln D = -11\ cm^2/s$. The diffusivity at the same conditions using $CO_2$ is less than $\ln D = -12\ cm^2/s$. To elucidate the catalyzing agent, we have annealed olivine in a mixture of carbon-14 labelled amorphous carbon and graphite with and without water present. Concentration gradients are determined by beta track autoradiography and new results will be presented.

Improved sample assemblies for solid medium apparatus which allow retrieval of relatively large (1-2 mm) uncracked specimens from high pressure, combined with very small apertures (25-200 μm) for Fourier transform infrared spectrometers have allowed us to measure hydroxyl contents on specimens annealed in the presence of water where $f(O_2)$ is buffered by graphite-$CO_2$. Preliminary results at 3.0 GPa are in agreement with those of Mackwell et al. (1985) at 1.5 GPa that olivine can dissolve up to a few hundred ppm water-related species, in addition to a hundred ppm C (Tingle et al., 1987). (Authors' abstract)

GREGG, J.M. and HAGNI, R.D., 1987, Irregular cathodoluminescent banding in late dolomite cements: Evidence for complex faceting and metalliferous brines: Geol. Soc. Am. Bull., v. 98, p. 86. First author at Geol. Res. Lab., St. Joe Minerals Corp., P.O. Box 500, Viburnum, MO 65566.

Irregular cathodolominescent growth banding occurs in late diagenetic dolomite cements in the Bonneterre Dolomite and Davis Formation (Cambrian), southeastern Missouri. The dolomite cements were precipitated by warm basinal brines and are paragenetically related to the sulfide mineralization of the Viburnum Trend Mississippi Valley-type lead-zinc district. Universal stage microscopy has revealed that the irregular growth bands correspond to complex (noncleavage rhombohedron) crystal faces that developed during growth of the dolomite cements. During later stages of crystal growth, the cleavage rhombohedron became the dominant morphological form, and the earlier complex faces disappeared. Similar complex faceting has been observed elsewhere, where dolomite and halite occur together. We speculate that metal cations in the chloride-rich, mineralizing brines had a "poisoning" effect on growing dolomite surfaces which allowed the complex crystal faces to develop. (Authors' abstract)

GRIGSBY, C.O., GOFF, Fraser, SHEVENELL, Lisa, ARCHULETA, J., CRUZ, J., TRUJILLO, P.E., COUNCE, D., BAYHURST, G.K., JANIK, C.J., WHITE, A.F. and CARSON, C., 1987, Downhole fluid sampling and analytical data for the SSSDP well, Salton Sea, California (abst.): EOS, v. 68, p. 454. First author at Los Alamos Nat'l. Lab., Los Alamos, NM 87545.

In-situ fluid sampling activities were conducted at SSSDP well during December 1985, and March 1986, to obtain unflashed samples of brine. Three sampling runs were made to depths of 1800 m and temperatures of 300°C in December, whereas ten sampling runs were made to 3150 m and 350°C in March. The Los Alamos tool obtained samples from 4 of 8 runs, the LBL tool obtained 1 sample from 1 run, the Luetert tool obtained samples from 0 of 3 runs, and the USGS quartz crystal experiment was lost downhole. Tritium analyses show that produced fluids were contaminated by drilling fluids during the

March flow test. Contamination is also shown by mixing lines when plotting ρ, B, etc. vs. Cl and δD vs. $\delta^{18}O$ of downhole samples. The uncontaminated downhole composition of brine can be estimated by the intersection of the mixing line and the steam fractionation line (surface steam and flashed brine) on the δD vs. $\delta^{18}O$ plot. The uncontaminated brine at 351°C and 296 bars has $\rho = 0.998$ ($g/cm^3$); 0.77 $SiO_2$, 29.9 Ca, 57.2 Na, 18.9 K, 1.56 Fe, 1.40 Mn, 157 Cl, 2.33 $HCO_3$, 0.16 $H_2$, 0.017 $N_2$, 0.33 $CH_4$, 0.004 $H_2S$, 0.007 $SO_4$, 0.30 B, 0.11 Br, 0.27 $NH_4$, 0.58 Zn, 0.12 Pb, 0.004 Ag (all in g/Kg); and -75.0 δD and +2.00 $\delta^{18}O$ (‰). (Authors' abstract)

GRISHINA, S.N., 1987, $H_2S$-bearing inclusions in recrystallized halite: Chem. Geol., v. 61, no. 1/4, p. 91-94.

Full paper for abstract in Fluid Inclusion Research, v. 18, p. 153-155, 1985. (E.R.)

GRISHINA, S.N., DUBESSY, J., KONTOROVICH, A.E. and KUDRINA, T.R., 1987, Inclusions in Cambrian salts of the Bakhtin megaprojection as the indication of conditions for the formation and preservation of oil and gas deposits: Geologiya i Geofizika 1987, no. 12, p. 31-38 (in Russian; English abstract).

The composition of fluid and solid inclusions in salts has been studied from deep wells of the Bakhtin megaprojection. Identified are sulphur bands lacking carbon dioxide admixture, bands with high content of carbon dioxide showing no solid phases and carbon acidic ones with crystalline or amorphous sulphur. Oil-producing sulphate rocks and dolomites reconstructed in the zone of contact with intrusions are believed to be the source for the inclusion constituents. (Authors' abstract)

GROVES, I.M., 1987, Epithermal/porphyry style base-metal and precious-metal mineralization in the Miralga Creek area, eastern Pilbara Block: B.S. thesis, Dept. Geol., The Univ. Western Australia, Nedlands (unpubl.), 82 pp.

At the Miralga Creek Prospect in the eastern Pilbara, subeconomic Au-Ag and base-metal mineralization (dated at ca 3.42 Ga) is associated with a stock-like Archaean felsic-porphyry intrusion and related high-level porphyry dikes.

Disseminated, stringer, vein and hydrothermal (hydraulic) breccia-hosted mineralization is found throughout the marginal intrusive-breccia of the porphyry stock and adjacent to porphyry dikes. Four discrete phases of sulphide deposition are recognized in the one mineralizing event: 1) pyrite and minor chalcopyrite; 2) chalcopyrite; 3) sphalerite and galena; and 4) tetrahedrite-tennantite, chalcopyrite and Ag minerals (±Au). The metallogenic association is Zn-Pb-Cu-As-Ag-Sb-Au-(Hg-Bi-Mo-Tl-Se), and vertical metal zonation results in enrichment of Au, Pb, Zn and Cu at different levels in the system. Quartz and carbonate gangue minerals in stringers and veins have equigranular to microcrystalline textures, with locally well-developed zones of cockade and comb structures and crustiform banding.

Porphyry-related alteration is most intense within the porphyry stock, and adjacent to porphyry dikes and mineralized zones. A 1 km-wide alteration halo surrounding the porphyry stock is dominated by mineral assemblages formed during potassium metasomatism (quartz, muscovite, pyrophyllite and lesser amounts of pyrite, rutile and phlogopite) and subsequent carbonation (ankerite and siderite).

Fluid inclusion studies indicate that two fluids of different origins were involved in mineralization; 1) a high-T (i.e., >600°C), high-salinity (i.e., <70 wt% NaCl eq.) magmatic fluid evolved from the porphyry stock; and 2) a low-T (i.e., <250°C), low- to medium-salinity (i.e., <13 wt% NaCl eq.), seawater-dominated fluid (determined by C- and O-isotope studies) associated with mineralization. Mixing of these two fluids, during the evolution of the mineralizing system, probably caused deposition of ore minerals. The features of this system are consistent with a continuum between epithermal- and porphyry-Cu-style mineralization. Epithermal-style mineralization in Archaean terrains has not previously been documented. (From the author's abstract)

GRUNDMANN, G. and MORTEANI, G., 1987, Multistage emerald formation in regional metamorphism: Case studies from Gravelotte, South Africa, and Habachtal, Austria (abst.): Terra Cognita, v. 7, no. 2-3, p. 292. Authors at Lehrstuhl für Angewandte Min., Tech. Univ., München, FRG.

Fluid inclusions in emerald (Habachtal) match those in quartz from synmetamorphic alpine clefts. (E.R.)

GÜBELIN, E., 1987a, Diagnosis of new synthetic emeralds: Rev. de gemm. a.f.g., 1987, no. 92, p. 5-7 (in French).

Presents 2 pages of color plates that illustrate various solid and fluid inclusions. (H.E.B.)

GÜBELIN, E., 1987b, The diagnostic properties of the latest synthetic stones: The Australian Gemm., v. 16, no. 9, 1988, p. 329-345. Author at Meggen, Switzerland.

Presents colored plates and detailed discussion of fluid and solid inclusions in the Lennix-, Biron-, Soviet-, Seiko-synthetic emeralds, Seiko-, Lechleitner-synthetic corundums, and Knischka-synthetic rubies. (H.E.B.)

GÜBELIN, E.J. and KOIVULA, J.I., 1987, Chalcedony and its inclusions: Lapidary J., v. 40, p. 27-34.

Reprinted from Gübelin et al., 1986 (Fluid Inclusion Research, v. 19, p. 166-167). (E.R.)

GUHA, Jayanta and KANWAR, Ram, 1987, Vug brines-fluid inclusions: A key to the understanding of secondary gold enrichment processes and the evolution of deep brines in the Canadian Shield, in Saline water and gases in crystalline rocks, eds., Fritz, P. and Frape, S.K.: Geol. Assoc. Canada Special Paper 33, 1987, p. 95-101. First author at Sci. de la Terre, Univ. Québec à Chicoutimi, Chicoutimi, Québec, Canada G7H 2B1.

A systematic evaluation of $CaCl_2$-NaCl-$CH_4$ fluid-bearing vugs in the Copper Rand mine in the Chibougamau mining district indicates that zones of anomalously high Au concentration are spatially associated with these vugs. They occur in late structures and the Au mineralization in them has a completely different character from that found in the majority of the deposit. The latter is in the form of finely dispersed native Au grains associated with pyrite and chalcopyrite whereas the former contains nuggets of varying dimensions associated with quartz and carbonate fillings.

Based on structure, lithology, fluid inclusions and isotope data of these deposits it is postulated that the formation of nugget type Au occurred after the initial mineralizing period. The fluids in the vugs, which are comparable to the "deep brines" in their chemical and isotopic composition, are modified formation waters that infiltrated from the Proterozoic sedimentary basin during the stages of shearing.

This study also suggests the possibility that some of the other "deep brines" reported in the Canadian Shield may have similar origins and that the correlation between these brines and Au enrichment needs more investigation. (Authors' abstract)

GUHA, J., LANGE-BRARD, F., PÉLOQUIN, S., TREMBLAY, A., RACICOT, D. and BUREAU, S., 1984, Devlin deposit, a part of an Archean porphyry system?: Chibougamau-Stratigraphy and Mineralization, eds., J. Guha and E.H. Chown, CIM Spec. Vol. 34, p. 345-356. First author at Sci. de la terre, Univ. Quebec à Chicoutimi, Chicoutimi.

The Devlin copper deposit consists of a flat-lying vein and a network of steeply dipping mineralized veinlets hosted by leucotonalite of the Chibougamau Pluton. Widespread selective alteration of the leucotonalite, followed by multiple alteration veining stages characterize the deposit. Fluid inclusions associated with the mineralization indicate low T, variable salinities with a variety of dms, and a vapor-dominated phase. The fluid shows evidences of boiling at shallow depths. From the alteration characteristics and the fluid data it is inferred that the Devlin deposit is the near-surface expression of a porphyry system. (From the authors' abstract)

GUIJARRO GALIANO, J., MONSEUR LESPAGNARD, J. GUITERREZ MAROTO, A. and MEDINA NUÑEZ, J.A., 1987, Wolframite ore contained in the adamellite batholith in Trujillo (Cáceres, Spain): Boletín Geol. y Minero., v. 98, p. 49-57 (in Spanish; English abstract).

The study, by means of a Leitz heating stage (model 350), of the Th of the primary fluid inclusions in quartz has provided the following result: Th = 236 to 280°C. It is concluded that the wolframiferous ore deposit of Trujillo belongs to the pneumatolytic-hydrothermal classical type. (From the authors' abstract)

GUILHAUMOU, N., BOUHLEL, S. and TOURAY, J.C., 1987, Hydrocarbon fluid inclusions in the stratabound F-Ba deposit of Hamman Zriba-Guebli (northeastern Tunisia) (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 49. First author at Lab. Géol. de l'École Normale Supérieure. ER 224 du C.N.R.S., 45 rue d'Ulm-75230 Paris Cédex 05, France.

The stratabound F-Ba deposit of Hamman Zriba-Guebli has recently been studied by Bouhlel et al., 1987 (submitted to Mineralium Deposita). Fluid inclusion data show an increase of the T and the salinity of the fluids between the first banded and last geodic episode of crystallization of fluorite. Liquid hydrocarbon trapped as P inclusions was observed in all generations of fluorite. They were easily identified under microscope by their yellow-brown color in transmitted light and their strong white-blue fluorescence in UV light.

From preliminary investigations by IR spectrometry, a characterization of these organic liquids has been performed and $CO_2$, $CH_4$ and $H_2O$ were detected. Experimental studies about casual changes of shapes, densities and contents during overheating under P have been performed on these hydrocarbon-bearing inclusions (Guilhaumou et al., 1987). Their behavior with regard to stretching and decrepitation has been compared with those of aqueous inclusions and isochore slopes of hydrocarbon inclusions have been deduced. On the other hand, these experiments demonstrate that dislocated shapes in the earliest generation of banded fluorite could be more related to mechanical deformation during an early tectonic episode than the result of overheating. The origin of such liquid hydrocarbon in relation to deep diagenesis and geological frame is [also] discussed. (Authors' abstract)

GUILHAUMOU, N., COUTY, R. and DAHAN, R., 1987, Deformation of fluid inclusions in fluorite under confining pressure: Chem. Geol., v. 61, no. 1/4, p. 47-53.

Full paper for abstract in Fluid Inclusion Research, v. 18, p. 157-158, 1985. (E.R.)

GUO, Jibao, 1987, An experimental study of the formation conditions of grossular-andradite series garnets in Shizhuyuan skarn: Acta Mineral. Sinica, v. 7, no. 4, p. 372-380 (in Chinese; English abstract).

GURNEY, G.G. and FRIEDMAN, G.M., 1987, Burial history of the Devonian Cherry Valley carbonate sequence, Cherry Valley, New York: Northeastern Geol., v. 9, no. 1, p. 1-11. First author at Brooklyn College, Brooklyn, NY 11210.

Lower and middle Devonian carbonates including the Helderberg Group and the Onondaga Formation as well as interbedded clastics near Cherry Valley New York State compose over 300 feet of vertical section.

Fluid inclusion analysis, stable isotope ratios, and vitrinite reflectance values suggest that the Cherry Valley sequence was buried to depths between 4.5 and 5.0 km using 26°C/km as a previous geothermal gradient.

Data for vitrinite reflectance and stable isotope ratios imply that the Helderberg Group was buried 0.5-1.0 km deeper than the Onondaga Formation. This difference in burial depth indicates that tectonic-related deposition and the subsequent erosion of thick sedimentary sequences occurred following Helderberg deposition and prior to the deposition of the Onondaga.

Stable isotope ratios, fluid inclusion analysis, and petrographic evidence indicate that most of the Cherry Valley coarse cements precipitated from saline brines in a deep-burial setting. (Authors' abstract)

GURNEY, J.J. and MOORE, R.O., 1987, Diamonds and inclusions: Remnants of old lithosphere? (abst.): Terra cognita, v. 7, p. 614. Authors at Dept. Geochem., Univ. Cape Town, Rondebosch, South Africa.

Diamonds and their peridotitic inclusions provide evidence that the metasomatism has produced such extreme light rare earth element enrichment that the fluid phase must have had an unusual composition (Shimizu and Richardson, 1987). The restricted range of carbon isotope ratios in peridotitic diamonds leads to the interpretation that the fluids were derived from devolatilization of relatively homogeneous convecting asthenospheric peridotite in the Archean. (From the authors' abstract)

GUROVICH, B.M., KAMILOV, R.R. and MEZHERITSKII, S.M., 1986, Calculation of the heat of vaporization of aqueous $CaCl_2$ solutions: Zhurnal Prikladnoi Khimii, v. 59, no. 12, p. 2692-2694, 1986 (in Russian; translated in J. Appl. Chem., v. 59, no. 12, p. 2459-2461, 1987).

GUTSALO, L.K. and PLOTNIKOV, A.M., 1987, Fractionation of isotopes of gases in the present-day hydrotherms: Dokl. Akad. Nauk SSSR, v. 292, no. 6, p. 1468-1472 (in Russian). Authors at Inst. Geol. & Geochem. of Mineral Fuels of Acad. Sci. of Ukrainian SSR, L'vov, Ukrainian SSR.

Analysis of the published data on the C and H isotope fractionation in the presently active hydrotherms from New Zealand and Italy was used for the construction of the equations describing the $CO_2$, $CH_4$, $CO_2$-$CH_4$, $H_2$ and $CH_4$-$H_2$ isotope partition of $^{13}C/^{12}C$ and D/H during the boiling of hydrothermal fluid, depending on T of the wall rock. A number of the proposed isotope (C, H) geothermometers for hydrotherms may be used only if the phenomena of boiling and gas escape from the system were absent. (A.K.)

GUTIÉRREZ MAROTO, A., GUIJARRO GALIANO, J. MORENO GUTIÉRREZ, A. and ALVAREZ MARTIN, J.B., 1986, Fluid inclusions in baritine and fluorite deposit in South Western Guadarrama range (Spain): Rev. Mat. Proc. Geol., v. 4, p. 91-101 (in Spanish; English abstract).

The paragenesis and the intrusion of barite and fluorite associated with sulphides in the S.W. Guadarrama was studied in an earlier paper. In this paper fluid inclusions in barite and fluorite are studied. [On the basis of paragenesis and Th, these ores are epithermal.] There are a unimodal distribution in barite inclusions, ranging from 35° to 45°C, and bimodal in fluorite inclusions, ranging from 42 to 50°C. (Authors' abstract)

HAGNI, R.D., 1986, Mineral paragenetic sequence of the lead-zinc-copper-cobalt-nickel ores of the southeast Missouri lead district, U.S.A.: Min. Parageneses, J.R. Craig, et al., eds., p. 93-132. Author at Dept. Geol. & Geophys., Univ. Missouri-Rolla, Rolla, MO, USA.

Discusses and reviews relevant and published fluid inclusion data. (H.E.B.)

HALL, D.L., BODNAR, R.J. and BONNER, B.F., 1987, Contribution of fluid inclusion decrepitation to acoustic emission profiles of Westerly granite (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 690. First author at Dept. Geol. Sci., Virginia Polytech. Inst. & State Univ., Blacksburg, VA 24061.

Acoustic emissions produced during slow heating of rocks at 1 atm. have generally been attributed to intergranular stresses generated by differences in thermal expansion coefficients and elastic moduli of neighboring grains. Little attention has been given to the role of intragranular or grain boundary fluid inclusions in initiating or facilitating fracturing. Overpressures generated within high density fluid inclusions become substantial upon heating to T above those of homogenization owing to the large coefficient of thermal expansion of the fluid relative to the host crystal. These overpressures result in brittle failure when the local stress around the inclusion exceeds the local strength of the host crystal.

To assess the degree to which fluid inclusion decrepitation may contribute to acoustic emission profiles of rocks, samples of Westerly granite were heated (2°C/min) in a gas-flow stage while visually monitoring fluid inclusions in quartz. Three different types of inclusions were noted: (1) one-phase, high density, aqueous, (2) two-phase, liquid-rich, aqueous and, (3) two-phase, moderate density, $CO_2$-$H_2O$ fluids. The inclusions generally decrepitated between 75-500°C (peak at 275-300°C) producing microfractures which emanate from decrepitated fluid inclusions. Many small inclusions developed visible microfractures upon heating through the $\alpha/\beta$ transition, thus contributing to the prominent spike observed in acoustic emission profiles at 573°C.

The results suggest that acoustic emission profiles for Westerly granite, and presumably for other rocks as well, probably contain significant contributions from decrepitating fluid inclusions, and that peaks in such profiles may represent different fluid inclusion populations with different compositions or densities. Furthermore, these data indicate that fluid inclusions are active in generating microfractures during heating, as opposed to representing passive features which the fractures happen to intersect, as has been previously suggested. (Authors' abstract)

HALL, D.L., STERNER, S.M. and BODNAR, R.J., 1987a Solubility relations in the system NaCl-KCl-$H_2O$ (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Authors at Virginia Polytech. Inst. & State Univ., Blacksburg, VA 24061.

Vapor-saturated solubility relationships in the system NaCl-KCl-$H_2O$ have been determined using synthetic fluid inclusions. Inclusions were formed in the presence of homogeneous one-phase fluids having known bulk compositions and the appropriate bulk densities such that total homogenization occurred by near-simultaneous disappearance of salt crystal and vapor bubble. Under these conditions, dissolution of the final salt crystal represents the true vapor-saturated solubility for that brine composition at the measured T.

Sylvite solubilities in the $KCl-H_2O$ binary system along the three-phase (L + V + Sylvite) curve are described by the equation:

$$\text{wt\% KCl} = 25.3375 + 0.1026T - 6.537 \times 10^{-6}T^2 \quad (100 < T < 770°C)$$

Solubilities described by this equation are in excellent agreement with those determined by Chou (GSA Abst., 18, 564, 1986) using DTA. Solubility relations for high salinity bulk compositions within the ternary extrapolate to published T along the liquidus in the NaCl-KCl binary.

Above ~300°C substantial solid-solution occurs between halite and sylvite. The thermal dependence of coexisting halite and sylvite compositions above this T can strongly influence estimation of the compositions of fluid inclusions containing high-salinity NaCl-KCl brines. The position of the solvus in the anhydrous binary has been calculated using data obtained from synthetic fluid inclusions. Result are in excellent agreement with published data indicating that coexisting halite and sylvite within fluid inclusions continually re-equilibrate through recrystallization during slow heating. Thus, final dissolution T of halite and sylvite represent true equilibrium phase transitions and are directly related to the true composition of the inclusion fluids. However, rapid heating during microthermometric studies of fluid inclusions in this system results in the reproducible determination of disequilibrium phase transitions and erroneous estimation of bulk fluid compositions.

The complex, metastable behavior of moderately saline brine compositions in the system $NaCl-KCl-H_2O$ requires special attention during routine microthermometric analysis. Failure to renucleate halite or sylvite during cooling and heating runs can result in inaccurate estmation of fluid compositions. For bulk fluid compositions lying near the cotectic at salt saturation <~140°C the stable phase assemblage may fail to nucleate even when the inclusion is supercooled. However, through proper and unequivocal identification of the phases present at all T above the ternary eutectic (-22.9°C) bulk fluid compositions may be accurately estimated using metastable extensions of isotherms on the vapor-saturated solubility surface. (Authors' abstract)

HALL, D.L., STERNER, S.M. and BODNAR, R.J., 1987b Phase equilibria in the system $NaCl-KCl-H_2O$ (abst.): EOS, v. 68, p. 450. Authors at Dept. Geol. Sci., Virginia Polytech. Inst. & State Univ., Blacksburg, VA 24060.

Solubility relations along the vapor-saturated liquidus in the system $NaCl-KCl-H_2O$ have been determined utilizing synthetic fluid inclusion and standard freezing point depression techniques. The data allow more accurate determinations of bulk compositions to be made during routine fluid inclusion studies and provide an internally consistent data set over most of $NaCl-KCl-H_2O$ composition space.

Halite solubilities in the $NaCl-H_2O$ binary system along the three-phase curve are described by the equation:

$$\text{wt\% NaCl} = 46.100 - 0.1508T + 4.964 \times 10^{-4}T^2 - 2.796 \times 10^{-7}T^3$$
$$(300 < T < 801°C).$$

Similarly, sylvite solubilities are described by the equation:

$$\text{wt\% KCl} = 28.057 + 0.0748T + 6.680 \times 10^{-5}T^2 - 5.53 \times 10^{-8}T^3$$
$$(100 < T < 770°C).$$

Ternary solubility relations are described by regression of measured dissolution temperatures of halite, sylvite and hydrohalite, and ice melting temperatures to produce an algorithm which predicts the topology of the solid + liquid + vapor surface throughout the ternary composition space. Solubility data obtained from synthetic fluid inclusions are in good agreement with phase relationships reported by Chou (GSA Abst., 18, 564, 1986, and pers. comm.) but disagree with some earlier works.

Isotherms within the ice sub-field have been determined from the freezing point depression of NaCl-KCl-$H_2O$ solutions. Compositions of brine in equilibrium with ice are described by the equation:

$$\text{wt.\%} = [(-b/2) + (b^2/4 + a^3/27)^{1/2}]^{1/3} + [(-b/2) - (b^2/4 + a^3/27)^{1/2}]^{1/3}$$

$$a = c/e;\ b = -\theta/e;\ c = 0.4597 + 0.1440(S);$$
$$e = 2.227 \times 10^{-4} + 1.999 \times 10^{-4}(S) + 4.633 \times 10^{-5}(S)^2 + 1.123 \times 10^{-4}(S)^3;$$
$$\theta = \text{freezing point depression } (^\circ\text{C}) \text{ and } S = \text{NaCl}/(\text{NaCl} + \text{KCl}).$$

Data for the NaCl-$H_2O$ and KCl-$H_2O$ binaries agree with earlier determinations, except that our data for NaCl-$H_2O$ deviate significantly from the equation of Potter et al. (Econ. Geol., 73, 284, 1978) at salinities above 13 wt.%. (Authors' abstract)

HAMES, Willis E., TRACY, R.J. and BODNAR, R.J., 1987, Fluid composition during metamorphism of pelitic rocks as indicated by mineral assemblage and fluid inclusions (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 691. Authors at Dept. Geol. Sci., Virginia Polytech. Inst., Blacksburg, VA 24061.

The composition of fluid inclusions from within a portion of the Rowe-Hawley belt, western Connecticut, are in sharp contrast to estimates of fluid composition based on the mineral assemblage. The Rowe-Hawley belt represents outboard portions of the north American miogeocline that were emplaced during the Taconian Orogeny and remetamorphosed to kyanite grade in the Acadian Orogeny. Samples from the Rowe Schist contain the assemblage garnet-staurolite-chlorite-muscovite-biotite-plagioclase-quartz-(ilmenite). The compositions of these minerals indicate peak metamorphic conditions of ~535°C and 5.6 kb. The assemblage suggests that metamorphic fluids were water-dominated, and that the fluid composition was internally controlled.

Fluid inclusions occur within these samples as: 1) inclusions trapped within and around the margins of crystals during their growth; 2) along secondary annealed fractures; and, 3) as clusters of inclusions which formed through decrepitation. Most of the observed inclusions (~90%) contain $CO_2$-$CH_4$ mixtures, and the remainder are $H_2O$ inclusions. The $CO_2$-rich inclusions have Tm $CO_2$ in the range -60 to -57°C and Th of -6 to +6°C. The consistency of Tm $CO_2$ and Th and the resulting isochore indicate that the $CO_2$-rich inclusions re-equilibrated subsequent to their formation.

These samples contain less than 1 modal percent graphite, and they are not associated with any carbonate minerals or lithologies. In addition, the Rowe-Hawley belt is notable for its lack of carbonate units. The $CO_2$-rich inclusions must then have originated from reactions which involved the dissociation of water and consumption of graphite, or from fluids external to the Rowe-Hawley belt. The occurrence of $CO_2$-rich inclusions in apparent conflict with metamorphic assemblage has been reported in other medium-grade metamorphic terranes, and suggests that $CO_2$ may be a more dominant component in the metamorphism of pelitic sequences than previously recognized. (Authors' abstract)

HAMMARSTROM, J.M. and THEODORE, T.G., 1987, Mineralogy of Late Cretaceous and Tertiary skarns in the gold skarn environment of the Battle Mountain mining district, Lander County, Nevada (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 692. First author at U.S. Geol. Survey, Reston, VA 22092.

Garnet skarns formed locally in 1) limey beds of Upper Cambrian Harmony Formation intruded by late Eocene-early Oligocene leucogranite, 2) along a contact between Harmony and Battle Formations cut by Late Cretaceous monzogranite related to the Buckingham porphyry Mo system, and 3) in Middle Pennsylvanian Battle Formation and Pennsylvanian and Permian Antler Peak Limestone intruded by Oligocene granodiorite porphyry. Andraditic garnet veins, distal to the Buckingham Mo system, were emplaced at approximately 300°C at extremely low $XCO_2$ in association with non-boiling $CaCl_2$-bearing fluids (= 13 wt.% NaCl equiv.). (From the authors' abstract)

HANEL, I.V., KESLER, S.E., WALSH, J.N. and SMITH, T.J., 1987, Hydrothermal fluids in greenstone gold deposits of the Porcupine Camp, Superior Province, Ontario (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Authors at Dept. Geol. Sci., Univ. Michigan, Ann Arbor, MI 48109.

Fluid inclusions in veins at the McIntyre-Hollinger and Pamour #1 gold mines, along with those in ~500 quartz veins throughout the surrounding 1500 km 2 area, provide information on Archean gold-related and regional fluids, as well as on the relation between these fluids and lithologic and structural features of the host greenstone belt. The "primary" gold-related fluid at the McIntyre-Hollinger and Pamour #1 mines appears to have consisted of low salinity $H_2O$ with 5 to 10 mole% $CO_2$, somewhat less $CO_2$ than observed in other greenstone gold districts. T of this fluid were 380 to 480°C in the McIntyre-Hollinger mine, where the veins are peripheral to intrusive rock, and about 325°C in the Pamour #1 veins, which are not associated with igneous rocks and probably formed at a higher level. This primary fluid apparently unmixed widely in the gold deposits to form an $H_2O$-rich fluid and an associated $CO_2$-rich (carbonic) fluid that produced widespread hanging wall alteration and might have caused ore deposition. Fluids in the McIntyre-Hollinger mine increase in $CH_4$ content downward (to ~ <50 mole% in the carbonic fluid at depths of about 2 km). In many areas of both mines the $CH_4$ content of the fluids is greatest in veins hosted by metasediments or graphitic material and lowest in veins hosted by volcanic rocks, suggesting that much of the $CH_4$ resulted from reactions between the primary fluid and these rocks. Support for this interpretation is seen in the regional veins, which are highest in $CH_4$ where they are hosted by sediments. Fluids in these regional veins are generally similar to those in the gold deposits, including limited examples of unmixing, although they homogenize at lower T. The abundance of $CO_2$ in these regional fluids is spotty, but tends to be highest in areas near the Destor-Porcupine fault, which is closely associated with the gold mineralization. These data indicate that the source for the Porcupine greenstone gold fluids was regionally extensive, whether it was of metamorphic or igneous origin, and that it was thermally zoned vertically and with respect to regional fault zones. (Authors' abstract)

HANEY, J.M. and JANSONS, Uldis, 1987, Geology of the McKinley Lake gold area, Chugach National Forest, southcentral Alaska: Bureau of Mines Open File Report no. 32-87, 40 pp.

P and S fluid inclusions in three groups of quartz veins in granite and metasedimentary rocks were mainly simple two-phase types (liquid and vapor) with 2 to 20 vol. % vapor and no dms. Th and salinity ranged from

190-340°C and 6-23 wt. % NaCl eq. for P inclusions, and somewhat lower for secondaries.

The P fluids in mineralized quartz are more saline than those in barren quartz. The bimodal salinity distribution in mineralized and barren veins suggests two primary fluid phases. (From the authors' text, by E.R.)

HÄNNI, H.A., SCHWARZ, D. and FISCHER, M., 1987, The emerald from Belmont mine at Itabira, Minas Gerais, Brazil: Occurrence and characteristics: Z. Dt. Gemmol. Ges., v. 36, no. 1/2, p. 33-49 (in German; English abstract).

The emeralds, which are very rarely associated with chrysoberyl and alexandrite, are found within Precambrian schists, former pegmatites and quartz masses. They have relatively low contents of FeO, MgO and $Na_2O$, and few mineral inclusions. In addition to high-F micas, quartz, tremolite, dolomite, andesine, apatite and hematite/molybdenite are found as mineral inclusions.

Growth tubes are very widespread. They are arranged either as single tubes, parallel to the c-axis of the emeralds or in dense layers and show different kinds of fillings: one or two fluids possibly combined with a gas bubble and/or a solid. Most numerous are growth tubes consisting of a birefringent white crystal (apatite?) associated with a mostly rectangular cavity with a bi-phase filling. Polyphase inclusions are common. Typical for the Itabira emeralds are disc-shaped tension cracks, which in their center as a rule contain a cavity filled with a fluid. The Itabira emeralds are typical of the association of mafic-ultramafic rocks with pegmatites. Based on fluid and gas inclusions the minimal T and P conditions of emerald formation can be determined as 380°C and 1400 bars. (From the author's abstract)

HANNINGTON, M.D. and SCOTT, S.D., 1987, Sulfidation equilibria as guides to gold mineralization in volcanogenic massive sulfides (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 692-693. Authors at Dept. Geol., Univ. Toronto, Toronto, Ontario, Canada M5S 1A1.

Temperature-$aS_2$ controls on Au distribution are identified in Archean Cu-Zn deposits at Noranda, Quebec, Phanerozoic Kuroko-type deposits in Japan and British Columbia, and modern polymetallic sulfides on the East Pacific seafloor. In these deposits, T and $aS_2$ are indicated by sulfidation equilibria among minerals, FeS contents of sphalerite, and fluid inclusion temperatures. Gold occurs with sulfides formed at high $aS_2$ (<10 mole % FeS in sphalerite) and low temperature (<300°C). Associated sulfur-rich assemblages may be related to excess sulfur in solution, reactions between fluids and existing sulfides, local sulfate reduction, or boiling. (From the authors' abstract)

HANOR, J.S., 1987, Kilometre-scale thermohaline overturn of pore waters in the Louisiana Gulf Coast: Nature, v. 327, p. 501-503. Author at Dept. Geol., Louisiana State Univ., Baton Rouge, LA 70803, USA.

Here I present geochemical and physical evidence for the existence of density inversions in Gulf Coast pore fluids sufficient to drive large-scale convective fluid flow at rates conceivably as high as metres per year. The density inversions are caused in part by the dissolution of salt diapirs and the formation of dense, saline brines at shallow depths. (From the author's abstract)

HANSEN, E.C., JANARDHAN, A.S., NEWTON, R.C., PRAME, W.K.B.N. and RAVINDRA KUMAR, G.R., 1987, Arrested charnockite formation in southern India and Sri Lanka: Contrib. Mineral. Petrol., v. 96, p. 225-244. First author at Dept. Geol., Hope College, Holland, MI 49423, USA.

Arrested prograde charnockite formation in quartzofeldspathic gneisses is widespread in the high-grade terrains of southern India and Sri Lanka. $CO_2$-rich fluid inclusions in quartz from the Kabbal-type localities support the concept that this type of charnockite formation was driven by influx of $CO_2$ from some deep-seated source. The open-system behavior and high oxidation states of the metamorphism are in accord with the $CO_2$-streaming hypothesis. $CO_2$-rich inclusions in graphite-bearing charnockites of the Ponmudi type, however, commonly have low densities and compositions not predictable by vapor-mineral equilibrium calculations. These inclusions may have suffered post-metamorphic $H_2$ leakage or some systematic contamination.

Neither the close-pair analyses nor the fluid inclusions strongly suggest an influx of $CO_2$ drove charnockite formation of the Ponmudi type. The possibility remains that orthopyroxene and $CO_2$-rich fluids were produced by reaction of biotite with graphite without intervention of fluids of external origin. Further evidence, such as oxygen isotopes, is necessary to test the $CO_2$-streaming hypothesis for the Ponmudi-type localities. (From the authors' abstract)

HANSEN, F.D., 1987, Physical and mechanical variability of natural rock salt: Bull. Assoc. Engrg. Geol., v. 24, no. 2, p. 227-234. Author at RE/SPEC Inc., P.O. Box 725, Rapid City, SD 57709.

Includes tables (p. 229) showing percentage of fluid inclusions in Palo Duro Basin salt units 4 and 5. (E.R.)

HARDER, V.M. and GILMER, A.L., 1987, The use of fluorite fission track dates and fluid inclusion data to constrain the thermal evolution of ore deposits (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Authors at Univ. Texas at El Paso, El Paso, TX.

For the characterization of the origin and development of ore deposits related to plutonic rocks information on the evolution of the ore deposit is necessary. This information has basically consisted of such things as isotopic dates of the plutonic rock itself to determine the time of emplacement and source of the mineralizing fluids; studies of the mineral assemblages present and their paragenesis; fluid inclusion studies to determine the nature of the mineralizing fluids; and stable isotope analyses of gangue and ore minerals to determine hydrothermal fluid characteristics.

Fluorite occurs in a wide range of ore deposits both as an ore and a gangue mineral. It is common in stratiform deposits and in many hydrothermal replacement and fissure filling deposits. It also occurs in tin greisen, hydrothermal Au-Te, Sn-W and hydrothermal U deposits. Additionally, fluorite occurs as an accessory mineral in some volcanics, fluorine-rich pegmatites and skarns. Where fluorite is the major ore mineral, an understanding of possible mechanisms of deposition is possible and where fluorite is a gangue or accessory mineral it may give clues to the processes that controlled the deposition of the ore minerals.

Timing of mineralization itself has rarely been dated except for a few examples of K/Ar dating of adularia and alunite, Pb/Pb techniques, or by the bracketing of unaltered premineralization and postmineralization units. A new technique has recently become available in which fluorite can be dated by the fission track method. Since fluorite is so widespread in mineral deposits and is often used for fluid inclusions, it is now possible to add the constraint of time to ore deposition. Fluorite fluid inclusions usually exhibit low Th but have also been documented up to 450°C. The fluorite closure T is 108°C. By using time/T cooling curves, extrapolation of the fluorite date to formation of the fluid inclusions, at either a higher or lower T, can be attempted. If other minerals in the deposit have fluid inclusion T which overlap those of the fluorites, this extrapolation could be carried even further. The addition of all fluid inclusion data and any isotopic dates from the area could constrain these extrapolations even further, outlining the thermal evolution of the ore deposit. (Authors' abstract)

HARMON, R.S., HOEFS, J. and WEDEPOHL, K.H., 1987, Stable isotope (O, H, S) relationships in Tertiary basalts and their mantle xenoliths from the Northern Hessian Depression, W. Germany: Contrib. Mineral. Petrol., v. 95, p. 350-369. First author at Geochem. Inst., Goldschmidststr. 1, D-3400 Göttingen, FRG.

The high $\delta^{18}O$ and $\delta^{34}S$ values observed for the alkali basalts and peridotites are best explained in terms of metasomatic alteration of the mantle source region by fluids enriched in $^{18}O$, K, and incompatible trace elements prior to partial melting. The $\delta^{18}O$-K relationships for the peridotites indicate that the mantle beneath the Northern Hessian Depression has had a complex stable isotope history involving at least two distinct metasomatic events. The earlier event involved a $CO_2$-rich fluid which modified $^{18}O/^{16}O$ ratios without altering the mineralogical character of the mantle peridotite. The second event involved an aqueous fluid, which mainly altered the clinopyroxene and introduced phlogopite (plus possibly apatite, carbonate, and amphibole). It superimposed an $^{18}O$ and K enrichment upon a previously altered mantle. (From the authors' abstract)

HARRIS, Chris and SHEPPARD, S.M.F., 1987, Magma and fluid evolution in the lavas and associated granite xenoliths of Ascension Island, in J.G. Fitton and B.G.J. Upton, eds., Alkaline Igneous Rocks: Geol. Soc. Spec. Publ. No. 30, p. 269-272. First author at Dept. Geochem., Univ. Cape Town, Rondebosch 7700, South Africa.

The mildly alkaline lava of Ascension Island evolved in a $H_2O$-undersaturated environment. $H_2O$ comprises less than 0.4 wt.% of glassy equivalents of the most evolved lavas (comendites) for which there is no evidence that it has been lost by degassing. In contrast, peralkaline granite xenoliths which are chemically similar to the evolved lavas contain silicate glass and fluid inclusions which demonstrate that the original granite body crystallized from a water-saturated magma. Microprobe analysis of the glass inclusions gives low totals suggesting that the $H_2O$ content was high (5-8 wt.%). Amphibole $\delta D$ values for the granite xenoliths are significantly different from the whole-rock $\delta D$ values of the comenditic obsidians while whole-rock $\delta^{18}O$ values are similar. It is suggested that the high water content in the original granite magma is due to sea-water addition and that this explains these differences. Sea-water interaction with high-level magma chambers on Ascension may have been the cause of the extensive pyroclastic volcanism which occurred on the island. (Authors' abstract)

HARTE, B., 1987, Metasomatic events recorded in mantle xenoliths: An overview, in Mantle Xenoliths, P.H. Nixon, ed.: John Wiley & Sons, p. 626-640.

HAXEL, G.B., BAGBY, W.C. and TOSDAL, R.M., 1987, Upper-crustal section through a Middle to Late Jurassic regional metamorphic and plutonic terrane, Kofa Mountains, southwestern Arizona (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 697. First author at U.S. Geol. Survey, Flagstaff, AZ 86001.

A Middle to Late Jurassic regional metamorphic gradient from unmetamorphosed to amphibolite-facies rocks, accompanied by a progression in the intrusive style of syntectonic granitoids, is preserved in a small area of the southwestern Kofa Mountains. Metamorphogenic quartz and quartz-tourmaline veins are common in the phyllite and schist zones. Fluid inclusions in quartz veins from both the phyllite zone and the schist zone, and in intrusive pegmatite, all appear petrographically similar at room temperature. (From the authors' abstract)

HAYBA, D.O., 1987, Fluid-inclusion evidence for hydrologic and hydrothermal processes in the Creede mineralizing system, Colorado (abst.): Geol. Soc. Am. Abst. with Programs, v. 19, p. 282. Author at U.S. Geol. Survey, MS 959, Reston, VA 22092.

Fluid-inclusion data compiled for samples from the Creede district, Colo., (>5000 measurements to date) indicate that meteoric fluids from at least two main source areas were involved in three different hydrothermal processes during ore deposition. In concert with the stable isotope data, the fluid-inclusion data demonstrate that chemically (and isotopically) distinct fluids were derived from northern and southern sources. Fluids that entered the system at depth from the south had high salinities (>13 wt.%), probably as a result of evaporation in the closed shallow basin in which the Creede Formation was deposited. The northern fluids, in contrast, had salinities of less than 2 wt.%. Because of the regional north-to-south hydrologic gradient, these northern solutions entered the system both as fluids feeding the hydrothermal plume at depth and as shallow ground waters mixing in the ore zone from above.

The hydrothermal processes identified at Creede are 1) deep mixing of fluids in the hydrothermal plume, 2) shallow mixing of hydrothermal brines with dilute ground waters, and 3) occasional periods of boiling. The general north-to-south increase in salinity and decrease in temperature of the fluid inclusions across the district are interpreted to be the result of deep mixing in the upwelling hydrothermal plume located in the northern portion of the district. Evidence for shallow mixing is based on the general upward decrease in both enthalpy and salinity for fluid inclusions from each individual vein system. This trend for each vein suggests that the hydrothermal fluids usually cooled by mixing with overlying ground water. However, some of the data plot along boiling paths on enthalpy-salinity plots (increasing salinity with decreasing enthalpy). There is also textural evidence from fluid inclusions for periods of boiling, although it appears that mixing was the dominant cooling mechanism during most ore deposition. (Author's abstract)

HAYBA, D.O. and BETHKE, P.M., 1987, Techniques for analyzing and interpreting fluid-inclusion data sets: Examples from Creede, Colorado (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Authors at 959 National Center, U.S. Geol. Survey, Reston, VA 22092.

With the advent of the gas-flow fluid-inclusion stage, it has become possible to readily produce large fluid-inclusion data sets. This instrumentation also facilitates accurate and precise measurements, eliminating the need to average data to remove random error. Each inclusion, which represents a sample of the ore fluid trapped at a specific time and place, can and should be considered individually. The differences between inclusions provide the most important information about process, and such information is lost when the results are reported as averages. In addition, textural observations on the size, shape and distribution of inclusions in the sample are usually not reported or used in evaluating the data.

Using a personal computer, it is relatively easy to store information on the location, analyst, host mineral, textural relations, interpreted origin (P, PS, S), paragenetic stage, size, and shape of each inclusion along with its Th and Tm. The data set can be queried in a number of different ways to analyze relationships in the data. Systematic errors may become apparent when sorting by analyst, for example. Or, inclusions that have higher Th than the rest of the population may be identified as being larger than their neighbors, thus indicating the possibility of stretching or leaking. Provided the proper measurements have been made, the data set can be manipulated to calculate the salinity (in terms of wt.% NaCl eq.), enthalpy, and volume of each inclusion. Enthalpy and salinity are particularly useful quantities for interpreting fluid-inclusion data because cooling processes for hydrothermal fluids (i.e., boiling, mixing, and conductive cooling) plot as straight lines on enthalpy-salinity diagrams. Although enthalpy-salinity diagrams have been used extensively in studies of geothermal systems, they have been used rather sparingly in fluid-inclusion research. Examining the distribution of data in space is another common way of analyzing data that is readily handled by a personal computer. Depth-T diagrams, for example, can aid in interpreting whether the system operated near the boiling curve, and if so, in estimating the paleodepth below the water table.

We have used all the above-mentioned techniques to interpret the more than 5000 fluid-inclusion measurements that have been made on samples for the Creede district, Colorado, by investigators in several different laboratories using different types of heating/freezing stages. Because of the large range in salinities (0-12 wt%) present in the district enthalpy-salinity diagrams provide an excellent means of distinguishing between boiling and mixing, both of which occurred at Creede. These diagrams have also been used to interpret the regional hydrologic conditions during ore deposition by showing districtwide variations in the fluid-inclusion data. They also have been particularly useful in identifying data falling outside geologically reasonable ranges. Depth-T diagrams corroborate the evidence for boiling in the district, first interpreted from observations of inclusions having variable liquid/vapor ratios. Textural observations in support of interpretations (e.g., P, PS, boiling, etc.), such as those made by Foley et al. (this volume), are necessary and should be included in the data set. The lack of such observations in most cases has frustrated the analysis of the data because it has been the combination of textural information and the above outlined data-manipulation techniques that has provided the most important information for interpreting the Creede hydrologic system. (Authors' abstract)

HAYMET, A.D.J., 1987, Freezing: Science, v. 236, p. 1076-1080. Author at Chem. Dept., Univ. California, Berkeley, CA 94720.

There is no first principles theory of freezing or melting, even for the simplest materials. The prediction of phase diagrams is an important first step in understanding the crystal-melt interface, crystallization near equilibrium, and nucleation. Recently, a new approximate theory for the freezing of classical liquids, known as the density functional theory, has been developed. The predictions of the theory are relatively accurate and its mathematical structure is simple enough to provide an attractive starting point for theories of more complex, dynamical phenomena. (Author's abstract)

HAYNES, F.M. and KESLER, S.E., 1987a Chemical evolution of brines during Mississippi Valley-type mineralization: Evidence from East Tennessee and Pine Point: Econ. Geol., v. 82, p. 53-71. Authors at Dept. Geol. Sci., Univ. Michigan, Ann Arbor, MI 48109-1063.

The major element chemical composition of inclusion fluids from Mississippi Valley-type deposits has been evaluated semiquantitatively using scanning electron microscopy and energy dispersive analysis of individual inclusion decrepitates in ore and gangue minerals. The volcano-shaped decrepitates are produced by heating polished plates above Td of the inclusions, forcing the enlcosed fluids to the surface where the nonvolatile components precipitate. Energy dispersive analyses of these precipitates, here called decrepitates, are expressed in cation and anion weight ratios and carry errors of ±10%.

Application of this technique to fluid inclusions in sphalerite and dolomite from the Mascot-Jefferson City zinc district of East Tennessee and the Pine Point lead-zinc district of the Northwest Territories reveals that fluids attending sulfide deposition in both districts are dominantly Na-Ca chloride brines. Subordinate but significant amounts of K, Mg, and locally Sr and Fe are also present. $CaCl_2/(CaCl_2 + NaCl)$ weight ratios vary greatly among the samples from both deposits but are consistently lower (0.1-0.3) in gangue dolomites not associated with sulfides than in sphalerite and ore-stage dolomite (0.2-0.6 East Tennessee; 0.4-0.8 at Pine Point). Although Cl is the only significant anion detected in the East Tennessee analyses, a significant proportion of decrepitates from sphalerite and ore-associated dolomite at Pine Point contain appreciable S, occasionally in amounts equal to or exceeding Cl.

Mass balance calculations show that the increase in the $CaCl_2/(CaCl_2 + NaCl)$ ratio in decrepitates associated with ore from both districts cannot result simply from limestone dissolution at the site of brecciation and mineralization. Instead, they appear to require either fluid mixing or a chemical evolution of the fluids entering the carbonate host rocks. The presence of significant Ca and S together in the Pine Point fluid inclusions and the absence of daughter anhydrite requires that most S was reduced, which lends support to mixing models involving metal-rich brines and sulfur-rich waters in ore formation in that district. Further, the presence of excess S in ore-stage decrepitates from Pine Point suggests that sulfide deposition there was limited by the amount of metal-rich brine entering the $H_2S$-rich barrier reef complex. In contrast, the lack of detectable sulfur in the decrepitates from Mascot-Jefferson City ores suggests that mineralization there may have been limited by the availability of S, but does not permit selection between mixing and fluid evolution as a cause of ore deposition. (Authors' abstract)

HAYNES, F.M. and KESLER, S.E., 1987b Fluid inclusion chemistry in the exploration for Mississippi Valley-type deposits: An example from east Tennessee, U.S.A.: Applied Geochem., v. 2, p. 321-327. Authors at Dept. Geol. Sci., Univ. Michigan, Ann Arbor, MI 48109-1063, USA.

Scanning electron microscopy and energy dispersive analysis of fluid inclusion decrepitates in sparry dolomite cements associated with sphalerite mineralization in the Mascot-Jefferson City Mississippi Valley-type district of East Tennessee show a markedly lower Na/Ca ratio than those in dolomites unassociated with ore. The exploration potential of this variation in fluid inclusion chemistry has been evaluated by analyzing inclusion decrepitates from white sparry dolomite along a 150 m traverse in the New Market West mine area. The traverse extends from the central portion of a large domal collapse-breccia orebody with greater than 3% Zn, into the dolomite-veined, but unmineralized Knox Group limestones. Ratios of Na/Ca as low as 0.8-1.2 were common in dolomite-hosted decrepitates from the high-grade collapse ores. This anomalous decrepitate chemistry was not observed in sparry dolomites less than 12 m from the margins of the breccia bodies where Na/Ca ratios ranged from 1.8 to 3.6. Dolomite cements in low grade (<1.0% Zn) parts of the collapse bodies showed the greatest variation in Na/Ca ratio, with values ranging from 0.9 to 3.5. No systematic trends were observed in K/Na and S/Cl ratios from the same samples. (Authors' abstract)

HAYNES, F.M. and KESLER, S.E., 1987c, Fluid inclusion chemistry in the exploration for Mississippi Valley-type deposits: An example from east Tennessee (abst.): J. Geochem. Explor., v. 29, p. 416. First author at Dept. Geol. Sci., 1006 C.C. Little Bldg., Univ. Michigan, Ann Arbor, MI 48109-1435, USA.

SEM energy dispersive analyses of fluid inclusion decrepitates in sphalerite and dolomite from the Mascot-Jefferson City Mississippi Valley-type district of east Tennessee reveal a marked increase in the Ca/Na ratio of fluids associated with ore. Although the data indicate that anomalies in decrepitate chemistry are too local to be of use in regional exploration, the method could prove useful in evaluating the potential of areas adjacent to drilled intercepts containing marginal (0.5-1.5% Zn) mineralization. (From the authors' abstract)

HAYNES, F.M., KESLER, S.E. and BEANE, R.E., 1987, Chemical analysis of fluid inclusions by SEM/EDA: An application to Mississippi Valley-type mineralization (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). First author at Dept. Geol. Sci., Univ. Michigan, Ann Arbor, MI 48109.

Scanning electron microscopy and energy dispersive analysis of fluid inclusion decrepitates on ore and gangue minerals from the East Tennessee and Pine Point Mississippi Valley-type districts document that the fluids attending sulfide deposition in both districts were predominantly Na-Ca chloride brines. Integration of the cation ratio data obtained from decrepitate analyses with final melt T of fluid inclusions yields solution molalities of 2.2-3.6 m Na, 0.3-0.9 m Ca, 0.1-0.3 m K, and 0.04-0.20 m Mg. Ca/Na and Mg/Ca ratios are slightly higher in the Pine Point samples, but the significant difference in the inclusion compositions of the two districts is the presence of abundant S (S/Cl ratios in ore-stage material range from 0.05 to 0.35 and averaged 0.15) in the Pine Point decrepitates. No S was detected in the East Tennessee samples. The Ca/Mg ratio in both districts (4:1 to 7:1 at Pine Point and 9:1 to 12:1 at East Tennessee) indicate equilibrium with dolomite rather than calcite.

The compositional data from East Tennessee, in conjunction with inclusion $CO_2$ abundances of 0.4 to 1.5 mole% as determined by gas chromatography, are consistent with a model involving single solution transport of metal and sulfide sulfur at a pH near 4 and 125-150°C. Sphalerite deposition in East Tennessee could be induced by pH increase, T decrease, or dilution. However, the presence of abundant S in the Pine Point ore-stage decrepitates appears to preclude mutual transport of metal and reduced sulfur, and support mixing models for sulfide deposition in that district. (Authors' abstract)

HAYNES, F.M., STERNER, S.M. and BODNAR, R.J., 1987, Chemical analysis of fluid inclusions by SEM/EDA: Methodology and results from synthetic inclusions in natural quartz (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). First author at Dept. Geol. Sci., Univ. Michigan, Ann Arbor, MI 48109.

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 (Sterner and Bodnar, 1984; GCA). The two-phase, daughter-free inclusions homogenized at 170-250°C, began to decrepitate after about 100° of overheating and by 360-400°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 salt standards and mixed salt standards evaporated to dryness in a vacuum. Although the mixed salt standards better approximate the decrepitate compositions, difficulties were encountered in producing micron-scale chemical homogeneity in the mixed standards. As a result, analyses employing single salt standards yielded more reliable results.

Eight different solutions of 20-22 wt.% total salinity were run and in all samples the average composition of 10-20 discrete, single inclusion decrepitates fell within 6 wt% (0.2 to 5.4) of the original chemistry (see table below) suggesting that the decrepitates were chemically representative of their precursor inclusions. However, not all decrepitates provided similarly accurate results. Electron mapping revealed that fracture-aligned decrepitates were often chemically inhomogeneous and should be avoided. A sample decrepitated at 500°C yielded spurious results suggesting that volatility may be a problem when Td in excess of 450°C are used. Analyses from a single sample containing 11.3 wt% total salinity were also unsuccessful. Decrepitate with diameters between 10 and 30 micrometers yielded more consistent and accurate results than smaller or larger decrepitates on the same samples. The results are tabulated below. (Authors' abstract)

|  | # of | Measured avg. |  |  | Actual comp.† |  |  | Sal. | Actual |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  | Obs. | NaCl | KCl | $CaCl_2$ | NaCl | KCl | $CaCl_2$ | wt% | -X | S.E.M. |
| NK1 | 15 | 69.8 | 30.2 | ---- | 75.0 | 25.0 | ---- | 20.0 | 5.2 | 2.1 |
| NK2 | 17 | 44.9 | 55.1 | ---- | 50.0 | 50.0 | ---- | 20.0 | 5.1 | 1.4 |
| NK3 | 19 | 24.8 | 75.2 | ---- | 25.0 | 75.0 | ---- | 20.0 | 0.2 | 1.2 |
| NC1 | 20 | 43.6 | ---- | 56.4 | 40.0 | ---- | 60.0 | 23.3 | 3.6 | 2.3 |
| NC2 | 15 | 64.6 | ---- | 35.4 | 59.6 | ---- | 40.4 | 22.5 | 5.0 | 2.1 |
| NC3 | 15 | 86.5 | ---- | 13.5 | 83.3 | ---- | 16.7 | 21.6 | 3.2 | 1.3 |
| NCK1 | 13 | 42.1 | 12.4 | 45.5 | 45.9 | 13.1 | 41.0 | 21.8 | 4.1 | 1.8 |
| NCK2 | 10 | 55.6 | 15.7 | 28.7 | 55.1 | 11.5 | 33.5 | 21.6 | 4.4 | 1.9 |
| NC4* | 14 | 69.9 | ---- | 30.1 | 48.9 | ---- | 51.1 | 11.3 | 21.0 | 3.1 |
| NK2** | 9 | 35.4 | 64.6 | ---- | 50.0 | 50.0 | ---- | 20.0 | 14.6 | 3.3 |

† [i.e., by synthesis]
* lower salinity sample (11.3 wt%)
** sample decrepitated at higher T (500°C)
S.E.M. - standard error of means =
(standard deviation)(# of observations)$^{-1/2}$

HAYNES, P.S. and KESLER, S.E., 1987, Analysis of fluid inclusion gases in jasperoid as an exploration method for micron gold deposits, in Elliott, I.L. and Smee, B.W., eds., Geoexpo/86: Exploration in the North American Cordillera: Assoc. of Explor. Geochem. Pub., p. 142-149. Authors at Dept. Geol. Sci., Univ. Michigan, Ann Arbor, MI 48109.

We have evaluated the possibility that analysis of gases released from fluid inclusions in jasperoid might be used to guide exploration for sediment-hosted, micron Au deposits. Orientation studies were carrried out over the Pinson, Carlin, Rain, Dee and Standard deposits, the Taylor silver district and the Willow Creek and Gilbert prospects, and included both upper and lower plate jasperoid. (From the authors' abstract)

HAYNES, S.J., 1987, Classification of quartz veins in turbidite-hosted gold deposits, greenschist facies, eastern Nova Scotia: CIM Bull., Feb. 1987, p. 37-51. Author at Brock Univ., St. Catharines, Ontario, Canada.

It is suggested that the auriferous vein arrays formed as submarine exhalitive systems over synsedimentary tensional faults and that the Meguma domain may represent the opening of a basin similar to the modern Guaymas rift. (From the author's abstract)

HE, Mingyou, 1987, Melting experiment and investigation of inclusion in zircon from granite (abst.): Abstracts, Inter. Symp. on Petrogenesis and Mineralization of Granitoids, Dec. 7-10, 1987, Guangzhou, China, p. 92. Author at Dept. 3, Chengdu College of Geol.

Melting experiments and investigations on the inclusions in zircon of Shanxi granites were performed. This paper describes the types, the phase states, physical and optical characteristics of inclusions, and the character of their phase transitions in the melting experiments. (From the author's abstract)

HEAD, J.W., III and WILSON, Lionel, 1987, Lava fountain heights at Pu'u O'o, Kilauea, Hawaii: Indicators of amount and variations of exsolved magma volatiles: J. Geophys. Res., v. 92, no. B13, p. 13,715-13,719.

HEALD, Pamela, FOLEY, N.K. and HAYBA, D.O., 1987, Comparative anatomy of volcanic-hosted epithermal deposits: Acid-sulfate and adularia-sericite types: Econ. Geol., v. 82, no. 1, p. 1-26. Authors at U.S. Geol. Survey, Nat'l. Center, Mail Stop 959, Reston, VA 22092.

Two types of epithermal precious and base metal deposits hosted primarily by Tertiary volcanic rocks have been distinguished through a detailed examination of the characteristics of 16 well-documented epithermal districts. These characteristics include the ore, gangue, and alteration mineral assemblages, the spatial and temporal distributions of these assemblages, host-rock composition, age relations between ore deposition and emplacement of the host rock, size of the district, T of mineral deposition, chemical composition of the fluids, paleodepth estimates, origin(s) of the fluids, and regional geologic setting. The relative value of each of these features for distinguishing epithermal precious and base metal deposits is estimated. The vein and alteration mineral assemblages are the most important factors, and age relations between ore deposition and emplacement of host rock also appear to be significant. The two major types are designated the acid-sulfate type (Goldfield, Nevada) and the adularia-sericite type (Creede, Colorado; Round Mountain, Nevada). Both types have gold-rich and silver-rich subsets. Base metal content in the acid-sulfate-type deposit are relatively high and relatively Cu rich; there is a wide range in the base metal contents in the adularia-sericite-type deposit, although most are relatively Cu poor. Adularia-sericite-type deposits are considerably more abundant than acid-sulfate-type deposits.

The two types of deposits appear to form under similar P-T conditions but in different geological and geochemical environments in ancient geothermal systems. The acid-sulfate-type deposit forms in the root zones of volcanic domes from acid waters that contain residual magmatic volatiles. The adularia-sericite-type deposit forms in a geothermal system where surficial waters mix with deeper, heated saline waters in a lateral flow regime, high above and probably offset from a heat source at depth; neutral to weakly acidic, alkali chloride waters are dominant. (Authors' abstract)

HEARN, P.P., Jr., LINDHOLM, R.C. and SUTTER, J.F., 1986, Authigenic potassium feldspar in ribbon rocks of the Cambrian-Conococheague Limestone, western Maryland, *in* F.A. Mumpton, ed., Studies in Diagenesis: U.S. Geol. Survey Bull. 1578, p. 183-196. First author at U.S. Geol. Survey, MS 957, Nat'l. Center, Reston, VA 22092.

Thin alternating beds of coarse-grained limestone and fine-grained dolostone, commonly known as ribbon rock, are a characteristic lithology in the Cambrian Conococheague Limestone of western Maryland as well as in other lower Paleozoic carbonate rocks of the central Appalachian basin.

Simple mass-balance calculations indicate that the authigenic K-feldspar could not have formed isochemically, but had to involve the movement of multiple pore volumes of K-bearing fluids through these rocks. Bulk-rock Cl/Br ratios and the presence of halite dxls in some fluid inclusions suggest that these fluids were brines with salinities considerably greater than seawater. (Frrm the authors' abstract)

HEARN, P.P., Jr., SUTTER, J.F. and BELKIN, H.E., 1987a Authigenic K-feldspar - An indicator of the geochronology and chemical evolution of mineralizing fluids in carbonate-hosted lead-zinc deposits (Extended abst.): U.S. Geol. Survey Circular 995, p. 28.

Rocks containing abundant authigenic K-feldspar are now known to occur in clastic-rich zones of lower Paleozoic carbonate rocks throughout the Valley and Ridge province of the central and southern Appalachians, in correlative lithologies in western New England, and in the midcontinent area. Recent $^{40}Ar/^{39}Ar$ analyses, petrographic and fluid-inclusion studies, and geologic setting strongly suggest that the authigenic K-feldspar formed during the migration of basinal brines mobilized by orogenic activity and, thus, may provide useful information regarding the origin of nearby carbonate-hosted Pb-Zn mineralization.

Fluid inclusions in quartz and K-feldspar overgrowths on detrital grains in unmineralized rocks from the central and southern Appalachians have Th from 100 to 200°C and Tm ice from -14 to -18.5°C (18-21 wt.% NaCl eq.). The similarity of these fluid inclusions to those in nearby Mississippi Valley-type (MVT) ore deposits (Mascot-Jefferson City, Austinville-Ivanhoe, Friedensville) suggests that the authigenic K-feldspar and the ore deposits may be related genetically. This hypothesis is supported by the recent discovery of authigenic K-feldspar intergrown with sulfide minerals in siliceous zones of MVT ore deposits in eastern Tennessee (Mascot-Jefferson City) and eastern Pennsylvania (Friedensville), and at four smaller stratabound Pb-Zn deposits of indeterminate origin in New York, Vermont, and Quebec.

These findings agree with the conclusions of other workers that MVT mineralization in the central and southern Appalachians and the midcontinent region is related to the movement of basinal brines mobilized during late Paleozoic deformation along the Ouachita-Appalachian fold belt. Also, the apparent stability of K-feldspar in these ore fluids supports the contention that such fluids were not strongly acidic and implies that the metasomatism of clays may have been a more important source of metals than the dissolution of detrital K-feldspar.

The results of this work suggest that the association of authigenic K-feldspar with sediment-hosted ore deposits may be more common than had been realized. Accordingly, this mineral phase promises to provide useful information regarding the time of migration and the chemical evolution of ore-forming fluids in a variety of geologic environments. (From the authors' abstract)

HEARN, P.P., Jr., SUTTER, J.F. and BELKIN, H.E., 1987b, Evidence for Late-Paleozoic brine migration in Cambrian carbonate rocks of the central and southern Appalachians: Implications for Mississippi Valley-type sulfide mineralization: Geochimica Cosmo. Acta, v. 51, no. 5, p. 1323-1334.

See previous item. (E.R.)

HEDENQUIST, J.W., 1987, Evidence for boiling in the epithermal environment from fluid inclusion gases (abst.): Mining Geol., v. 37, no. 1, p. 72 (in English). Author at D.S.I.R., New Zealand.

The composition of gases in hydrothermal fluids of the epithermal environment is controlled by several T-dependent equilibria between gases and minerals. Such equilibria can be predicted on the basis of thermochemical relations, and they are confirmed by direct analysis of fluids and T in analogous geothermal systems. Geothermal study has shown reactions such as $CO_2 + 4H_2 = CH_4 + 2H_2O$ and $FeS_2 + H_2 = FeS + H_2S$ are among those important in controlling relative proportions of gases in a reducing environment.

Gases have differing solubilities in the vapor phase, resulting in the equilibrium proportions of gases in the liquid phase being disturbed when boiling occurs. By comparing the departure of the analytical equilibrium quotient for a gas reaction with an independent T estimate (from measured or fluid inclusion Th results), the degree of boiling of a geothermal or epithermal fluid can be determined. Trends in such data can also be extrapolated to an equilibrium condition to estimate the T of first boiling and the initial gas content of a fluid; this information is important in assessing the transport capability of a fluid for metals such a Au (and ultimately for rating the potential of an epithermal prospect).

The analysis of gases extracted from fluid inclusions of epithermal Au deposits is becoming practical with advances in analytical techniques. Published gas data from the Au deposits of Acupan, Philippines and Tayoltita, Mexico are very similar in total amounts, species and relative proportions to those for active geothermal systems. In particular, gas equilibria for these deposits tend to show the predicted boiling trends, supporting the theory that boiling of a relatively gassy fluid is the principal cause of Au deposition in the epithermal environment. Based on gas-mineral reaction constraints, the $H_2$ contents of inclusion fluids from those two deposits appears to be excessively high, probably due to problems in extraction. (Author's abstract)

HEIN, U.F. and TISTL, M., 1987, Characteristics of fluid inclusions in the porphyry copper deposit at La Granja, Peru: Chem. Geol., v. 61, no. 1/4, p. 183-192.

Full paper for abstract in Fluid Inclusion Research, v. 18, p. 168-169, 1985. (E.R.)

HEINRICH, C.A. and HENLEY, R.W., 1987, Characterization of high-temperature aqueous fluids in relation to metal transport and ore deposition: Bur. Mineral Resources, Geology, and Geophysics [Australia] Yearbook, 1987, p. 95-96.

Raman and mass spectrometry studies of gases in inclusions from Mt. Isa copper and other deposits. (E.R.)

HELGESON, H.C. and LICHTNER, P.C., 1987, Fluid flow and mineral reactions at high temperatures and pressures: J. Geol. Soc., London, v. 144, p. 313-326.

HELZ, R.T., BANKS, N.G., HELIKER, Christina, NEAL, C.A., ULRICH, G.E. and WOLFE, E.W., 1987, Lava temperatures of recent eruptions of Hawaiian volcanoes: Comparison of field measurements with the results of glass geothermometry (abst.): Hawaii Symp. on How Volcanoes Work, Abst. Volume, Hilo, Hawaii, Hawaiian Volcano Observatory, p. 106.

HEMLEY, J.J., CYGAN, G.L. and d'ANGELO, W.M., 1987, Sulfide solubilities in buffered systems at elevated pressures and temperatures and their depositional implications (Extended abst.): U.S. Geol. Survey Circular 995, p. 30.

Experimental studies have been conducted on the solubility of Fe, Zn, Pb, and Cu sulfides in chloride solutions at elevated pressures and temperatures. The solutions were buffered in pH by quartz monzonite (that is, the assemblage K-feldspar-muscovite-quartz) and in O and S activities by assemblages in the Fe-S-O or Fe-Cu-S-O systems. Most experimentation was on the pyrite-pyrrhotite-magnetite buffer point. T ranged from 300 to 700°C, and P from 0.5 to 2 kb. (From the authors' abstract)

[Note - Three odd values for iron solubility in the abstract are the result of typographical errors; the correct values are 1000 ± 150, 7000 ± 700, and 12400 ± 1000 ppm. (E.R.)]

HEMLEY, J.J., CYGAN, G.C., WOO, C.C. and D'ANGELO, W.M., 1987, Exploratory studies on metal sulfide solubilities in buffered systems: Implications to zoning in ore deposits (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 699. Authors at USGS Nat'l. Center 959, Reston, VA 22092.

The solubilities of pyrite, galena, sphalerite and chalcopyrite have been measured together in chloride solutions buffered in $fS_2$ and $fO_2$ by pyrite + pyrrhotite + magnetite and in pH by K-feldspar + muscovite + quartz, at T from 300 to 600°C and P 0.5 to 2 kb. The solutions were in the $H_2S$ field and contained more metal than sulfur. Solubilities increased with T and $Cl^-$ concentration, but decreased with increasing P. The P dependence is particularly pertinent to the transport process (Hemley et al., Geology, v. 14, 1986).

Using solution compositions such as those generated in this work as a rough guide to zonal relationships in more complex, real systems, the controls on spatial zoning are best illustrated in terms of T-X relationships, with the effects of P, $Cl^-$ concentration, or other chemical variables superimposed. The order of solubility in gms/kg solution is Fe>>Pb>Zn>>Cu. In deposits related to magmatic centers, such as porphyry coppers, Cu or Zn-Pb skarns, volcanogenic massive sulfides, and Butte-type hydrothermal deposits, Fe is abundant in the source materials, is highly concentrated (often magnetite or pyrrhotite saturated) in the initial high T fluid, and plays an important role through most of the depositional process. The zonal sequence expected outward is Cu-Zn-Pb, with Fe mineralization manifested as different phases across the zonal pattern, and pyrite characteristic of the lower T portion. In Mississippi Valley and many other lower T environments, however, Fe mineralization should not be predominant, and the typical sequence is Cu-Zn-Pb-Fe. Comparable solubilities were found for Pb and Zn, which is consistent with lack of clear depositional separation in many instances and provides for zoning reversals due to differences in relative concentration of the metals in different depositional regimes, or changes in other parameters possibly affecting sequence such as $Cl^-$ concentration, type of complexing, etc. (Authors' abstract)

HENDERSON, W.A., Jr., 1987a, Microminerals: The Mineralog. Record, v. 18, no. 2, p. 141-146.

Discusses and illustrates fluid inclusions commonly observed by the "micromount" mineral collector. (H.E.B.)

HENDERSON, W.A., Jr., 1987b Microminerals: The Mineralogical Record, v. 18, no. 6, p. 435-438.

Tabular hexagonal plates of pyrrhotite up to 1 mm diameter were found in liquid inclusions in quartz from a "railroad cut west of Newton-Hamilton, Mifflin Co., Pennsylvania." The plates can be moved with an external magnet. (E.R.)

HENLEY, R.W., HEDENQUIST, J.W. and ROBERTS, P.J., eds., 1986, Guide to the active epithermal (geothermal) systems and precious metal deposits of New Zealand: Monograph Ser. Min. Deposits, no. 26 Gebruklder Borntraeger, Verlagsbuchhandlung, 211 pp.

Based in part on papers given at a 1983 conference in New Zealand, including reviews of the various geothermal systems and the Au-Ag and Cu deposits of the Coromandel Peninsula. (E.R.)

HENLEY, R. and HOFFMANN, Chris, 1987a Complex hydrocarbons in fluid inclusions in gold and tin deposits: BMR Res. Newsletter, no. 6, p. 1-2 [Bureau of Mineral Resources, Canberra, Australia].

Traces of complex hydrocarbons in fluid inclusions are beginning to provide for mineral exploration important clues about palaeotemperatures and source rocks deep within ancient hydrothermal systems. These compounds provide a basis on which exploration can focus on both the regional and deposit scales.

We have now detected trace quantities of hydrocarbons in fluid inclusions in quartz veins from the Aberfoyle Sn-W deposit, the active Au-depositing geothermal system at Broadlands (NZ), the Pine Creek Au deposit (NT), and the Archaean Southern Cross Au deposit (WA).

We used thermal decrepitation-mass spectrometry (TD-MS) to identify hydrocarbons in the samples. Milligram-size samples were introduced into a mass spectrometer, and the fluid inclusions decrepitated under vacuum by gradually increasing T (from 50-550°C) at which the sample was maintained. Hydrocarbons were chiefly evolved above 250°C, and show good correlation with carbon dioxide and water. The observation is important since it provides evidence that they are actually present in the inclusions and are not simply the result of surface contamination.

The distribution of hydrocarbons was obtained by gas chromatography-mass spectrometry (GC-MS). We identified the biomarkers cholestane (derived from cholesterol) and other steranes, hopanes (of bacterial origin), and pristane and phytane (derived in part from chlorophyll) in quartz from Aberfoyle. The distribution that we found is similar to that in mature sedimentary rocks, and therefore suggests at least a minor contribution of fluids of non-magmatic origin to the fluids which produced the Aberfoyle quartz veins; otherwise - from their distribution and isotopes - the vein fluids are considered to be magmatic.

The (epithermal) quartz sample from Broadlands contained fluid inclusions which also possessed a range of n-alkanes; however, their distribution was quite different, and maximized at C-17 rather than C-21. The distribution of biomarkers in this sample also contrasted with that in the Aberfoyle deposit. The inclusions were consumed[sic] at 260°C from fluids whose gas chemistry (based on sampling of geothermal wells) suggests higher T of origin, so that the hydrocarbon mixture probably reflects thermal maturation at depths of over 2 km and ~320-350°C. (From the authors' abstract and text)

HENLEY, R.W. and HOFFMANN, C.F., 1987b Pacrim conference, Gold Coast, August 1987 Gold: Sources to resources: Pacific Rim Congress 87, 26-29 August, 1987, Australasian Inst. Mining & Metallurgy, Victoria, Australia, p. 159-168. Authors at Bureau of Min. Resources, P.O. Box 378, Canberra, ACT, Australia 2601.

Thermal conditions at depths of several kilometers in hydrothermal systems are a major factor controlling gold transport into the epithermal environment. Understanding of the coupling of thermal, metal and ligand ($H_2S$) sources in the root zones of hydrothermal systems therefore becomes important for the application of tectonic and igneous petrochemical studies of regional scale precious metal exploration.

The evaluation of favorable conditions in this source zone and application to exploration rests on a detailed knowledge of the gases, $H_2S$, $CO_2$ hydrocarbons and other trace components preserved in fluid inclusions. Recent developments in analytical techniques now permit examination of these components and the recognition of complex hydrocarbons in fluid inclusions from epithermal and other hydrothermal systems appears promising for deposit-source correlation. (Authors' abstract)

HENN, U., 1987, Inclusions in yellow chrysoberyl, natural and synthetic alexandrite: The Australian Gemmol., v. 16, p. 217-220. Author at Deutsche Stiftung Edelsteinforschung, Idar-Oberstein, West Germany.

This paper deals with the description of solid and fluid inclusions in minerals of the chrysoberyl group with a particular consideration to the distinction of natural and synthetic alexandrite. (Author's abstract)

HERRERO, J.M., PEREZ-ALVAREZ, M., TOURAY, J.C. and VELASCO, F., 1987, Microthermometric study of Cretaceous fluorites from Carranza and Manaria (Biscayne, Spain): Evidence for abnormal geothermal gradients (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 51-52 (in French; translation by R.J. Bodnar). First author at Dept. Mineralogy, Univ. del Pais Vasco. Apdo. 644. 48080 Balboa, Spain.

Fluorite deposits occur in the Cretaceous Basco-Cantabrian basin of northern Spain (localities: Carranza, Manaria, Aulestia). Except at Aulestia, where massive fluorite is associated with pyrite, mineralization is of the Zn-Pb-F-(Ba) type and is associated with Urgonian (Aptian-Albion) biosedimentary strata.

At Carranza there are two types of mineralization: "Anselma"-type with 1-2 cm euhedral crystals of fluorite-I disseminated in a dark dolomite with sphalerite, barite, galena, microcrystalline quartz and framboidal pyrite. Recrystallized fluorite-II, along with barite, sparry calcite and ankerite, fill small fractures and open spaces. The second, "Matienzo"-type, fills Alpine-type fractures in Urgonian carbonates. Sphalerite, galena, fluorite and sparry calcite gangue are associated with the veins.

At Manaria (Urkuleta) mineralization is represented by disseminated sphalerite (crystals <1 cm) in calcareous Urgonian sedimentary rocks, by small bands that are concordant with the strata, and by violet, cm-size fluorite-I crystals disseminated in the carbonate or filling Rudista [clam] casts. Fluorite-II fills irregular fractures 10's of cm across, along with sparry calcite and recrystallized sphalerite.

At Carranza inclusions are small (<12 μm at Anselma and <25 μm at Matienzo), two-phase, aqueous, and probably all S as the majority occur in planes parallel to cleavage. Histograms of Th of fluorite-I from Anselma show a maximum at ≈250°C. Histograms for Anselma-II and Matienzo are very scattered, with Th values concentrated around 140°, 190°, and 260°C. Tm ice indicate two populations with salinities of 3-5 and 12-15 wt% NaCl eq. There is no correlation between Th and salinity. (Authors' abstract)

HERVIG, R.L., KORTEMEIER, W.T. and BURT, D.M., 1987, Ion-microprobe analyses of Li and B in topaz from different environments: Am. Mineral., v. 72, p. 392-396. First author at Dept. Chem., Arizona State Univ., Tempe, AZ 85287, USA.

Ion-microprobe analyses of Li and B in topaz show a range of four orders of magnitude for Li and three orders of magnitude for B and vary as a function of association. Li (mean = 121 ppmw - parts per million by weight) and B (mean Li = 1.4, B = 1.3 ppmw) are high in topaz from topaz rhyolites but low in pegmatites (mean Li = 1.4, B = 1.3 ppmw) and hydrothermal greisens (mean Li = 1.0, B = 1.5 ppmw). A suggestion that high Li and B in topaz are related to an igneous origin is supported by high Li and B in topaz in topazite and ongonite dikes and very low Li an B in topaz from a hydrothermal topazite. (Authors' abstract)

HERVIG, R.L., SHERIDAN, M.F. and KOVALENKO, V.I., 1987, High water contents in melt inclusions from pantellerite and trace elements in glass and coexisting phenocrysts (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 701. First author at Dept. Chem., Arizona State Univ., Tempe, AZ 85287.

Ion probe microanalyses of glass inclusions in anorthoclase phenocrysts show much higher water contents (up to 6.4 wt.% $H_2O$) than matrix glass (<1.0 wt.%). Analyses of other elements show no significant change in Li, Be, B, F, P, Rb, Sr, Y, Zr, Nb, Sn, Cs, Ba, La, Ce and Eu in the two glasses, signifying that volatile loss during eruption was not associated with ore metal migration. The high water contents suggest that this pantellerite was near saturation levels at depths corresponding to 1-2 kbar if the Burnham equimolal solubility model can be applied to these peralkaline compositions.

Microanalyses of coexisting anorthoclase, hedenbergite, aenigmatite, quartz and apatite give estimates of crystal/liquid partition coefficients. Matrix effects in ion microprobe analysis restrict the accuracy of these values, biasing them to values approximately 15-50% too high. Despite this, partition coefficients are still <1 for B, F, P, Rb, Zr, Nb, Sn, and Cs for all silicate phenocrysts. Even when partition coefficients are >1 (Sr, Y 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. The low partition coefficients in this peralkaline rhyolite contrast with the 2-10 times higher values determined for high-silica rhyolites (Mahood and Hildreth, 1983).

Higher partition coefficients for Cs than Rb suggest that large "defect" sites are present in silicate minerals, which may be related to growth rates.

This study used a Cameca IMS-3f ion microprobe. Hydrogen and trace element analyses were calibrated against bulk analyzed, experimentally hydrated rhyolites (Mahood, G. and Hildreth, W. (1983) Geochim. Cosmochim. Acta <u>47</u>, 11-30). (Authors' abstract)

HERVIG, R.L., STANTON, T.R. and WILLIAMS, Peter, 1987, Ion probe microanalyses of hydrogen in glasses and minerals (abst.): EOS, v. 68, p. 441. First author at Dept. Chem., Arizona State Univ., Tempe, AZ 85287.

Problems in ion probe analyses of H in geologic materials include rarity of standards, poorly understood matrix effects and low peak to background ratios. Our efforts to make H analyses routine and reliable on the Camecca IMS 3f instrument began by hydrating or deuterating a suite of rhyolite glasses and characterizing them by thermogravimetric analysis. Carefully controlled analysis conditions have resulted in linear calibrations for H+ and D+ secondary ions and high peak to background ratios (peak/background for H = 2 at 0.03 wt.% $H_2O$). However, H+ ions are enhanced by a factor fo 4 over D+ ions. Crucial to lower background measurements is the elimination of H ions formed by electron stimulated desorption (ESD). The high yield of secondary electrons generated during sputtering ionizes surface H very efficiently, but the yield is extremely sensitive to sample topography and degree of charging. ESD ions have a narrow energy spread so that a small offset voltage on the sample (~20eV) effectively eliminates them. ESD ions are important in analysis of negative secondary ions as well; precise measurements of O-isotopes and H- requires discrimination against ions formed by ESD processes. These techniques have been applied to a) analysis of trapped melt inclusions in phenocrysts to determine preeruption volatile contents and b) experimental run products.

D in experimentally deuterated quartz was analyzed by the in situ implantation technique, giving 62 ± 7 ppm D (atomic). IR spectroscopy gave 66 ppm D. Application of this technique to other hydrous and "anhydrous" phases will be discussed.

Because F analyses are routine, determination of F and H in coexisting hydrous minerals is now possible. We are investigating the effect of chemistry on H ion yield for a wide variety of apmphiboles. (Authors' abstract)

HERZ, Norman and HUDSON, T.A., 1987, Tin-tungsten mineralization in 650 Ma alkalic granites of the Virginia Blue Ridge, U.S.A. (abst.): Int'l. Symp. on Granites and Associated Mineralizations, Salvador, Bahia, Brazil, Jan. 21-31, 1987, Extended Abstracts, p. 231-233. First author at Dept. Geol., Univ. Georgia, Athens, GA 30602, USA.

Sn and W as well as some Be and Th were concentrated in final liquids of the crystallizing magma and released into tensional fractures around the granite. Greisenization followed as magmatic waters mixed with meteoric water in the rock. Mineralization occurred in three stages.

The first stage of mineralization was characterized by the deposition of quartz, muscovite, fluorite, cassiterite, biotite, beryl, tourmaline, wolframite, and sulfides. Fluid inclusion uncorrected Th in fluorite average 318°C and salinities are greater than 40 eq. wt% NaCl. $\delta^{18}O$ of water in equilibrium with this greisen assemblage at 320°C ranges from +2.88 to +1.83 per mil, indicating substantial dilution of original magmatic fluids by meteoric water.

A second pulse of magmatic fluids continued the deposition of quartz, muscovite, fluorite, and biotite, with the addition of carbonates, parasite, phenakite, and scheelite. Fluid inclusions of quartz indicate Th of 370°C and fluid salinities of 6 to 8 eq. wt% NaCl. Significant amounts of gaseous $CO_2$ were also present. Vein quartz was the final deposition stage, precipitating from fluids dominated by meteoric waters. The proposed paragenetic sequence is similar to others recognized in tin deposits in Portugal and England. (From the authors' abstract)

HICKMAN, R.G., ELLIOTT, T.L. and SMITH, B.M., 1987, Gold mineralization associated with the Whipple detachment fault near Savahia Peak, San Bernardino County, CA (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 702. Authors at Unocal Sci. & Tech. Div., P.O. Box 76, Brea, CA 92621.

In the western Whipple Mtns. the Whipple detachment defines a NW-plunging antiform and N-plunging synform and superposes an upper plate of altered, mid-Tertiary, volcanic and volcaniclastic rocks over a lower plate of PG and young felsic gneisses. Most mineralization occurs in NW- and NE-striking fractures which cut the lower plate. This mineralization includes (1) very low grade disseminated gold in fractured gneiss and (2) minor epithermal quartz-calcite-(barite-pyrite-chalcopyrite) veins, locally with high gold values. Because gold is localized near the detachment within sympathetic extensional fractures and faults, and because mineralized zones are truncated by the detachment, we infer that gold deposition occurred during faulting and during or subsequent to dike emplacement.

The following paragenesis is indicated for the lower-plate veins: (1) Calcite I (white color, $\delta^{13}C$ more depleted than -5‰ PDB, dark cathodeluminescence), (2) quartz (fluid inclusion Th = 200°C), (3) Calcite II (brown color, patchy CL, F.I. Th = 90-120°C), and (4) Calcite III (white color, alternating bright and dark CL zones). High gold values are associated only with Calcite I and quartz, which formed from $^{18}O$-rich, deep seated fluids at about 200°C. The later stages of barren calcite formed when the deep-seated fluids mixed with cooler waters of meteoric origin, resulting in complex CL zoning, $\delta^{13}C$ values of -1 to -5‰, and in a wide range of more $^{18}O$-depleted oxygen-isotopic compositions. (From the authors' abstract)

HIGGINS, N.C., 1987, Magmatic and hydrothermal processes related to tin and tungsten mineralization: Bur. Mineral Resources, Geology, and Geophysics [Australia] Yearbook, 1987, p. 80-86.

Includes data on Mount Carbine (Queensland) (see next item); Mount Paynter (NSW); and Aberfoyle and Lutwyche (NE Tasmania). (E.R.)

HIGGINS, N.C., FORSYTHE, D.L., SUN, S.-S. and ANDREW, A.S., 1987, Fluid and metal sources in the Mt. Carbine tungsten deposit, North Queensland, Australia: Pacific Rim Congress 87, 26-29 August, 1987, Australasian Inst. Mining & Metallurgy, Victoria, Australia, p. 173-177. Authors at Bureau of Min. Resources, P.O. Box 378, Canberra, ACT, Australia 2601.

Paragenetic, fluid inclusion, stable isotope, and $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ isotope studies of the Mt. Carbine W deposit in North Queensland provide information on the sources of the mineralizing components and record the history of fluid-rock interaction during the hydrothermal process.

The ore minerals, wolframite and scheelite, are contained in quartz veins. Two major stages of mineralization are present and separated by a brittle fracturing episode.

The stable isotope and Sr and Nd isotope data suggest that the ore fluids during stage I and most of stage II mineralization were a mixture of magmatic water and non-magmatic water (connate or metamorphic) which had experienced a long residence time and had extensively exchanged with the sediments at high T. Subsequent mineralization events were dominated by fluids of meteoric derivation with a short residence time. The data imply that other solutes, such as W, were probably derived in minor part from local country rock sources with the major contribution coming from a magmatic source related to the granite batholith. (From the authors' abstract)

HILTON, D.R. and CRAIG, H., 1987, The Siljan deep well: Helium isotope results (abst.): EOS, v. 68, p. 1514. Authors at Isotope Lab., Scripps Inst. Oceanography, Univ. California, San Diego, La Jolla, CA 92093.

The Siljan Ring impact structure in Sweden is the scene of the current deep-drilling program to test the Gold hypothesis that 'deep-earth' abiogenic methane is trapped in crustal reservoirs. In conclusion the Siljan helium is highly radiogenic and crustal and there is no evidence for the presence of a mantle-derived helium component. (From the authors' abstract)

HINKLEY, T.K. and TATSUMOTO, Mitsunobu, 1987, Metals and isotopes in Juan de Fuca Ridge hydrothermal fluids and their associated solid materials: J. Geophys. Res., v. 92, No. B11, p. 11,400-11,410.

HIRAI, Hisako and ARAI, Shoji, 1987a $H_2O$-$CO_2$ fluids supplied in alpine-type mantle peridotites: Electron petrology of relic fluid inclusions in olivines: Earth & Planet. Sci. Letters, v. 85, p. 311-318. Authors at Inst. Geosci., Univ. Tsukuba, Ibaraki, 305, Japan.

Fluids supplied in alpine-type mantle peridotites and trapped as fluid inclusions in olivines have been fixed by low-T reactions, and their $CO_2$/$H_2O$ ratios can be deduced from the minerals in the inclusions. Relic fluid inclusions were commonly observed by the optical microscope in olivines from almost all examined solid intrusive ultramafic complexes (Papua, Oman, Troodos and eleven alpine-type complexes of Japan). Such complexes were emplaced into the crust in a solid state. Electron microscopic studies of olivines from three complexes, Higashiakaishi, Horoman and Iwanai-dake, showed that relic fluid inclusions in these olivines have distinctive mineral parageneses: serpentine + magnesite + talc, serpentine + magnesite + brucite, and serpentine + brucite, respectively, depending on the $CO_2$/($H_2O$ + $CO_2$) ratio of the trapped fluid.

It is deduced that the fluids had been supplied to peridotite, at least partly, but almost wholly in some case, when the peridotites were still hot, probably at the upper mantle for the following reasons: (1) the curved surfaces along which the inclusions are distributed are cut by post-emplacement serpentine veins; (2) for the Higashiakaishi dunite, the relic fluid inclusions are exclusively found in porphyroclast olivines and are totally absent in matrix olivines recrystallized during the Sanbagawa metamorphism.

Recent models on the derivation of ophiolitic or some alpine-type peridotites favor the island-arc or fore-arc settings. Dehydration of the descending oceanic slab may supply $H_2O$-$CO_2$ vapor to the overlying mantle wedge. Fluid inclusions trapped in such mantle wedge may abound in $H_2O$ component. $H_2O$-bearing fluid inclusions may, therefore, be important $H_2O$ containers in the upper mantle, especially near the edge of the mantle wedge above downgoing oceanic slabs. (Authors' abstract)

HIRAI, Hisako and ARAI, Shoji, 1987b, Electron petrography of relic fluid inclusions in olivines from solid intrusive peridotites: Sci. Rep., Inst. Geosci. Univ. Tsukuba, Sec. B, v. 8, p. 93-103.

See previous item. (E.R.)

HIRSCH, P.B., PIROUZ, P. and BARRY, J.C., 1986, Platelets, dislocation loops and voidites in diamond: Proc. R. Soc. Lond., v. 407, p. 239-258. First author at Dept. Metal. & Sci. of Materials, Univ. Oxford, Parks Rd., Oxford OX1 3PH, UK.

A type IaB diamond specimen containing partially decomposed platelets, dislocation loops and voidites has been investigated by transmission electron microscopy. Voidites are assumed to originate as bubbles of fluid N formed at high P and T as a result of decomposition of the platelets; at room T they may be liquid or solid depending on the P, which cannot be estimated accurately. Electron diffraction patterns and microscope images of voidites prove that many consist of a solid phase at 300 K. It is suggested that the diamond has been subjected to a drop in P at high T, causing platelet decomposition and the generation of voidites, that may occur during ejection of the diamond to the earth's surface. (From the authors' abstract)

See also Hirsch et al., 1986, Fluid Inclusion Research, v. 19, p. 183. (E.R.)

HITCHON, Brian, 1987, Can the Pine Point Zn-Pb deposit be derived from formation waters in Middle Devonian rocks of northern Alberta with Pb>Zn? (abst.): GAC-MAC, AGC-AMC Joint Ann. Mtg., Program with Absts., v. 12, p. 56. Author at Basin Analysis Group, Alberta Geol. Survey, Alberta Research Council.

Trace metals have been determined in a suite of formation waters recovered from drillstem tests in Middle Devonian and Granite Wash rocks of northern Alberta. Contents of Pb up to 350 mg/L and Zn up to 90 mg/L have been found, with total Pb > total Zn in about 60% of the samples. Using the program SOLMNEQF it is found that the dominant form of Pb and Zn in the formation waters under reservoir conditions is as chloride complexes, with the balance of these metals occurring in ionic form. Cooling of these brines results in little change in the proportions of chloride complexes and ionic form of these metals. Cooling and dilution, however, result in both an increase in the proportion of metals held in ionic form (that is, a breakdown of the chloride complexes) and in a change in the ratio of the ionic form to mainly $Zn^{2+} > Pb^{2+}$. A simplistic model is developed to derive the Pine Point Zn-Pb deposit from existing formation waters with Pb > Zn; whether this model is correct remains enigmatic. (Author's abstract)

HLADKY, G. and WILKINS, R.W.T., 1987a A new approach to fluid inclusion decrepitometry - Practice: Chem. Geol., v. 61, no. 1/4, p. 37-45.

Full paper for abstract in Fluid Inclusion Research, v. 18, p. 172, 1985. (E.R.)

HLADKY, George and WILKINS, R.W.T., 1987b, An evaluation of fluid inclusion decrepitometry using quartz from the Kingsgate molybdenite-bismuth deposits, New South Wales, Australia: N. Jb. Miner. Mh., v. 12, p. 537-549.

A study has been made of the relationship between heating-freezing stage and decrepitation data for fluid inclusions in three growth zones of a large quartz crystal from Kingsgate, New South Wales, Australia. It was found that the mean Th can be estimated from the decrepitation data either by specific corrections related to the known inclusion salinity (more precise) or by a general correction which is independent of salinity (less precise).

Discrepancies of up to 30-40°C exist between the actual and estimated Th. Of the several possible reasons for these discrepancies the most likely is that the inclusion size affects Td. (Authors' abstract)

HO, S.E., 1986, A fluid inclusion study of Archaean gold deposits in the Yilgarin Block, Western Australia: PhD thesis, Univ. Western Australia, Nedlands, Australia, 90 pp. (unpublished).

See next item. (E.R.)

HO, S.E., 1987, Fluid inclusions: Their potential as an exploration tool for Archaean gold deposits, in Ho, S.E. and Groves, D.I., eds., Recent advances in understanding Precambrian gold deposits: The Geol. Dept. & Univ. Ext., The Univ. Western Australia, 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 gold 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 $g \cdot cm^{-3}$). Deposition occurred over 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 primary 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 environmetns. 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)

HOBBS, B.E., 1987, Principles involved in mobilization and remobilization: Ore Geol. Reviews, v. 3, p. 37-45.

HODGSON, M.A., 1985, Ore deposition (with particular reference to fluid inclusion studies) at Nenthead mine, North Pennines (England): B.Sc. thesis, Univ. St. Andrews.

Quartz samples from the Nenthead locality yielded mean P fluid inclusion Th in the range 90-298°C. A P correction of 8°C applied to the data, gives mean formation T in the range 98-306°C. Freezing studies indicate that the ore-forming fluid had a salinity of 29.4 wt % of $CaCl_2$ with only 1.8 eq. wt % of NaCl. Three distinct periods of deposition are envisaged. An evolutionary model is proposed in the light of new data, which is in agreement with Vaughan and Ixers' 1980 paper, suggesting a higher T (ore) environment than in previous, North Pennine ore field (and in particular, the Alston Block) literature. (Author's abstract)

HOFSTRA, A.H., LANDIS, G.P. and ROWE, W.A., 1987, Sediment-hosted disseminated gold mineralization at Jerritt Canyon, Nevada. IV -- Fluid geochemistry (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 704. First author at U.S.G.S., MS 918, Denver, CO 80225.

Fluid inclusions in quartz veins, jasperoid, and barite studied by microthermometry, mass spectrometry, laser Raman spectroscopy, and gas chromatography record changes in composition, T, and P that characterize 3 hydrologic events. Event I fluids contain ≈10 eq. wt. % NaCl, high $CH_4$, $C_2H_6$, $H_2$, $N_2$, and $CO_2$, and small amounts (<1 mole %) of short chain hydrocarbons (HC), $H_2S$, and Ar. Fluid immiscibility produced variable gas to water ratios. During Event I the fluids evolved from a HC:$CO_2$ ratio of ≈10 to a HC:$CO_2$ ratio of ≈1. P-T conditions were 250°-300°C and 1-1.5 kbars.

Event IIA fluids responsible for gold mineralization have a wide range of compositions. At one extreme are 3-10 eq. wt. % NaCl brines 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 HC, $H_2S$, $SO_2$, and Ar. However, some inclusions contained up to 1 mole % $H_2S$. At the other extreme are very low salinity (<0.1 eq. wt. % NaCl), low gas (<0.5 mole %) fluids. The observed variation in salinity suggests mixing of two fluids. Minimum trapping conditions for the saline, gas-rich inclusions are 200°-300°C and 0.5-1.0 kbars.

Event IIB fluids contain <0.5 eq. wt % NaCl and 0.5 to 1.5 mole % gases. $CO_2$ is the dominant gas with 0.05 to 0.1 mole % of $CH_4$ and $N_2$ and <0.02 mole % of $H_2S$, $SO_2$, Ar, and HC. $CH_4$:$CO_2$ ratios are <0125. P-T conditions were 200°-250°C and <200 bars.

Gas compositions and P-T conditions of Event I fluids are typical of natural gas generated during metagenesis of carbonaceous sediments; this probably took place during the Antler orogeny. Although gold-bisulfide complexes may have been dominant during Event IIA, the pH (≈4) indicated by dolomite dissolution, high P($CO_2$), T, and salinity suggest that gold may have also been carried as a chloride complex. Our data suggest that gold deposition resulted from mixing of a gold-bearing, chemically reduced, saline brine with an oxidized solution. Regardless of how gold was complexed, mixing of these two fluids would have been an effective mechanism for gold precipitation. The ≈500 bar drop in fluid P between Event IIA and IIB may represent a shift from lithostatic to hydrostatic P at the same depth. Widespread fracturing and brecciation at the onset of Event IIB allowed meteoric water to flood the system, ending ore deposition. However, these fluids contained enough $H_2S$ ($10^{-2}$ to $10^{-3}$ mole %) to redistribute gold. (Authors' abstract)

HOISCH, T.D., 1987, Heat transport by fluids during Late Cretaceous regional metamorphism in the Big Maria Mountains, southeastern California: Geol. Soc. Am. Bull, v. 98, p. 549-553.

HOLDER, G.D., MALONE, R.D. and LAWSON, W.F., 1987, Effects of gas composition and geothermal properties on the thickness and depth of natural-gas-hydrate zones: J. Petrol. Tech., v. 39, p. 1147-1152. First author at Univ. Pittsburgh.

When natural gas and water contact at low temperature and high pressure, gas hydrates can form. In colder climates (such as Alaska, northern Canada, and Siberia) and beneath the oceans, conditions are appropriate for gas-hydrate formation. This paper gives the depths and potential thicknesses of such hydrate formations as a function of the geothermal gradient, gas composition, and where appropriate, permafrost thickness, pressure gradient, and ocean-bottom temperature. (Authors' abstract)

Pertinent to understanding the significance of clathrates in fluid inclusions. (E.R.)

HOLDICH, R.G. and LAWSON, G.J., 1987, The solubility of aqueous lead chloride solutions: Hydrometallurgy, v. 19, p. 199-208.

HOLLISTER, L.S., 1987, Use of fluid inclusion densities and morphologies as constraints for determining uplift paths of metamorphic rocks (abst.): GAC-MAC, AGC-AMC Joint Ann. Mtg., Program with Absts., v. 12, p. 57. Author at Dept. Geol. & Geophys. Sci., Princeton Univ., Princeton, NJ 08544.

Pressure-temperature constraints provided by fluid inclusions have led to the recognition that several high grade metamorphic terranes had experienced periods of rapid uplift while still at high temperatures. Such uplift results in P-T loops convex to the temperature axis and requires a high rate of uplift (>1 mm/yr) which has been supported in some cases by cooling rate determinations.

Fluids in inclusions have the density appropriate for the P-T conditions of entrapment. The P-T conditions of the host rock must therefore lie on a path which passed across or along the isochore of the fluid. If the fluid inclusion contains immiscible phases which were homogeneous when entrapped, then the temperature of entrapment exceeded that required to homogenize the fluids. This constraint severely restricts the range of P-T conditions for formation of the fluid inclusion.

If these conditions are at lower pressure than P-T conditions determined by mineral phase equilibria, then the uplift P-T path can be shown to be convex towards the temperature axis. In many cases, such inclusions occur with other inclusions in a geometric array suggestive of having formed by decrepitation of an earlier, higher density inclusion. This texture strongly implies rapid uplift in order to generate the excess pressure (generally 1-2 kbar) to decrepitate the original inclusion. (Author's abstract)

HOLLISTER, L.S. and CRAWFORD, M.L., eds., 1986, Short course in fluid inclusions: Applications to petrology: Beijing, Geology Publ. House, 338 pp. (in Chinese).

This is a Chinese translation of the 1981 Mineral Association of Canada Short Course volume. (E.R.)

HOLM, D.K., 1987, Mesoscopic ductile to brittle deformation and thermal structure: Central Southern Alps, New Zealand (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 705. Author at Dept. Geol., Univ. Otago, P.O. Box 56, Dunedin, New Zealand.

Fluid inclusions in quartz from subhorizontal extension fractures have both water and $CO_2$-rich phases which homogenize at 290°C. P estimates, assuming immiscibility, are on the order of 700 bars (3 km). Inclusions in quartz from boudinage structures are all liquid-dominated $CO_2$-rich and homogenize over a range of 300°-400°C (mode of 310°-350°C) suggesting a minimum P determination for the ductile/brittle transition of 1.3-1.6 kb or 5-6 km. The above data show that the thermal structure in this area of rapid uplift (8 mm/yr) involves a shallow (probably 7-8 km) ductile/brittle transition with high T persisting to shallow depths in the brittle regime. This provides important constraints on recent thermal models for uplift of the Southern Alps. (From the author's abstract)

HONDA, M., REYNOLDS, J.H., ROEDDER, E. and EPSTEIN, S., 1987, Noble gases in diamonds: Occurrences of solarlike helium and neon: J. Geophys. Res., v. 92, no. B12, p. 12,507-12,521. First author at Res. Sch. of Earth Sci., Australian Nat'l. Univ., Canberra, Australia.

We have measured noble gases in 17 diamond samples, mostly inclusion free, from diverse, known locations. The $^3He/^4He$ ratios are characterized by a large spread ($10^4$), ranging from values below atmospheric to close to the solar ratio. Highest ratios were seen for an Australian colorless diamond composite and an Arkansas diamond. These samples also have imprecise but intriguing neon isotopic ratios, which are close to the solar value. An origin for the solarlike He and Ne in the diamond samples is unlikely to be accounted for by the presence of nucleogenic or spallogenic components. For single diamond stones a positive correlation is found between $^3He/^4He$ and $^{13}C/^{12}C$, possibly indicating that heavy carbon is accompanied by primordial helium. However the He result for the Australian colorless diamond composite with low $\delta^{13}C$ value requires another explanation, possibly sedimentary carbon contaminated with cosmic dust. The wide variation in $^4He/^{40*}Ar$ ratios observed from diamond samples suggests a complex history for the source regions and the diamond crystallization processes. Results for two Australian diamond composites (colorless and colored), which came from the same kimberlite pipe, are especially notable: the colorless stones contain no radiogenic components but solarlike He and Ne isotopic ratios, whereas the colored stones are enriched in radiogenic and fissiogenic components. Seemingly the Australian diamonds crystallized in a heterogeneous environment in the mantle source region. A pair of Arkansas diamonds, believed to be from a single pipe, exhibits similar anomalies. (Authors' abstract)

HORIBE, Y. and CRAIG, H., 1987, Trapped gases in amber: A paleobotanical and geochemical inquiry (abst.): EOS, v. 68, p. 1513. Authors at Isotope Lab., Scripps Inst. Oceanography, UCSD, La Jolla, CA 92093.

Amber is a fossil tree resin (Pliny, 0077) which contains about 10% by volume (STP) of gases trapped in occluded bubbles. In Baltic amber (Eocene) the gases (extracted with a Pyrex vacuum ball mill) average (in ccSTP/g) 0.07 for non-condensible ("air") gases and 0.03 for $CO_2$. The so-called "air" gases are quite different from atmospheric composition: mean ratios are $N_2/Ar$ = 39 (range 37-41) and $O_2/Ar$ = 0.4 (0.2-0.8), vs. air ratios = 83.6 and 22.4. Helium and argon isotope ratios are essentially atmospheric. $CH_4$ is also present, averaging 1.2% (0.84-2.0) of the "air" gases. The observed $N_2/Ar$ ratios are close to the atmospheric solubility ratios in water, but the water content of the amber is 0.3 wt.% so that the

$N_2/H_2O$ ratio is 14 ccSTP/g $H_2O$ or 1000 x the air solubility concentration in water.

We understand these data as follows. The gases in amber were derived from solution in the original sap during the extrusion of the resin from the tree: they represent the concentrations in solution in the ground water taken up by the roots, with possibly a second solubility component from the leaves. $O_2$ was consumed both in ground water and in the sap by respiration, and $CH_4$ may be derived from both these sources. The $CO_2$ content is 78% of the $O_2$ deficit vs. solubility ($N_2/O_2$ = 1.84). We have also observed $N_2/Ar$ = 37.4 and $O_2/Ar$ = 0.6 in modern pine resin from Yellowstone Park. Gases in amber have thus been preserved intact for 60 My and record some aspects of ground water chemistry and sap composition in ancient forests. Isotopic and chemical studies of amber and other fossil resins are continuing. (Authors' abstract)

HORITA, Juske, 1987, Stable isotope study on brines and evaporites: Ph.D. dissertation, Dept. Chemistry, Tokyo Inst. Technology, Tokyo, Japan, 193 pp. (in English).

Involves a fairly extensive discussion of experimental checks on the many errors inherent in the various techniques that have been used for isotopic analysis of brines, and in fluid inclusions in saline minerals, particularly halite. Considerable attention was also given to the many serious problems of appropriate sample preparation, and inclusion release procedures (ball milling, decrepitation, and melting under vacuum) are compared. The melting method is inadequate, and the ball milling procedure is recommended, but only with appropriate corrections to the isotopic values found. Analyses were made of Chinese salt samples for $\delta D$ $\delta^{13}C$, $\delta^{18}O$, $H_2O$, $CO_2$, $SO_2$ and non-condens. gas. In addition, carefully cleaned bulk salt analyses were made for K, Ca, Mg, Fe, $SO_4$, Br and I.

Includes also a discussion of isotopic modeling of the processes affecting brines in evaporitic environments, with studies of the Dead Sea, Mt. Sedom diapir (Israel), and Searles Lake, CA. These include both equilibrium and disequilibrium steady state processes. Analyses of Ca, Mg, Fe, Zn, Cu, K, Br, I, and $SO_4$ are given for 10 samples of salt from Mt. Sedom, as well as $\delta D$ and $\delta^{18}O$ of the extracted inclusion water, and $\delta^{13}C$ and $\delta^{18}O$ of $CO_2$. Simple evaporation of seawater is inadequate to explain the inclusion compositions found.

Inclusions in halite from Searles Lake are assumed to fall in the system $Na_2CO_3$-$NaHCO_3$-$Na_2SO_4$-NaCl-KCl-$H_2O$, and hence do not present serious isotopic fractionation effects on extraction for $\delta D$ and $\delta^{18}O$. The resulting isotopic data are useful in interpreting paleoclimatic trends over the last 2 million years. Analyses of $CO_2$, $H_2O$, $\delta D$ and $\delta^{18}O$ for $H_2O$, $\delta^{13}C$ and $\delta^{18}O$ for $CO_2$, non-condensable gas, and trace elements in the salt are given. (E.R.)

HORN, E. and BEHR, H., eds., 1987, Current research on fluid inclusions (Eighth Symp. on Current Research on Fluid Inclusions, Göttingen, FRG, Apr. 10-12, 1985): Chem. Geol., v. 61, no. 1-4, 308 pp.

HORN, E.E., NEUSER, R. and RIEKEN, R., 1987, Fluid inclusion systems in diagenetic environments at depths of 1000-6000 M (North German basin) (abst.): Terra cognita, v. 7, no. 2-3, p. 343. Authors at Inst. Geol. Dyn. der Lithos., Goldschmidtstr. 3, D-3400 Göttingen, FRG.

Fluid inclusions from core samples of the Mesozoic and Paleozoic (N-German basin) reveal various stages in diagenetic mineralizations. The development of the formation water regime was reconstructed using fluid chemistry. Formation T and salinities correlate with depth, increasing in salinity and T from 1200 to 6000 m. Mesozoic core samples from below 1800 m contain $CO_2$- and methane-bearing fluid inclusions in the cements and growth rims which allow an estimation of the (minimum) formation P. Paleozoic core samples have methane inclusions between 3800 and 4700 m and $CO_2$ between 4500 and 6200 m. (From the authors' abstract)

HORN, E.E. and REUTEL, Chr., 1987, Contribution of laser Raman spectroscopy to distinguishing of fluid inclusions (abst.): Fortschritte der Mineralogie, Bd. 65, Bhf. 1, p. 79 (in German). Authors at Inst. Geol. & Dynamics of Lithosphere, Univ. Göttingen, FRG.

During the last 10 years the application of laser Raman spectroscopy had increasing importance for studies of fluid inclusions. The possibility to study an individual inclusion nondestructively is the main advantage of this method. It is possible to record the molecular spectra of gases, solid phases and polyatomic ions. The detection limits are close to $10^{-10}$ μmole, and then gas composition can be determined semiquantitatively. Identification of the trapped solid phases may be made by comparing obtained spectra with reference ones. The Raman probe studies are especially important when a specimen contains several generations of fluid inclusions of different gas composition ($CO_2$, $N_2$, $CH_4$, CO, $H_2S$, etc.), which cannot be distinguished unambiguously by microthermometry. The combination of Raman probe determinations and microthermometric studies helps in identification of hydrates and in qualitative analysis of the inclusion solution composition. Also indications can be obtained on fluid inclusion composition, mineral-forming medium of minerals and migration of fluids. (Authors' abstract, translated by A.K.)

HORN, E.E. and TRAXEL, K., 1987a Studies of fluid inclusions by use of the proton microprobe (PIXE) (abst.): Fortschritte der Mineralogie, Bd. 65, Bhf. 1, p. 80 (in German). First author at Inst. Geol. & Dynamics of Lithosphere, Univ. Göttingen, FRG.

For determination of the chemical composition of fluids in inclusions, the proton microprobe from Heidelberg (PIXE = proton-induced X-ray emission) was applied. The proton microprobe is a perfect device for the nondestructive analysis of individual inclusions in crystals due to high penetration of protons. Principally it is possible to determine elements with atomic number > M (sodium onwards) depending on the matrix composition. There are distinct relations between atomic number, matrix, proton beam and detection limits. The latter is higher for elements with higher atomic number. Thus it is possible to detect the heavier elements, e.g., Fe, Br and Sr in fluid inclusions at the depth 5-40 μm from the surface of the preparation. The preparations used for PIXE are the same as for microthermometric studies, and both proton analysis and Th, Tfrz [presumably Tm ice] etc., determinations may be made on the same inclusions. The results are presented, showing the qualitative analysis of fluid inclusions in quartz and calculations in relation with the depth of occurrence of inclusions in preparation. (Authors' abstract, translated by A.K.)

HORN, E.E. and TRAXEL, K., 1987b Inclusion studies with the proton microprobe (PIXE) (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). First author at Inst. Geol. und Dynamik Lithosphäre der Univ. Göttingen, 3400 Göttingen, FRG.

To obtain chemical information on geologic fluids, we have used the Heidelberg proton-induced X-ray emission (PIXE) microprobe on fluid inclusions. The high penetration of the protons makes the proton microprobe an ideal tool for nondestructive elemental analysis of individual fluid inclusions inside the crystals. Principally, it is possible to detect elements with atomic numbers >11, corresponding to Na, which in reality is matrix dependent. Between atomic number, matrix, beam, and limit of detection there are distinct relationships. The detection limit is more sensitive for higher atomic numbers. Therefore it is possible to analyze heavier elements, e.g., Fe, Br, Sr, in inclusions at a depth of 5-40 μm beneath the sample surface.

For investigations with PIXE the same samples can be used as for fluid inclusion studies. Therefore it is possible to collect microthermometric data and to study chemical composition of fluid inclusions within the same sample.

Results of qualitative chemical analysis of fluid inclusions in quartz and the calculations as a function of depth are presented. (Authors' abstract)

Ed. notes: This paper was presented as a poster at the session but the abstract was not in the abstracts volume. The same abstract was printed in ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 145. (E.R.)

HORN, E.E. and TRAXEL, K., 1987c Investigations of individual fluid inclusions with the Heidelberg proton microprobe - A nondestructive analytical method: Chem. Geol., v. 61, no. 1/4, p. 29-35.

Full paper for abstract in Fluid Inclusion Research, v. 18, p. 177-178, 1985. (E.R.)

HUA, Renmin, 1987, A simple method for studying gaseous phase in mineral inclusions: Geol. & Prospecting, v. 23, no. 3, p. 39-40 (in Chinese; English abstract). Author at Dept. Geol., Nanjing Univ., PRC.

A brief review of the design and use of the crushing stage. (E.R.)

HUANG, Dianhao, WU, Chengyu and NIE, Fengjun, 1987, Geological features and origin of the Jinduicheng porphyry molybdenum deposit, Shaanxi Province: Mineral Deposits, v. 6, no. 3, p. 22-34 (in Chinese; English abstract). Authors at Inst. Min. Deposits, Chinese Acad. Geol. Sci., Beijing.

Mineralization occurs in a porphyry and biotitized and hornfelsized spilite within the exocontact zone. The ore body consists chiefly of fine stockwork, reaching 1000 meters below the surface. Five vein assemblages are present (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. Molybdenite occurs in impregnations and veinlets. Wall rocks show a gross zonation of K-feldspathization-greisenization → silicification → propylitization from the porphyry outwards; of these alterations, silicification is intense and has close relationship with Mo mineralization.

Fluid inclusion studies yield Th from 250°C to 240°C, with the main ore-forming stage ranging from 400°C to 300°C[sic]. Gaseous inclusions are frequently coexistent with multiphase inclusions containing such dms as halite, sylvite, molybdenite and K-feldspar. Medium-high T, low $fO_2$, high $fS_2$ and weak acidity, and boiling of ore-forming fluids are prerequisite for the precipitation of molybdenite.

Isotope compositions of S, O, and C suggest that the high T stage (450°C) mainly has magmatic water ($\delta^{18}O_{SMOW}$ = +9.4‰, $\delta^{34}S$ = +4.5 - +5.4‰), and the main ore-forming stage (400-300°C, $\delta^{18}O_{SMOW}$ = +8.3 - +2.0‰, $\delta^{34}S$ = +5.6 - +3.7‰) is characterized by a mixed solution with magmatic water as the major source. In contrast, the late stage is dominated by meteoric water (250-240°C, $\delta^{18}O_{SMOW}$ = +4.8 - -1.6‰). It is therefore conceivable that S and Mo are mostly derived from magmatic source. (From the authors' abstract)

HUANG, Shujun, ZENG, Yongchao, JIA, Guoxiang and CHEN, Yuanrong, 1987, On the genesis of Dabaoshan polymetallic deposit in Guangdong Province, China: Geochemistry, v. 6, no. 4, p. 322-330 (in English). Authors at Res. Inst. of Geol. for Min. Resources, China Nat'l. Nonferrous Metals Industry Corp.

The Dabaoshan deposit is a polymetallic deposit containing Mo, W, Cu, Pb and Zn. There is much controversy about the genesis of the deposit. In the early 1960s, it was considered as a mesohypothermal deposit resulting from interstratified replacement. Recently, some other genetic models have been put forward, e.g., the strata-bound deposit model.

Studies of the contents of characteristic elements in pyrite and sphalerite, the compositions of sulfur and lead isotopes, zoning of primary halos, Th of fluid inclusions in minerals from the deposit and element abundances in the strata led to a conclusion that the deposit is of post-magmatic hydrothermal origin. (Authors' abstract)

HUBERT, Pascal, 1986, Textures and fluid inclusions of gold quartz; application to the Cros-Gallet deposit (Haute-Vienne, France) and the Au prospect of Sanoukou, Kenieba district: PhD dissertation, Univ. d'Orléans; BRGM Document 114, 350 pp. (in French; English abstract).

Au is related geochemically and/or mineralogically, in both deposits, to microcrystalline quartz assemblages. These result from local silica remobilization during brittle (cataclasis) or semi-ductile deformation (deformation-recovery-recrystallization).

This early mineralization results from a fall in P in the shear-zone system, initially at high P (1.8-2 kb) and T (300-400°C). This P drop is accompanied by the arrival of $CO_2$ vapor which mixes mechanically with the pre-existing solutions. Later, this early mineralization is enriched through remobilization by low T (<300°C) Pb-bearing fluids with a minor $CO_2$ content. This later mineralization is characterized by the crystallization of clear quartz in small vugs. The formation of economic concentrations of Au in the two studied deposits occurred during this stage. Bulk fluid inclusion analysis shows that a correlation exists between Au content and certain parameters of the fluid chemistry (K/Na, Li/Na, $CO_2$/Na and to a lesser extent $CO_2/CH_4$). This study established the best conditions and environments for this type of Au deposit and determined useful measures for its prospection. (From the author's abstract)

HULEN, J.B., NIELSON, D.L., GOFF, Fraser and GARDNER, J.N., 1987, Hydrothermal alteration and molybdenum mineralization in the active geothermal system at Sulphur Springs, Valles caldera, New Mexico (abst.): EOS, v. 68, p. 469. First author at Univ. Utah Res. Inst., 391-C Chipeta Way, Salt Lake City, UT 84108.

See next item. (E.R.)

HULEN, J.B., NIELSON, D.L., GOFF, F., GARDNER, J.N. and CHARLES, R.W., 1987, Molybdenum mineralization in an active geothermal system, Valles caldera, New Mexico: Geology, v. 15, p. 748-752. First author at Univ. Utah Res. Inst., Salt Lake City, UT 84108.

Shallow, sub-ore-grade molybdenite mineralization has been discovered in the active, high-temperature geothermal system penetrated by Continental Scientific Drilling Program corehole VC-2A at Sulphur Springs, in the western ring-fracture zone of the Valles caldera, New Mexico. This mineralization is hosted by fractured, quartz-sericitized, intracaldera ash-flow tuffs younger than 1.12 Ma. The molybdenite is an unusual, poorly crystalline variety that occurs in vuggy veinlets and breccia cements also containing quartz, sericite (illite), pyrite, and fluorite, as well as local sphalerite, rhodochrosite, and chalcopyrite. Fluid inclusion data suggest that this assemblage was deposited from very dilute solutions at temperatures near 200°C. Geochemical modeling indicates that under restricted pH and $fO_2$ conditions at 200°C, the molybdenite and associated phases would be in equilibrium with hydrothermal fluids now circulating in the deep subsurface. The shallow molybdenite zone intersected in VC-2A may be the near-surface expression of deep, Climax-type stockwork molybdenum mineralization. (Authors' abstract)

HULSEBOSCH, T.P., 1987, The Mount Helen structural belt: Mineral changes, element mobility, and fluids associated with deep shearing in the Wyoming Archean Province (abst.): Abstracts, NATO Advanced Research Workshop, Fluid movements, element transport, and the composition of the deep crust, Lindås, Norway, 18-24 May, 1987 (unpaginated). Author at Univ. Wyoming.

Fluid inclusions within the mylonitic orthogneiss are very abundant and contain saline brines with approximately 20 wt % NaCl eq. Less deformed orthogneisses contain relatively fewer saline inclusions and orthogneisses collected well away from any mylonitic gneiss contain $CO_2$-rich fluid inclusions with no $H_2O$ inclusions. These data indicate that ductile deformation in the Mt. Helen structural belt occurred in the presence of highly saline, aqueous fluids. These fluids diluted any $CO_2$ that was present in the rock before deformation. (From the author's abstract)

HURAI, Vratislav and ČEPLIK, Jaroslav, 1987, A modified LEITZ 350 heating-cooling stage: Mineralia Slov., v. 19, p. 91-92 (in Slovenian; English abstract). First author at Geol. ústav Univ. Komenského, Zadunajská 15, 851 01 Bratislava.

The LEITZ 350 heating stage was improved for fluid inclusion observations in both heating and cooling modes. Originally used Hg thermometers were changed by a Pt resistance thermometer coupled with a digital voltmeter that involves a switch-operated "hold" on the readout. The single hand-operated valve permits direct pumping of $LN_2$ from dewar with help of compressed air. (Authors' abstract)

HURAI, V. and STRESKO, V., 1987, Correlation between quartz crystal morphology and composition of fluid inclusions as inferred from fissures in central Slovakia (Czechoslovakia): Chem. Geol., v. 61, no. 1/4, p. 225-239.

Full paper for abstract in Fluid Inclusion Research, v. 18, p. 182-183, 1985. (E.R.)

IGARASHI, K., OHTANI, H. and MOCHINAGA, J., 1987, Phase diagram of the system $LaCl_3$-$CaCl_2$-NaCl: Z. Naturforsch., v 4a, p. 1421-1424 (in English).

IMAI, H., The relation between geothermal fluids and fluids forming epithermal gold-silver deposits (abst.): Mining Geol., v. 37, no. 1, p. 70 (in Japanese).

INGHAM, Caroline, 1987, A study of fluid inclusions in gold bearing quartz veins, Commoner mine, Zimbabwe: Undergrad. thesis, Southampton Univ., 54 p.

A study of fluid inclusions in samples of auriferous vein quartz from the Commoner gold mine, Zimbabwe, was undertaken, to provide controls to the distribution of Au in the orebody. The inclusions present in the quartz were two-phase aqueous-rich inclusions, possibly containing dissolved carbon dioxide in the aqueous phase. They are low salinity (4 wt.% NaCl eq.) and density (0.95 $g.cm^3$). The quartz was deposited over the range 140°C to 190°C at P as low as 250 bars, suggesting Au transportation by hydrosulphide complexes.

Deposition occurred possibly as a result of dilution with more acidic fluids from the surrounding andesitic lavas of the Maliyami Formation, or due to loss of hydrogen sulphide by the formation of sulphide complexes, with which the economic concentrations of Au are associated. (From the author's abstract)

IRISH, N.F. and LOUCKS, R.R., 1987, High-precision thermometry from fluid inclusions that trapped boiling solutions (abst.): American Current Research on Fluid Inclusions, Jan 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Authors at Dept. Earth & Atmos. Sci., Purdue Univ., West Lafayette, IN 47907.

P fluid inclusions (fi's) that trapped single-phase vapor-saturated liquid or liquid-saturated vapor yield Th and P that correspond (within limits of the typically small experimental error) to the actual T-P conditions of host crystal growth, so such inclusions are generally recognized as offering potentially very sensitive and accurate geothermobarometers. However, populations of fi's that trapped boiling solutions present a number of obstacles to accurate geothermobarometry. We focus here on difficulties in estimating Tt of inclusion populations that include a substantial fraction of fi's that trapped liquid + vapor mixtures and thus yield liquid-vapor Th's that are spuriously high with respect to Tt.

Our results for populations of penecontemporaneously formed inclusions that trapped non-boiling liquids show Th frequency histograms (with more than 30 fi's) that are statistically symmetrical and very spiked, with standard deviations of 2-3°C.

We have done microthermometry on about 3000 quartz-hosted fi's that trapped boiling solutions in four epithermal Ag-Au vein districts. A Th histogram representing more than about 25 penecontemporaneously trapped fi's virtually always shows a well defined frequency mode near the low-T end of the Th range. The strongly asymmetric Th frequency histogram indicates that entrapment of vapor-saturated, single-phase liquid is more common than entrapment of liquid-dominant, liquid + vapor mixtures. Among the ~80 Th frequency histograms we have done, the one-tailed standard deviation on the low-T side of the mode averages about 3°C, which is very similar to the two-tailed standard deviation about the mean in Th histograms for non-boiling fluids, cited above.

Reproducibility of Th modes in individual samples has been tested by means of "blind" reruns by three persons, which show that modes obtained by different operators on the same sample (i.e., the same generation or population of fi's, but usually not the same specific fi's) vary with a standard deviation of 2-3°C. These results demonstrate that relatively high-precision Tt thermometry is readily attainable from inclusion populations that include heterogeneous trapping, provided that the number of coeval inclusions measured is large enough (usually >25) to yield a statistically robust frequency mode.

Applications of high-precision geothermometry include (1) recognition of T fluctuations during crystal growth (which can induce dramatic oscillatory migrations of mineral saturation fronts in the fluid column and produce oscillatory crustification banding) and (2) use in combination with fluid composition data for high-precision geobarometry, which has applications to interpreting the fluid dynamic regime or estimating depth below outcrop to drilling targets in mineral exploration. (Authors' abstract)

ISHIYAMA, Daizo, MATSUEDA, Hiroharu and NAKAMURA, Takeshi, 1987, Polymetallic mineralizations in the Jokoku-Katsuraoka mining area, southwestern

Hokkaido, Japan: Mining Geol., v. 37, no. 1, p. 1-14 (in Japanese; English abstract).

Includes Th values (129-467°, mostly 150-300°C) for quartz, sphalerite, rhodochrosite, dolomite and barite from 11 polymetallic deposits associated in part with skarns. Salinities range from 0 to ~10 wt% NaCl, except Katsuraoka stages 1 and 2, which are 30-40%, and have Th = ~350-450°C.(E.R.)

ISHKOV, Yu.M. and REIF, F.G., 1987, Development of procedures for laser-spectral analysis of fluid inclusions: Geokhimiya i Metody Anal. Geol. Ob'ektov v Zabaikal'e, Ulan-Ude, 1987, p. 145-155 (from Ref. Zh., Geol. 1987 Abstr. No. 7V622) (in Russian).

IVANOVA, G.F., BANNYKH, L.N., IGNATENKO, K.I. and KLUGER, F., 1987, Trace components in scheelites from ore deposits of diverse genetic types (concentration and form of occurrence): Geokhimiya, 1987, no. 5, p. 611-631 (in Russian).

IVANOVA, G.F. and NAUMOV, V.B., 1986, Genesis of tungsten deposits, in Geology of tungsten, Inter. Geol. Correl. Prog. Proj. 26 "MAWAM," A.A. Beus, ed., p. 245-270. Authors at Inst. Geochem. & Anal. Chem., Acad. Sci. USSR, Moscow, USSR.

Presents a detailed discussion of the fluid inclusion evidence for the genesis of tungsten deposits. (H.E.B.)

IVANOVA, G.F. and NAUMOV, V.B., 1987, Physico-chemical conditions of the formation of the tungsten mineralization according to the fluid inclusion data (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 53-54. Authors at Vernadsky Inst. Geochem. & Anal. Chem., USSR Acad. Sci., Moscow, USSR.

1. A set of well-known genetic types of W mineralization represented by wolframite greisens and vein-types and by scheelite skarn-type has been extended owing to the discovery of stratabound scheelite mineralization in metamorphic rocks of different composition and age and findings of scheelite in association with Sn, Au, Mo, Cu, Pb, Zn, Sb, Hg mineralization. We have summarized our results and the data available in the literature on the fluid inclusions in minerals of various types of W deposits.

2. The relations between the values of Th, P, chemical composition of solutions and wolframite were considered. The formation of wolframites differing in the composition from hubnerite to ferberite occurred as a rule in the range 340-260°C from low salinity solutions (<10-15 wt.%), sometimes with a high content of $CO_2$. The high T (420-340°C) are typical for the high-salinity multiphase fluid inclusions. The wolframite composition is considered as independent of T. On the basis of these data it may be concluded that wolframites cannot be used as a geothermometer. The range of P for wolframites of 11 W deposits that were formed from $CO_2$-rich solutions was estimated. The data indicate that wolframites from 15 to 90% $MnWO_4$ were formed under high P. On the basis of these results we may confirm the independence of the wolframite composition from P. It means that the wolframite composition cannot be used as a geobarometer.

3. The relations between Th, P and the composition of scheelite-forming solutions were analyzed. The highest T (600-300°C) correspond to scheelites of skarn, breccia pipes and some Au deposits that were formed as a rule from high-salinity solutions (30-60 up to 75 wt.% eq. NaCl). Scheelites associated with cassiterite, wolframite and molybdenite were found to have lower T (350-200°C) and the low salinity of ore-forming solutions (2-10 up to 15 wt.%).

4. The comparison of the main physico-chemical parameters of wolfram-

ite and scheelite mineralization reveals a few differences:

a) Scheelites are formed over a wider T (600-150°C) than wolframites of various compositions (450-250°C).

b) Wolframites are formed as a rule from low salinity solutions containing high content of $CO_2$. The high-salinity solutions are more typical for scheelites.

c) Wolframites and scheelites are formed under high P conditions: 2100-300 bars for wolframites, 1700-300 bars for scheelites. (Authors' abstract)

IVANYUK, B.O. and KARAVAEV, I.B., 1986, Thermobarogeochemical parameters of formations of tin-tungsten deposits of the Iultin region, in Thermobarogeokhimiya Endog. Protsessov, Vladivostok, 1986, p. 55-61 (in Russian). (C.A. 107: 158600h)

IXER, R.A., 1986, The ore mineralogy and parageneses of the lead-zinc-fluorite-baryte ore fields of the English Pennine and Mendip Hills: Min. Parageneses, J.R. Craig, et al., eds., p. 179-210. Author at Dept. Geol. Sci., The Univ. Aston in Birmingham, Gosta Green 4, Birmingham, England.

Discusses and reviews relevant published fluid inclusion data. (H.E.B.)

JACKSON, D.H., MATTEY, D.P., HARRIS, N.B.W. and SANTOSH, M., 1987, Stable isotope studies on charnockites and related granulites from South India (abst.): Abstracts, NATO Advanced Research Workshop, Fluid movements, element transport, and the composition of the deep crust, Lindås, Norway, 18-24 May, 1987 (unpaginated). Authors at Dept. Earth Sci., The Open Univ., Walton Hall, Milton Keynes MK7 6AA, UK.

Carbon dioxide-rich fluid inclusions from the high grade terrane of South India have been cited as evidence for granulite metamorphism being caused by pervasive carbon dioxide flushing, possibly from a deep seated source. This study tests the model of external $CO_2$-buffering and investigates the source of the carbon dioxide, using a stepped heating technique to extract gas from separated quartz grains. All samples studied so far show similar stepped release profiles and have a maximum carbon release between 500°C and 700°C. This release, characterized by the isotopically heaviest carbon in the sample, is interpreted as $CO_2$ from the decrepitation of fluid inclusions.

Whereas the khondalite and massive charnockite appear to have similar fluid characteristics, the incipient charnockite may be related to the influx of isotopically heavier $CO_2$ as a separate later event. The isotopic composition of this $CO_2$ falls within the range of normal mantle compositions (-4‰ to -8‰) but a possible mixed source involving decarbonation of carbonates and organically derived isotopically light carbon cannot be excluded. (From the authors' abstract)

JACKSON, J.J. and POLLACK, H.N., 1987, Mantle devolatilization and convection: Implications for the thermal history of the Earth: Geophys. Res. Letters, v. 14, no. 7, p. 737-740.

JAIRETH, S., 1987, Fluid inclusion geochemistry of quartz-wolframite-sulphide veins of Chhendapathar, Bankura District, West Bengal, India: Trans. Instn. Min. Metall., Sec. B: Appl. Earth Sci., v. 96, p. B59- B64.

The Chhendapathar group of W deposits is genetically related to adamellite (quartz monzonite) bodies that were intruded about 850 m.y. ago into metamorphic rocks of Proterozoic age (2000-1700 m.y.). Primary T mineralization is present in the form of quartz veins that contain ferberite, scheelite, magnetite and sulphides. The ore veins are accompanied by sericitic, argillic and propylitic alteration.

Optical microscopy and heating-freezing studies of fluid inclusions in quartz revealed the presence of four kinds of fluid inclusion: type A ($CO_2$-$H_2O$; $CO_2$, 1.5-9.9 mol%), type B ($CO_2$-$H_2O$; $CO_2$, 22-37 mol%), type C (pure $CO_2$) and type D (pure aqueous) inclusions. Type A, B and C inclusions are P and/or PS, whereas type D are S. The four types of inclusion have the following heating-freezing characteristics -- type A: Th $CO_2$L-V(L), 11.5-29.7°C; Te, -32.1 to -33.5°C; Tm ice, -5 to -11.7°C; Tm $CO_2$ hydrate, 0.1-1.1°C; Th L-V(L), 234-336°C; type B: Th $CO_2$L-V(L), 6.7-18.7°C; Th L-V(G), 244-361°C; type C: T $CO_2$L-V(L), 6.7-18.7°C; and type D: Th L-V(L), 139-175°C. The Tm $CO_2$ indicates that the low-density phase in all the inclusions is pure $CO_2$.

The final Th of type A and B inclusions produces different phases in a similar T range (244-336°C), indicating that these inclusions were entrapped from boiling, $CO_2$-bearing, saline hydrothermal solutions.

A log $f(S_2)$-log $f(O_2)$ diagram at 245°C and 1 atm is used to interpret the $f(O_2)$, $f(S_2)$ and pH conditions of formation of the quartz-wolframite-scheelite-sulphide association. (Author's abstract)

JAIRETH, S. and SARKAR, S.N., 1986, Fluid inclusion studies in quartz from quartz-sulphide veins of central section, Mosabani mines, Singhbhum, copper belt (Bihar): Indian J. Earth Sci., v. 13, no. 4, p. 295-310. First author at Dept. Earth Sci., Univ. Roorkee.

Quartz from quartz-sulphide veins show ample P polyphase L-G and relatively rare S biphase L-G inclusions. All P inclusions with halite as the dominant dm homogenize into liquid phase by halite disappearance at 291°C (18th level), 260°C (20th level), 321°C (21st level), 284°C (25th level), 311°C (29th level), 288°C (30th level), 301°C (depth = 1300 meters). These temperatures are very close to the true T of entrapment as other geothermometer (Ni, Co partitioning in coexisting pyrrhotite and pyrite) has given indentical T. Ore-forming fluids were dense, saline (39.4 wt.% to 35.3 wt.% NaCl) chloride-rich hydrothermal solutions which transported Cu and Fe as chloride complexes. Cooling of hydrothermal solutions from above 325°C to 260°C was the dominant factor that caused ore deposition. (Authors' abstract)

JAMBON, Albert and ZIMMERMANN, J.L., 1987, Major volatiles from a North Atlantic MORB glass and calibration to He: A size fraction analysis: Chem. Geol., v. 62, p. 177-189. First author at G.I.S. C.N.R.S.-B.R.G.M., Centre de Recherches sur la Synthèse et la Chimie des Minéraux, F-45071 Orléans Cédex 2, France.

The analysis of major volatiles in a North Atlantic mid-ocean ridge basalt (MORB) glass, has been performed using a new procedure based on the analysis of several size fractions of one single sample. It enables us to separate the contributions of volatiles from the glass phase, from the vesicle gas phase and eventually gas adsorbed on the grain surface. The vesicle composition (mole fractions) obtained upon crushing is 0.94 $CO_2$, 0.002 $H_2$, 0.06 $H_2O$. Volatiles extracted from the glass at 1150°C are $9.7 \cdot 10^{-6}$ mol $g^{-1}$ $CO_2$, $156 \cdot 10^{-6}$ mol $g^{-1}$ $H_2O$. The gases released at 500°C are mostly adsorbed contaminants but contribute marginally to the total amount except for numerous organic compounds which are destroyed at higher T.

When previous noble-gas data for the same sample are considered, one obtains the evidence that: (1) the He/$CO_2$ ratio does not fractionate between glass ($4.1 \cdot 10^{-5}$) and vesicles ($4.6 \cdot 10^{-5}$); and (2) water is not quantitatively degassed from MORB glasses. The ratio He:$CO_2$:$H_2O$ of $10^{-4}$:

2.4:13 for primitive magma has to be confirmed by further results to be considered as a typical value for a MORB source. (Authors' abstract)

JANECKY, D.R., CHARLES, R., GOFF, F. and HULEN, J., 1987, Geochemistry of molybdenum-bearing assemblages in CSDP well VC-2a, Valles caldera, New Mexico (abst.): EOS, v. 68, p. 469-470. First author at Los Alamos Nat'l. Lab., Los Alamos, NM 87545.

The unusual occurrence of molybdenum mineralization in an actively evolving hydrothermal system is a salient feature of the upper reaches of VC-2a, Sulphur Springs. At depths from approximately 22 m to 163 m, authogenic molybdenite coexists with illite ($K_{0.6}Mg_{0.25}Al_{2.3}Si_{3.5}O_{10}(OH)_2$), quartz, pyrite, and minor rhodochrosite ($CaMnCO_3$), sphalerite, chalcopyrite, and fluorite. Molybdenite concentrations decrease strongly below approximately 163 m. Succeeding assemblages are chlorite ($daph_{50}clin_{50}$) and calcite bearing, in addition to illite and quartz. Fluid inclusion temperatures in this region of VC-2a are approximately 200°C. The phase relations have been used to examine the stability of the assemblages observed and to estimate some of the thermodynamic properties for molybdenum. Fluid compositions are based upon samples from the similar WC 23-4 well, 2 km away. With solubility constants calculated using the SUPCRT database at 200°C, 15.5 bar, l = 0.15, and appropriate solid solution models for the chlorite and rhodochrosite, we have been able to define the solubility constant for molybdenite of 19.5 ± 0.5 for the reaction:

$$Mo^{++} + 2H_2S + 0.5O_2 = MoS_2 + 2H^+ + H_2O$$

The rather tight constraints on the molybdenite solubility constant is possible due to the tight bounding reactions in log $fO_2$-pH activity space. (Authors' abstract)

JANG, B.-A., WANG, H.F., REN, X. and KOWALLIS, B.J., 1987, Secondary fluid inclusions and origin of microcracks in granite from the Wolf River Batholith, Wisconsin (abst.): EOS, v. 68, p. 404. First author at Dept. Geol. & Geophys., Univ. Wisconsin, Madison, WI 53706.

Uniformly oriented, healed microcracks from the 1500 Ma Wolf River Batholith in east-central Wisconsin may represent the orientation of paleostress fields. All of the samples which we have examined have a strongly oriented set of healed cracks striking to the northwest, and some of them have secondary and tertiary sets. The melting and homogenization temperatures were measured for a number of the secondary fluid inclusions that are trapped in the healed cracks.

Samples from each locality showed two to four distinct melting temperatures, which varied from 0°C (pure water) to -26°C (highly saline). All melting temperature groups could generally be found in each crack set, although some melting temperatures might occur more frequently in particular sets. However, the melting temperature within a single healed crack was almost always the same. Reopening of earlier, healed cracks during a later event would lead to the range of melting temperatures found in each crack set. The homogenization temperatures ranged from 150° to 400°C, regardless of the locality and orientation of the crack. The highest fluid inclusion trapping temperature would have been above 600°C, if a 200 MPa pressure correction is assumed.

The fluid inclusion observations indicate that microcrack sealing occurred when the granite body was quite warm. The several distinct fluid inclusion melting temperatures show that the different units of the Wolf River Batholith have undergone two to four separate microcrack healing and sealing events, probably during primary cooling. (Authors' abstract)

JANSEN, J.B.H. and MAIJER, Cees, 1987, $CO_2$ and preferential $H_2O$ depletion in fluid deficient local rock systems during granulite facies metamorphism related to anorthositic magmatism in the Precambrian of Rogaland, SW Norway (abst.): Abstracts, NATO Advanced Research Workshop, Fluid movements, element transport, and the composition of the deep crust, Lindås, Norway, 18-24 May, 1987 (unpaginated).

A gradual $H_2O$ depletion manifested by increasing scarcity of OH-bearing mineral during peak metamorphic conditions leads to an increased $XCO_2$ in fluid inclusions closer to the intrusive complex. With increasing M 2 metamorphic grade amphibolites show a net decrease in F-content (as well as in other volatile elements, e.g., $P_2O_5$ and $K_2O$). The F-content of the Ca-amphiboles and the biotites varies a lot, but the highest values are observed in the granulite facies area. The F-substitution forms an extra argument for $H_2O$ depletion. Renewed introduction of fluid during the cooling stage (M 3) is evidenced by the formation of new biotites and amphiboles. The "driest" M 2 rocks possibly have an increased tendency to react with newly introduced water.

The compositions of fluid inclusions correlate with rock composition, being $CH_4$-rich in graphite-bearing metapelites and $CO_2$-rich in marble environments, with $\delta^{13}$-values indicating derivation of the $CO_2$-rich fluids from decarbonation reactions. If the measured amounts of $CO_2$, $CH_4$ and $N_2$ reflect primary fluid compositions, such a correlation should also hold for the M 2 phase of metamorphism.

Finally it can be concluded that evidence for pervasive fluid flushing from the intrusive complex or from deeper crust is lacking. Instead, M 2 metamorphism is characterized by closed system behavior where fluids were controlled in local domains. (From the authors' abstract)

JANSEN, J.B., MATTHEZING, Robert and RYE, D.M., 1987, Carbon isotope exchange in the internally controlled rock system of the graphite-bearing calcareous metapelites from Naxos, Greece (abst.): Abstracts, NATO Advanced Research Workshop, Fluid movements, element transport, and the composition of the deep crust, Lindås, Norway, 18-24 May, 1987 (unpaginated). First author at Inst. Earth Sci. Univ. Utrecht, Budapestlaan 4, P.O. Box 80.021, 3508 TA Utrecht, The Netherlands.

It can be concluded that calcite and graphite in the rock system tend to equilibrate particularly at high metamorphic grades, that their isotopic equilibrium fractionation depends on the crystallinity of the graphite, which is mainly governed by T and the presence of a diffusion medium, that low amounts of metamorphic fluid were effective for carbon isotope exchange and that the carbonaceous metapelites can be supposed to behave as an internally controlled rock system. (From the authors' abstract)

JAVOY, M., PINEAU, F. and PALENZUELA, P., 1987, Isotopic and chemical composition of volatiles in vesicles and glass of hot spot lavas from seamounts in Tahiti's area (abst.): Terra Cognita, v. 7, no. 2-3, p. 142. Authors at Lab. Géochimie des Isotopes Stables, Univ. Paris VII, Paris, France.

Samples of glasses have been recovered from the seamounts of Tehatetia, Mehetia and Rocard at a depth at 2500 meters. These glasses include alkali basalts and phonolites with vesicularities from 10 to >20%. The vesicles' gases have been recovered by crushing under high vacuum. They are $CO_2$-$H_2O$ mixtures, $H_2O$ comprising 50 to 80% of the total (in contrast to fresh MORB glasses, the vesicles of which generally contain no more than 25% water). The Tahiti glasses have high water contents (1.1 to 1.6%) which essentially correspond to the equilibrium solubilities for their eruption depths (as for most MORB). Incondensible gases constitute 1 to 2% of the vesicles' content, with again a significant difference with MORB. In Tahiti $H_2$ is the major incondensible gas (50 to 80% of total incondensibles) with $N_2$ varying from 50 to less than 20%. Whereas in MORB $N_2$ constitutes 85 to 90% of the total.

Although $\delta^{13}C$ of $CO_2$ in vesicles (-4.2 to -7.2) is not significantly different than that in MORB vesicles and that $\delta D$ in glass (-74 ± 2) and vesicles (-40 ± 5) is also very simlar to MORB values, the chemical characteristics, ($CO_2/H_2O$, $CO_2/He$, $CO_2/N_2$) are.

This suggests that the source for hot spot volatiles can have $^{13}C$ and D characteristics similar to that of MORB but with different chemical ratios. One way to achieve this would be if $CO_2$ and $H_2O$ from deep mantle sources were diluted to various extents in hot spots and MORB systems. (Authors' abstract)

JEFFREY, A.W.A. and KAPLAN, I.R., 1987, Geochemistry of gases in the Siljan well (abst.): Eos, v. 68, p. 1514. Authors at Global Geochem. Corp., Canoga Park, CA 91303.

Hydrocarbons in low concentrations (<1% of gas in drilling fluid) have been detected down to 6 km in the Siljan well. $^3He/^4He$ isotope ratios in the granite section between 5 and 6 km were low (0.02-0.07 $R/R_a$) indicating a crustal, rather than mantle, origin for helium. (From the authors' abstract)

JENNINGS, E.A., 1987, A survey of the Mainland and Island Belts, Thunder Bay Silver District, Ontario: Fluid inclusions, mineralogy, and sulfur isotopes: MS thesis; Lakehead Univ., Thunder Bay, Ontario, Canada, 159 pp.

The Thunder Bay Silver District is composed of two curvilinear groups of veins, the Mainland and Island Belts. The veins can be mineralogically divided into the barren, silver-bearing, and 5-element association veins.

During the present study, fluid inclusion, sphalerite composition, and sulfur isotopic composition were investigated, as well as some aspects of the mineralogy of the veins. Fluid inclusions in quartz, calcite, and fluorite indicating T ranging from 70°-450°C during vein deposition could be found in veins of both geographical and all mineralogical groups. Fluid inclusions in sphalerite indicate ore minerals were deposited between 80°-120°C at all locations. Salinity of the hydrothermal solutions was highly variable, 1-30 eq. wt. % NaCl. The dominant salt was $CaCl_2$.

Fe content in sphalerite indicates a log $a(S_2)$ of -18 to -25 during ore deposition at all deposits except Spar Island. At Spar Island Cu sulfide mineralogy suggests log $a(S_2)$ of -14 to -18. Sphalerite often contained trace quantities of Cd.

Sulfur isotopic composition of sulfides and barite ranged from -9.7 to +12.2%., with two anomalous values (near +30%.) from supergene samples. Paired data indicate isotopic nonequilibrium during deposition of sulfides.

The consistency of fluid inclusion, sulfur activity, and sulfur isotopic data suggest both depositional environment and hydrothermal fluid source were similar for all veins in the Thunder Bay district. Heterogeneity of the deposits, particularly the presence or absence of Ag, Ni, Co, and As may be due to the evolution of the fluids between their inception and entry into the depositional environment.

The source of the fluids is unknown, although their original sulfur isotopic composition is inferred to be fairly low (+4.7%.), suggesting a magmatic source of sulfur is possible. (Author's abstract)

See also Kissin and Jennings, this issue. (E.R.)

JENSENIUS, Jørgen, 1987a High-temperature diagenesis in shallow chalk reservoir, Skjold oil field, Danish North Sea: Evidence from fluid inclu-

sions and oxygen isotopes: The Am. Assoc. Petrol. Geol. Bull, v. 71, no. 11, p. 1378-1386.
See following three items. (E.R.)

JENSENIUS, Jørgen, 1987b Fluid inclusion microthermometry and stable isotope studies applied to the diagenesis of sedimentary rocks: Lic. Scient. degree thesis, Kobenhavns Univ., Denmark, 110 pp.
See following two items. (E.R.)

JENSENIUS, Jørgen, 1987c Fluid inclusion microthermometry, petrographic studies, $\delta^{18}O$, $\delta^{13}C$, $^{87}Sr/^{86}Sr$ and trace element analyses of fracture filling calcite from the Skjold oil field, Danish North Sea: Implications for the origin of the calcite precipitating fluid phase (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 55. Author at Inst. Petrology, Østervoldgade 10, DK-1350 København K, Denmark.

Subsidence and salt movement history, together with fluorescence and cathodoluminescence petrograpy, indicate a late origin for most of the fracture filling calcite (probably Late Miocene to Pliocene). Fluid inclusion microthermometry gives T significantly higher than those inferred by applying the present day geothermal gradient to the past. The dominant salt is NaCl and the salinity is ~13.5 wt. % NaCl eq. By combining T obtained from fluid inclusion studies with O isotope compositions of the calcite, a rough estimate of the O isotopic composition of the calcite-precipitating fluid phase can be made. C and Sr isotopes, and trace element results suggests an inter chalk origin for the calcite. C isotopes furthermore indicate a hydrocarbon origin for some of the $HCO_3$ used in calcite formation. It is concluded that hot water ascending along the margins of the diapir, underlying the oil field, flushed the reservoir, causing dissolution of chalk and reprecipitation in fractures. (Author's abstract)

JENSENIUS, Jørgen, 1987d Regional studies of fluid inclusions in Paleozoic sediments from southern Scandinavia: Bull. Geol. Soc. Denmark, v. 36, p. 221-235. Author at Inst. Petrol., Univ. Copenhagen, Østervoldgade 10, DK-1350 Copenhagen K, Denmark.

Fluid inclusions in diagenetic quartz and calcite have been investigated in order to determine minimum T attained during diagenesis and obtain information on composition of pore waters in the Paleozoic sediments. Surface samples and drill core samples have been studied. Two major types of fluids are described: aqueous and hydrocarbon mixtures. The aqueous inclusions can roughly be divided into 3 different groups based on Th with arithmetic means of 82°C (with a salinity ~25 eq. wt. % salts) and 136° and 175°C (with salinities ~5 eq. wt. % salts). The correlation of T and salinities of pore water is tentatively explained by dehydration of clay minerals diluting the pore waters. The hydrocarbon inclusions, some of which fluoresce green-yellow, homogenize into the liquid phase at -44° to +138°C. With regard to the thermal history the data indicate that 1: major thermal maturation occurred in pre-Carboniferous times, 2: all Cambro-Ordovician samples are post-mature with respect to hydrocarbon generations and 3: only small, dry gas potentials are present in the upper Silurian to Carboniferous rocks. (From the author's abstract)

JIN, Mingxia, 1987, Inclusion and metallogenesis in Late Proterozoic Sn-W granites, Kangdian area, China (abst.): Abstracts, Inter. Symp. on Petrogenesis and Mineralization of Granitoids, Dec. 7-10, 1987, Guangzhou, China, p. 123-124. Author at Chengdu Inst. Geol. & Min. Resources, Chinese Acad. Geol. Sci.

The evolution of mineral and fluid inclusions in Sn-W ores and granites is closely related with that of magmatic hydrothermal metallogenesis. From the early magma to the deposition of Sn-W deposits four evolutionary stages can be recognized and inclusions of various types can be found in each of these stages. (From the author's abstract)

JOHANSSON, S.A.E., 1987, Conference summary: Proc. of the 4th Int. Conf. on Particle Induced X-Ray Emission and its Analytical Applications, Tallahasse, Florida, USA, June 1986, Nuclear Instruments & Methods in Physics Research, v. B22, 1987, North-Holland, Amsterdam Pub., p. 1-4.

A review of the present status of PIXE analytical technique. (E.R.)

JOHN, D.A., 1987, Evolution of hydrothermal fluids in intrusions of the central Wasatch Mountains, Utah: PhD dissertation, Stanford Univ., Stanford, CA, 258 pp.

JOHNSON, M.C. and RUTHERFORD, M.J., 1987, P, T, and X($H_2O$) conditions in the Fish Canyon Tuff, Colorado magma chamber as determined experimentally (abst.): EOS, v. 68, p. 1542.

JOHNSTON, A.D. and WYLLIE, P.J., 1987, T-X($H_2O$) phase relations of the Nuk gneiss at 15 kbar: Constraints on the origin of Archean trondhjemites (abst.): EOS, v. 68, p. 1542.

JONES, B.F. and BODINE, M.W., Jr., 1987, Normative salt characterization of natural waters, in Saline water and gases in crystalline rocks, eds., Fritz, P. and Frape, S.K.: Geol. Assoc. Canada Special Paper 33, 1987, p. 5-18. First author at U.S. Geol. Survey, 432 Nat'l. Center, Reston, VA 22092, USA.

The salt norm is the quantitative idealized equilibrium salt assemblage that would crystallize if a natural water evaporated to dryness at 25°C and 1 bar P under atmospheric partial P of $CO_2$. The salt norms for a wide variety of natural waters were calculated using the new computer program, SNORM. SNORM distributes solutes into stable normative salt associations based on the Gibbs Phase Rule, available free energy values, and observed low-T mineral associations.

Although most natural water compositions represent multiple solute origins, three major categories can readily be identified: meteoric or weathering norms that are characterized by alkali-bearing sulfate and carbonate salts; marine-like norms with the familiar seawater-type halite-bischofite-carnallite-kieserite-anhydrite association; and diagenetic norms that yield salts, such as Ca-bearing chlorides (antarcticite and tachyhydrite) and sylvite, which suggest solute alteration by secondary mineral reactions. The solute source or derivation process within each of the above categories commonly is indicated by the presence or absence of diagnostic normative salts and their relative abundance in the normative salt assemblage. For example, salt norms may (1) identify lithologic source; (2) identify the relative roles of carbonic- and sulfuric-acid hydrolysis in the evolution of weathering waters; (3) identify the origin of connate waters from normal marine, hypersaline, or evaporite salt resolution processes; and (4) distinguish between dolomitization and silicate hydrolysis or exchange for the origin of diagenetic waters. (Authors' abstract)

JOYCE, D.B. and HOLLOWAY, J.R., 1987, Activity-composition relations for $H_2O$ in the system $H_2O$-$CO_2$-NaCl at high P and T by a new technique (abst.): EOS, v. 68, p. 450-451. Authors at Dept. Chem. & Geol., Arizona State Univ., Tempe, AZ 85287.

Continued next page.

Activity-composition relations ($aH_2O$-$XH_2O$) for $H_2O$ in $H_2O$-$CO_2$-NaCl fluids at high pressures and temperatures have been measured with a new technique. The technique involves the simultaneous buffering of $fO_2$ (with NiNiO) and $fH_2$ (with a hydrogen membrane) thereby buffering $fH_2O$ ($aH_2O$). Capsules were loaded with a source of $CO_2$ and/or NaCl (and sometimes water) along with NiNiO and held at the desired P, T, and $fH_2$. Because $aH_2O$ is fixed, the fluid reacts with the buffer to attain the equilibrium $XH_2O$. After the run the capsules were analyzed by the weight loss method to determine $XH_2O$. The validity of this technique rests upon 2 assumptions 1) that the dissolution of small amounts of the NiNiO buffer does not change the bulk properties of the fluid, and 2) that the fluid phase composition does not change significantly during the quench. Reversals have been obtained by simultaneously running capsules loaded with low and high $XH_2O$. Results in the $H_2O$-$CO_2$ system indicate ideality at 2 kb, 700°C, but increasing positive deviations from ideality with increasing temperatures, at least up to 840°C. Positive deviations from ideality were also found at 5 kb, 700°C and 6 kb, 700°C. Experiments run within the $H_2O$-$CO_2$-NaCl ternary 2-phase field delineate tie lines between coexisting $CO_2$-rich fluids and NaCl-rich fluids. (Authors' abstract)

KADKO, David and MOORE, Willard, 1987, Radiochemical constraints on the crustal residence time of submarine hydrothermal fluids: Endeavour Ridge: Geochimica Cosmo. Acta, v. 52, p. 659-668.

KAISER, C.J., KELLY, W.C., WAGNER, R.J. and SHANKS, W.C., III, 1987, Geologic and geochemical controls of mineralization in the Southeast Missouri barite district: Econ. Geol., v. 82, p. 719-734. First author at Dept. Geosci., The Pennsylvania State Univ., University Park, PA 16802.

Fluid inclusions in sphalerite indicate that warm Na-Ca-Cl brines (69°-105°C, 20-25.5 eq wt % NaCl) were present during early mineralization. Salinity data for fluid inclusions in barite (0-14 eq wt % NaCl) may be representative of the barite mineralizing fluid, but contamination by later fluids is possible. Sulfur isotope studies show that the paragenetically early sulfides are isotopically ligher than later barite. Individual minerals involved in main-stage mineralization have the following ranges of $\delta^{34}S$ values: pyrite-marcasite, 8.4 to 34.7 per mil; galena, 3.2 to 11.8 per mil; sphalerite, 7.2 to 15.8 per mil; barite, 20.5 to 32.2 per mil. Barite $\delta^{34}S$ values show enrichment in $^{34}S$ away from the central fault. This spatial distribution is due to the incorporation of sulfate from two reservoirs. Isotopically light sulfate, developed most strongly about the central fault, originated from the oxidation of $H_2S$ in the ore fluid emanating from the central fault. The heavy sulfate that prevailed distally was indigenous to the host dolostone formation water. The $\delta^{18}O$ values of main-stage barite vary from 17.0 to 19.6 per mil and the range is attributed to mixing of two fluids of different oxygen isotope composition and to variable isotopic fractionation between sulfate and water due to changing temperature. The light sulfur and oxygen isotope composition of supergene barite ($\delta^{34}S$ = 15.8‰, $\delta^{18}O$ = 9.0‰) is due to incorporation of isotopically light sulfate produced locally during the oxidation of sulfide minerals in the soil environment.

Barite precipitation was caused by fluid mixing, in which a Ba-Pb-Zn-$H_2S$-bearing brine discharged from faults and joints into lower Paleozoic dolostones and mixed with an oxidizing, sulfate-bearing, dilute fluid. (From the authors' abstract)

KALYUZHNYI, V.A., 1982 See Translations

KANEDA, H., SHIMAZAKI, H. and LEE, M.S., 1987, Fluid inclusion studies of ore deposits in South Korea, p. 129-189, in Akio Tsusue, ed., Final report, granite provinces and associated ore deposits in South Korea - A comparison of granite and metallogenic provinces in South Korea and those in southwest Japan: Privately printed, Kukmamoto, 189 pp. (in English).

Chapter I (pp. 129-170) consists of an extensive study, including 21 gas chromatographic analyses for $N_2$, $CH_4$, and $CO_2$ from 15 Korean Au-Ag ore deposits, prepared by ball milling or decrepitation, and compared with other analyses of Japanese deposits, and 27 Th histograms from various parts of these deposits. These data are interpreted in terms of their relationships to sulfur isotopic values.

Chapter II (pp. 170-189) is a similar but smaller study of Korean W-Mo-Sn ore deposits. It includes 19 G-C analyses from 13 deposits and 13 Th histograms. The deposits vary widely in $CO_2$ molality. (E.R.)

KANEDA, H., SHIMAZAKI, H., TAKENOUCHI, S. and LEE, M.S., 1987, Carbon and oxygen isotopes of $CO_2$ in fluid inclusions from the Korean Au-Ag quartz veins (abst.): Mining Geol., v. 37, no. 1, p. 71-72 (in Japanese).

KARAKAYA, I. and THOMPSON, W.T., 1986, A thermodynamic study of the system $MgCl_2$-NaCl-$CaCl_2$: Canadian Metal. Quarterly, v. 25, no. 4, p. 307-317.

KAY, B.D., 1986, Vein and breccia gold mineralization and associated igneous rocks at the Ortiz mine, New Mexico, U.S.A.: MS thesis; Colorado School of Mines, Golden, CO, 179 pp.

KEAYS, R.R., 1987, Principles of mobilization (dissolution) of metals in mafic and ultramafic rocks - The role of immiscible magmatic sulphides in the generation of hydrothermal gold and volcanogenic massive sulphide deposits: Ore Geol. Reviews, v. 2, p. 47-63.

KEITH, T.E.C., 1987, Scientific results of drilling at Newberry caldera, Oregon (abst.): Int'l. Union of Geodesy & Geophys., XIX Gen. Assembly, Vancouver, Canada; Aug. 9-22, 1987; Abstracts, v. 2, p. 411. Author at U.S. Geol. Survey, Mail Stop 910, 345 Middlefield Road, Menlo Park, CA 94025.

The first intracaldera drillhole (Newberry 2), sited 2 km from the vent of the youngest obsidian flow, was drilled to a depth of 932 m by the USGS Geothermal Research Program for the purpose of obtaining stratigraphic, heat flow, and hydrologic data. The bottom-hole temperature of 265°C is one of the hottest reported of any holes drilled in the Cascades region. A second intracaldera hole (RDO-1), drilled by Sandia National Laboratories, reached a depth of 424 m after drilling though an aquifer that produced an artesian flow of 158+°C water at 379-397 m depth.

Hydrothermal alteration began at a depth of 300 m and increased with depth; the T increased from 100°C at 697 m to 265°C at 930 m. The distribution of hydrothermal mineral assemblages is consistent with present T, although measurements from fluid inclusions in quartz indicate that T were as much as 50°C hotter than present for a short time.

Integrated petrography, mineralogy, and isotope data from intracaldera drill holes support the conclusions from modeling of flow-test data: the fluid produced from the bottom of Newberry 2 was largely steam with a large component of $CO_2$ and $H_2S$, a substantial amount of shallow hot water flows laterally in at least one aquifer within the shallow caldera fill, and the geothermal system is young and evolving. Hydrologic modeling shows that dikes feeding the young silicic intrusions within the caldera may be conduits for upflowing thermal water; however, the shallow hot water is cooled by mixing with shallow groundwater. (From the author's abstract)

KELLEY, D.S. and DELANEY, J.R., 1987a Multiple fracturing events and two-phase separation at 700°C in gabbros from the Mid-Atlantic Ridge, 23°N (abst.): American Current Research on Fluid Inclusions, Jan 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). First author at Dept. Geol. Sci., Univ. Washington, Seattle, WA 98195.

Microthermometric analyses of fluid inclusions on a suite of hydrothermally altered gabbros recovered just south of the eastern intersection of the Kane Fracture Zone and the Mid-Atlantic Ridge near 24°N, record the highest Th yet reported for mid-ocean ridge hydrothermal systems and indicate fluid salinities up to thirteen times that of seawater. Multiple generations of fluid inclusions along healed microcracks exhibit three distinct T-compositional relationships. We interpret these as inclusions trapped during three fracture events.

The earliest record of brittle failure in the gabbros is represented by coexisting conjugate vapor-brine fluid inclusions, occurring along healed microfractures in apatite. The vapor-dominated fluid inclusions, which exhibit apparent Th of 400°C, contain salinities of 1-2 wt% NaCl and are intimately associated with vapor- and liquid-dominated, metal-bearing inclusions which contain salinities of 50 wt% NaCl equiv. and which remain unhomogenized at >700°C. Compositional and phase relationships of the fluid inclusions may be accounted for by two-phase separation of a fluid under 1000-1200 bars P. These pressures require that fluid entrapment occurred under a significant lithostatic component and indicate a minimum depth of entrapment 2 km below the axial valley floor of the Mid-Atlantic Ridge. This corresponds to a minimum amount of tectonic uplift of 3 km, in order to place the samples at the 3100 m recovery depth.

The complex fracture networks within magmatic apatites represent fluid flow paths for either highly modified, deeply penetrating seawater or a late stage magmatic phase. The inclusions may have formed close to the solidus-rigidus zone adjacent to an active magma chamber. In this zone, encroachment of a cracking front on a cooling magma chamber would allow mixing to occur between high T hydrothermal fluids derived from seawater and late stage magmatic fluids released from the adjacent pluton.

Following collapse of the high T front, lower T fluids of definite seawater origin circulated through the open fracture networks, pervasively altering portions of the gabbros. This stage is represented by low-to-moderate (1-7 wt% NaCl equiv.) salinity inclusions in plagioclase, epidote, and augite, which homogenize at ~200-300°C and 400°C. Formation of hydrous mineral assemblages, under greenschist to lower amphibolite facies conditions, resulted in sealing of the vein system and may have resulted in modification of seawater salinities by as much as a factor of two. During or following these late stages of hydrothermal activity the gabbros were emplaced high on the axial walls by differential uplift attending formation of the flanking mountains which comprise the western bound of the eastern intersection of the Kane Fracture Zone with the Mid-Atlantic Ridge. (Authors' abstract)

KELLEY, D.S. and DELANEY, J.R., 1987b Two-phase separation and fracturing in mid-ocean ridge gabbros at temperatures greater than 700°C: Earth & Planet. Sci. Lett., v. 83, p. 53-66. See previous item.

KELLEY, S., TURNER, G., BUTTERFIELD, A.W. and SHEPHERD, T.J., 1986, The source and significance of argon isotopes in fluid inclusions from areas of mineralization (abst.): Terra Cognita, v. 6, no. 2, 1986, p. 105. First author at Physics Dept., Sheffield Univ., UK.

See Fluid Inclusion Research, v. 19, p. 208. (E.R.)

KEPEZHINSKAS, P.K., 1987, Origin of Cenozoic volcanic series of Komandorsky Basin framing according to geochemical and experimental data: Geol. Zbornik, Geol. Carpathica, v. 38, no. 1, p. 71-81. Author at Inst. Lithosphere, Acad. Sci., Staromonetny per., 22, 109180 Moscow, USSR.

High crystallization T (1230-1385°C) obtained from Th of melt inclusions in sub-liquidus mineral phases provide the evidence of relative $H_2O$ depletion of initial melt (water content in magma less than 1.5 wt.%). This melt underwent extensive sub-liquidus fractionation indicated by silicic glass inclusions in bronzites and Ca-plagioclases. All the geochemical and experimental data support the idea of anhydrous partial melting of quartz eclogites. (From the author's abstract)

KERKHOF, A.M., 1987, The fluid evolution of the Harmsarvet ore deposit, central Sweden: Geol. Föreningens i Stockholm Förhandlingar, v. 109, pt. 1, p. 1-12. Author at Inst. voor Aardwetenschappen, Vrije Univ., De Boelelaan 1085, 1081 HV Amsterdam, The Netherlands.

A fluid inclusion study of ores from the Harmsarvet deposit, 15 km NW of Aalun, Sweden, was made by means of microthermometry and Raman spectroscopy. Two main types of fluid inclusions can be distinguished: gaseous and aqueous inclusions. The gaseous fluids consist of 3 components: $CO_2$, $CH_4$ and $N_2$; aqueous inclusions are essentially complex brines of varying concentration. Most frequent are $CO_2$-rich inclusions with up to 30 mole % $CH_4$ and less $N_2$; $CH_4$ and $N_2$-rich inclusions are free of any $CO_2$. The present data indicate that the first ore minerals formed already during the regional metamorphic conditions estimated at 600 ± 50°C and about 3 kbar. Late phase minerals (e.g., acanthite) formed during retrograde conditions as trails associated with $CO_2$-$CH_4$-bearing inclusions. It is suggested that the gaseous fluid evolved from a $CO_2$-rich fluid to higher $CH_4$-contents by abstraction of $CO_2$ during the formation of carbonates (siderite). Hydrothermal water probably evolved from high saline brines of metamorphic origin to solutions of lower salt contents by mixing with meteoric water. Brines and gaseous fluids remained immiscible during retrograde conditions. (Author's abstract) (Other items entered under van den KERKHOV.)

KERRICH, R., 1986, Archaean lode gold deposits of Canada: Part II characteristics of the hydrothermal systems, and models of origin: Econ. Geol. Res. Unit, Information Cir. No. 183, Univ. Witwatersrand, Johannesburg, 34 pp. Author at Dept. Geol., Univ. Western Ontario, London, Ontario, Canada N6A 5B7.

[Geochemical studies and] the narrow recorded range in $\delta^{18}O$ of vein quartz at 12-15 per mil across banded veins, and of Au-bearing vein arrays within mines, independent of all-rock type, signifies an isotopically uniform fluid reservoir, a fluid-dominated system in the hydrofracture conduits, and a relatively small T span over which veins precipitated. Hydrothermal solutions transporting Au were isotopically characterized by $\delta^{18}O$ 6 to 9 per mil and $\delta D$ -80 to -40 per mil, consistent with a metamorphic fluid reservoir. These fluids were at 270 to 450°C, possessed low salinities of <2 wt. % NaCl eq., near neutral pH, Na/K ~0.1, and contained significant quantities of $CO_2$, along with the reduced gas species $CH_4$, $CO_2$, $H_2$, and ultrafine particulate hydrocarbons. The $CO_2$ may have been derived from mixtures of various possible carbon reservoirs, including marine and igneous carbonate, decarbonated marine carbonate or decarboxylation of organic hydrocarbons.

The fluid $\delta D$, $\delta^{18}O$, low salinity, high K/Na, variably elevated $CO_2$ and reduced gas species are all consistent with a metamorphic or magmatic fluid reservoir; whereas none of these geochemical features are typical of marine-water-derived ore-forming fluids. Of the various models proposed for greenstone-belt lode Au deposits, most are incommensurate with the geological and geochemical boundary conditions. Lateral secretion of Au and Au-associated chemical components into dilatant openings from enclosing wall rocks is not consistent with the known range of grain boundary diffusion distances over geological time spans and does not account for the separation of noble from rare elements.

Hence, the greenstone-belt Au deposits appear to form during the discharge of low-Cl, $CO_2$-rich, aqueous fluids of metamorphic and/or magmatic origin at depth in a compressive, crustal regime. (From the author's abstract)

KERRICH, R. and FYFE, W.S., 1987, Tectonics - fluids - resources (abst.): Abstracts, NATO Advanced Research Workshop, Fluid movements, element transport, and the composition of the deep crust, Lindås, Norway, 18-24 May, 1987 (unpaginated). First author at Dept. Geol., Univ. Saskatchewan, Saskatoon, Saskatchewan S7N 0W0, Canada.

Plate tectonic processes and associated ore deposits are all associated with multi-$Km^3$ fluid flow. Various examples are given. (E.R.)

KERRICH, R. and KAMINENI, D.C., 1987, Seismic pumping of deep thermal brines in the Superior Province: $\delta^{18}O$, fluid inclusion, and $^{40}Ar/^{39}Ar$ data from fracture minerals (abst.): GAC-MAC, AGC-AMC Joint Ann. Mtg., Program with Absts., v. 12, p. 61. First author at Dept. Geol. Sci., Univ. Saskatchewan, Saskatoon, S7N 0W0.

K-feldspar dominated vein systems have been encountered in Archean rocks of the Superior Province, during deep drilling of the Eye Dashwa Lakes granite (2,680 Ma), Atikokan, and East Bull Lake anorthosite gabbro complex (2,472 ± 60 Ma), Massey, Ontario. The hydrothermal adularia coexists with chlorite, quartz, ± prehnite, ± laumontite in fracture fillings, and as pervasive replacement of granite and gabbro in faults. Upper plateau $^{40}Ar/^{39}Ar$ ages of the K-feldspars are 1,100 Ma for Atikokan, and 940 Ma at Massey. In the Eye Dashwa Lakes granite, K-feldspar ($\delta^{18}O = 7.2$ to 7.8), and chlorite ($\delta^{18}O = -0.5$ to +0.1), formed at 100 to 140°C from fluids with a calculated $\delta^{18}O$ $H_2O = -7$ to -2‰. In the Folson Lake fault, which transects the East Bull Lake intrusive complex, metasomatic domains characterized by K-feldspar ($\delta^{18}O = 8.9$ to 10.2) and chlorite ($\delta^{18}O = 2.6$ to 4.0) were generated from fluids where $\delta^{18}O$ $H_2O = -2.6$ to +1.7‰. Quartz coexisting with adularia has primary fluid inclusions characterized by eutectic, and last ice melting temperatures of -52 to -40°C, and -17 to -12°C respectively, corresponding to fluids in the system $CaCl_2$-NaCl-$H_2O$, with solute concentrations of 12-15 wt.% NaCl equivalent. Filling temperatures are 140 to 220°C. We infer the presence of deep (~3 ± 1 km) thermal brine reservoirs of meteoric-$H_2O$ origin in the Archean rocks. Such fluids were expelled intermittently by seismic pumping that involved fault reactivation during Keweenawan (~1,100 Ma) and Grenville (~940 Ma) activity. (Authors' abstract)

KERRICH, R., KAMINENI, D.C., BORRE, D., BALDWIN, D.K., McLARTY, E. and THIVIERGE, R.H., 1987, Cyclic deformation and chemical transport in the Folson Lake fault zone, East Bull Lake anorthosite-gabbro complex: Evidence for seismic pumping?: Applied Geochem., v. 2, p. 103-126. First author at Dept. Geol. Sci., Univ. Saskatchewan, Saskatoon, Saskatchewan S7N 0W0, Canada.

The East Bull Lake anorthosite-gabbro, a late Archean (2472 ± 24 Ma) magmatically layered lopolith at the southern margin of the Superior Province, has experienced regional retrograde metamorphism, and is transected by the Folson Lake fault zone, a structure of regional extent. The fault zone displays repeated episodes of ductile-brittle deformation and vein development. It has been extensively metasomatized in domains marked by the sequential development of quartz, adularia, epidote, chlorite, laumontite, calcite, and clay-Fe oxyhydroxide.

Reconnaissance fluid inclusion studies have yielded eutectic and last ice melting temperatures as low as -49°C and -20°C respectively, indicating the presence of Ca-chloride brines. Within the fault zone, hydrothermal reservoirs involved in later K-metasomatism were at temperatures of 150-250°C, where $\delta^{18}O$ $H_2O$ = -2.6 to +1.7 per mil, likely representing isotopically and chemically evolved deep-pore fluids expelled during crustal activity related to tectonic processes in the nearby Grenville Province. Calcite and laumontite developed by the advection through the fault zone of Ca-rich thermal brines at temperatures around 50-200°C, where $\delta^{18}O$ $H_2O$ = -15 to 0 per mil; such fluids were evolved formation brines with a major component of meteoric $H_2O$, expelled in the lower Paleozoic. The multiple deformation-metasomatism events are interpreted in terms of episodic seismic pumping on a fault that was intermittently active over a time scale in excess of 1 Ga. (From the authors abstract and text)

KERRICH, R., KING, R.W. and MCLARTY, E., 1987, Systematics in $\delta^{13}C$ distribution of hydrothermal carbonates and fluid inclusion $CO_2$ from Au vein deposits of the Abitibi subprovince (abst.): GAC-MAC, AGC-AMC Joint Ann. Mtg., Program with Absts., v. 12, p. 61. First author at Dept. Geol. Sci., U. Saskatchewan, Saskatoon, S7N 0W0.

Hydrothermal carbonates from Au vein deposits of the Abitibi greenstone belt display local trends of $\delta^{13}C$ related to adjacent lithology, systematic variations of $\delta^{13}C$ values between deposits of a mining camp, and regional differences between camps. At Timmins, the $\delta^{13}C$ of Fe-dolomite ranges from average values of -1.3‰ (Paymaster) to -4.1‰ (Deep Dome, Buffalo Ankerite) on the south limb of the Porcupine synform. On the north limb, $\delta^{13}C$ values are generally more positive, averaging -3.1‰ (Hollinger), -1.9‰ (Coniarum) and -1.7‰ (Goldhawk); with minor exceptions such as Bell Creek where the mean $\delta^{13}C$ = -7.7‰. $\delta^{13}C$ values of calcite and/or Mn-siderite coexisting with Fe-dolomite are in compliance to within ± 0.2‰. At the scale of the subprovince, systematic differences exist between the average $\delta^{13}C$ of Fe-dolomite in the Matachewan ($\delta^{13}C = -3.7 \pm 1.3$), Kirkland Lake (-4.4 ± 0.6), Malartic (-5.8 ± 0.8) and Pontiac (-8.4 ± 0.4) camps. Step heating of vein quartz separates released $H_2O$-rich inclusions at <200°, but $H_2O$-$CO_2$-$H_2S$ ± $N_2$ at >300°C. Measured $\delta^{13}C$-$CO_2$ values span -3.9 to -1.2‰, and are systematically enriched by 0.5 to 1.2‰ relative to coexisting dolomite.

The provincial-scale distribution of $\delta^{13}C$ values is interpreted to reflect variations intrinsic to the source, whereas differences at a local scale arise from interactions with reduced C in wall rocks, which induces shifts of <+2‰ in Fe-dolomite by lowering the fluid Eh, or by <-1.5‰ where oxidation of low-$^{13}C$ graphite dominates. (Authors' abstract)

KHEANG, Lao and PERRAULT, Guy, 1987, Cl-rich and S-rich fluids related to the Archean gold deposits in the Val d'Or region, NW Quebec (abst.): GAC-MAC, AGC-AMC Joint Ann. Mtg., Program with Absts., v. 12, p. 61. Authors at Dépt. de Génie Min., Ecole Polytech., Montréal, Québec.

Microprobe analyses of fluid inclusion residues from 5 gold deposits reveal two distinct types of brines: (1) the classical Cl-rich type with weight-ratios of Cl/(Cl + S)>0.80 and (2) the unusual S-rich type with Cl/(Cl + S)<0.20. The other elements present in those inclusions include Na, K, Ca, Mg, Al, Mn, Fe and Ba, from which Na is generally the most abundant.

The Cl-rich brine is represented by the fluids of Sigma and Sigma-2 which have in common high $Na/(Na + K)>0.90$, high $Cl/(Na + K)>1.0$ and low $S/(Na + K)<0.10$. From the melting temperatures of ice, these two fluids have a large difference in their salinity: 11 wt% for Sigma-2 and >25 wt% for Sigma. In addition, the $CO_2$-phase associated with these fluids contains a minor amount of $CH_4$.

The S-rich fluid is represented by the fluids of Doyon-z3, New Pascalis vertical veins and Swanson. These fluids have in common high $S/(Na + K)>0.50$ and low $Cl/(Na + K)<0.10$, while the $Na/(Na + K)$ ratios are very variable, from 0.40 for New Pascalis to 0.91 for Swanson. Similarly, the S-rich fluids have a large variation in their salinity: 3.5-4 wt% for Swanson and New Pascalis and 24 wt% for Doyon-z3. The associated $CO_2$-phase is almost pure for all deposits.

In conclusion, Archean gold deposits in the Val d'Or region have been formed from various types of brines. At present, we recognize the Cl-rich and the S-rich types. These brines were probably generated by different mechanisms and possibly from different sources. Indeed, a refinement of thermo-chemical characteristics of the ore-brines may play an important role in understanding and improving the hydrogenetic model of the related deposits. (Authors' abstract)

KIEFERT, L. and SCHMETZER, K., 1987a Pink and violet sapphires from Nepal: The Australian Gemmol., v. 16, p. 225-230. Authors at Inst. Mineral. & Petrog., Univ. Heidelberg, West Germany.

Various types of solid inclusions are discussed. (E.R.)

KIEFERT, L. and SCHMETZER, K., 1987b, Blue and yellow sapphires from Kaduna Province, Nigeria: Z. Dt. Gemmol. Ges., v. 36, no. 1/2, p. 61-78 (in German; English abstract).

Refers to "mineral inclusions with or without primary liquid feathers (albite, uranpyrochlore, zircon ..." (E.R.)

KIM, G.S. and ENJOJI, M., 1987, Fluid inclusions in ore-forming minerals from the Chungju iron mine, Korea (abst.): Mining Geol., v. 37, no. 1, p. 71 (in Japanese).

KIMURA, E.T., BARDE, B.W. and THOMSON, I., 1987, Geology of Seabee gold deposit (abst.): GAC-MAC, AGC-AMC Joint Ann. Mtg., Program with Absts., v. 12, p. 61. Authors at Placer Dev. Ltd., P.O. Box 49330, Bentall Postal Station, Vancouver, B.C., V7X 1P1.

The Seabee gold deposit is 120 km northeast of La Ronge in northern Saskatchewan. It is regionally within the Glennie Lake Domain of granitoids and tectonically deformed and metamorphosed supracrustal rocks. More locally, the Seabee property is underlain by Laonil Lake Intrusive Complex that is mainly comprised of gabbro and diorite with minor granodiorite and feldspar porphyry components. North of the property, this igneous complex is overlain by a sedimentary sequence, and to the south it is bounded by younger Eyahpaise Lake granodiorite pluton. Rocks of the igneous complex are characteristically metamorphosed to amphibolite facies and display a strong east-northeast steeply-dipping tectonic fabric. Intense deformation and shear zones oriented parallel to the regional foliation can be traced across the property. Shear development commonly favors areas of crowded dyke intrusion.

Shear zones within the igneous complex are hosts for gold-bearing quartz-tourmaline veins and lenses. Along these structures, mineralized zones occur as distinct vertically-elongated shoots and as larger bodies up to several meters wide and 200 meters long. Pyrite, pyrrhotite, minor chalcopyrite and rare tellurides occur as local concentrations within quartz and adjacent sheared wallrock. Gold is intimately associated with quartz and sulphides as minute disseminations, wispy fracture fillings and occasionally as larger visible grains. Main alteration phases attendant with gold mineralizatiin include intense potassic metasomatism, weak carbonatization and sulphidation of pre-existing ferromagnesian minerals.

Structural studies demonstrate that mineralization pre-dates shearing, metamorphism and development of the tectonic fabric. Both gold mineralization and potassic alteration show a spatial relationship with feldspar porphyry bodies. Fluid inclusion data is compatible with a magmatic origin for the mineralizing fluids in a structurally confined porphyry-style stockwork system. (Authors' abstract)

KINNUNEN, Kari, LINDQVIST, Kristian and LAHTINEN, Raimo, 1987, Fluid history from crystal cavities in rapakivi, Pyterlahti, southeastern Finland: Bull. Geol. Soc. Finland 59, Part 1, p. 35-44.

The crystal cavities lined with quartz, feldspars, biotite, fluorite and a number of accessory phases occurring in the Haikonvuori pyterlite quarry in the Wiborg rapakivi massif were studied with mineralogical, petrographical and chemical methods. P fluid inclusions of quartz showed Th of 292°C to 342°C. The cavities as structures are considered to be miarolitic vugs of chamber pegmatites, but their filling is interpreted as largely secondary and deposited during at least three of the fluid stages present. The nature of the filling material was not reflected in the chemical composition of the pyterlites, but the presence of the cavities, irrespective of their filling, could be inferred from the La and Th depletion and from various petrographic characteristics indicating intensified fluid action. Thus, crystal cavities seem to provide ideal fluid traps for studies of the local fluid history of the crust. (Authors' abstract)

KIRSCHBAUM, C., IRWIN, J.J., BOHLKE, J.K. and GLASSLEY, W.E., 1987, Simultaneous analysis of halogens and noble gases in fluid inclusions in neutron-irradiated quartz veins: A laser microprobe study (abst.): EOS, v. 68, p. 1514. First author at Dept. Physics, U.C. Berkeley, CA 94720.

A small but important set of elements, including Cl, K, Ca, Se, Br, Te, I, Ba and U, are converted into isotopes of Ar, Kr and Xe by neutron irradiation. If the production of these elements during the irradiation is monitored, accurate values for their relative amounts can be determined by measuring the noble gases. We have applied this technique to fluid inclusions in gold-bearing quartz veins from Alleghany, CA.

Individual inclusions and small groups of inclusions in irradiated samples of quartz were decrepitated under vacuum with a laser microprobe and the released noble gases measured. Results indicate that the Xe/Ar and I/Cl ratios are variable and correlated. Furthermore, samples which are rich in $CO_2$ have lower Xe/Ar and I/Cl ratios and samples which are poor in $CO_2$ have higher Xe/Ar and I/Cl ratios. Argon concentrations in the inclusions are within a factor of three of air-saturated water at 20°C and the observed Xe/Ar ratios are higher than would be expected for air-saturated water. The I/Cl ratios are significantly higher than seawater and resemble those of NaCl-type connate brines or possibly metamorphic spring water (D.E. White, USGS PP 440F). The data may indicate mixing of two different fluids or some fractionation mechanism. (Authors' abstract)

KIRSTEN, T., HEUSSER, E., RICHTER, H., OEHM, J. and ROCHOLL, A., 1986, Rare gas isotopes in Hawaiian mantle xenoliths: Jahresberecht, 1986, Max-Planck-Inst. Kernphysik, Heidelberg, p. 150 (in German; English abstract). Authors at MPI Chemie, Mainz, FRG.

A series of Hawaiian ultramafic samples has been analyzed for all rare isotopes including high precision $^3He/^4He$-determinations. Isotopic systematics and possible implications for the origin of these gases are discussed. (Authors' abstract)

KISCH, H.J., 1987, Correlation between indicators of very low-grade metamorphism, in M. Frey, ed., Low Temperature Metamorphism, p 227-300.
Discusses the fluid inclusion T data for the prehnite-pumpellyite facies. (H.E.B.)

KISLITSYN, V.G., SIDIKOV, S., SULTANKHODZHAYEV, A.N., TOLSTIKHIN, I.N. and CHERNOV. I.G., 1987, Argon and helium isotopes in rocks, inclusions and waters of the Tashkent geodynamic testing area: Geokhimiya, 1987, no. 8, p. 1174-1181 (in Russian; English Summary).

KISSIN, S.A. and JENNINGS, E.A., 1987, Grant 300. The genesis of silver vein deposits in the Thunder Bay area, northwestern Ontario: Ontario Geol. Survey Misc. Paper 136, p. 230-241. Authors at Dept. Geol., Lakehead Univ., Thunder Bay.
Ag vein deposits in the Thunder Bay area occur in two northeasterly trending zones, known as the Island Belt and the Mainland Belt. Deposits within these belts form a spectrum of deposits ranging from barren quartz-calcite veins with minor base metals, to Ag and base-metal sulphide ± barite, to five-element (Ag-Ni-Co-As-Bi) veins. A survey of fluid inclusions and sulphur isotopes was made from representative deposits. Fluid inclusion Th indicate that the veins formed over wide T ranges, from 350° to 450°C to <100°C. T did not, however, differentiate the deposits. Salinities vary widely from 2 to 30 eq. wt.% NaCl, and boiling occurred sporadically. S isotopic studies of sulphide minerals and barite revealed a range of compositions and suggest that equilibrium within deposits was not generally obtained. Source S was likely distinctly lighter than sedimentary sulphide minerals of the Rove shale, a hypothesized source of sulphur. The results indicate that the deposits could not be the result of mobilization of solutions due to heating by Keweenawan hypabyssal intrusions, but that a more general source within the Proterozoic basin must be called upon. (Authors' abstract)

KITAMURA, Masao, KONDOH, Shinji, MORIMOTO, Nobuo, MILLER, G.H., ROSSMAN, G.R. and PUTIS, Andrew, 1987, Planar OH-bearing defects in mantle olivine: Nature, v. 328, p. 143-145. First author at Dept. Geol. & Mineral., Fac. Sci., Kyoto Univ., Kyoto 606, Japan.
TEM studies plus IR spectra suggest that the defects are OH-bearing monolayers. They are significant as a possible reservoir for water in the mantle and in the deformation of mantle olivine. (E.R.)

KITTELSON, R.C. and McSWEEN, H.Y., Jr., 1987, The amphibolite to granulite facies transition in the Blue Ridge Macon County, NC (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 93. Authors at Dept. Geol. Sci., Univ. Tennessee, Knoxville, TN 37916.
The transition from amphibolite to granulite facies during the mid-Paleozoic regional metamorphic event has been examined. Petrologic relationships and calculations based on the mineral assemblage gar + bi + plag + -musc + -ky(sill) indicate metamorphic conditions of 600-650°C and 4.0-6.0 kbar within the amphibolite facies, and 730-780°C and 7.5-8.0 kbar within the granulite facies. At the transition represented by the musc "out" reaction, conditions were 680-720°C and 6.8-7.2 kbar. Based on the field relationship between the ky-sill transition, the muscovite "out" reaction, and the first appearance of in situ partial melts, on fluid-mineral equilibria calculations, and on fluid inclusions, the fluid phase

contains other constituents besides water. Estimated X($H_2O$) is 0.8 in the amphibolites and 0.3-0.4 in the granulites. The drop in X($H_2O$) in the granulites may be explained by the scavenging of water by partial melts. Although the water content of the fluid phase was important in controlling the stability of certain minerals, especially muscovite, its change in composition appears to be more an effect of, rather than a cause for, the development of this granulite terrain. The main control appears to have been an increase in depth of burial. This would suggest that the elevated T required for granulite metamorphism can be achieved without invoking nearby intrusions or an influx of non-hydrous fluids from an unknown source. (Authors' abstract)

KLATT, Ekkehard and CLIFFORD, Tom, 1987, Copper mineralization in Namaqualand, S. Africa; spectrometrical and microthermometrical study of the fluid phase (abst.): American Current Research on Fluid Inclusions, Jan 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). First author at Univ. Bonn, FRG.

The O'okiep Copper District consists of over 1500 bodies of intrusive rock (Koperberg Suite) that are probably a result of progressive partial melting of a heterogeneous source of overall tholeiitic composition at a depth >25 km in the Earth's crust 1.1 b.y. ago.

Characteristics of $H_2O$-, $CO_2$-$N_2$-, $H_2O$=$CO_2$- and $N_2$-inclusions in quartz and garnet are as follows:

| COUNTRY ROCK<br>(gneiss, granulite) | KOPERBERG SUITE<br>(norite, diorite, hypersthene.) |
|---|---|
| Numerous, up to ~20 µm Ø | Only few "sec. incl." 1-6 µm Ø |
| Salinity between 0 and 5 mole % NaCl equiv. | "Sec. incl." show high salinity (14-23 mol% NaCl equiv.) and additionally up to 3 salt crystals per inclusion |
| $CO_2$-$N_2$-inclusions with high- to medium grade density: max. 0.90 to 0.73 g/$cm^3$ | Low degree of filling measured in the $CO_2$-$N_2$-inclusions rearranged at cracks: maximum densities: 0.6 to 0.2 g/$cm^3$ |
|  | "Ore"-daughter XX in incl., ± oriented rutile needles in qz |
| General trend of decreasing $CO_2$-densities with depth |  |
| Surface outcrop: 0.90 g/$cm^3$<br>1470' level: 0.73 g/$cm^3$ | Surface outcrop: 0.6 g/$cm^3$<br>2640' level: 01.2 g/$cm^3$ |

Laser-Raman-microspectroscopy showed the presence of almost pure $N_2$-inclusions and $CO_2$-$N_2$-inclusions with 0 to 7 mol % $N_2$. No hydrocarbons could be found in $CO_2$- or $N_2$-inclusions. (Authors' abstract)

(Paper not presented at meeting.)

KLATT, E. and RAITH, M., 1987, Fluid inclusion characteristics of the progressive gneiss-charnockite transformation in southern Kerala, India (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 59. Authors at Mineral.-Petrol. Inst., Univ. Bonn, Poppelsdorfer Schloss, D-5300 Bonn, FRG.

Progressive charnockitization of biotite-garnet gneisses is a widespread phenomenon in southern India. The area studied is the Proterozoic crustal segment south of the Achankovil shear zone in Kerala. Charnockite formation occurs along a system of shear planes.

The following types of fluid inclusions were identified by microthermometry: medium- to low-density (0.70-0.86 g/$cm^3$) carbonic inclusions, medium-density (0.89-0.94 g/$cm^3$) watery inclusions and mixed $H_2O$-$CO_2$ inclusions forming clathrate ices.

Raman analysis of single inclusions gave evidence of $N_2$ inclusions with up to 16 mole% hydrocarbons in both the gneisses and charnockite. $CO_2$-rich inclusions have $N_2$ contents up to 14 mole% and less [than] 1 mole% hydrocarbons. Pore fluids in the charnockites apparently are enriched in $N_2$ compared to the adjacent gneisses. Possible sources for $N_2$ are $NH_4^+$ in K-feldspar and biotite.

H and Ar were detected by mass spectrometry in addition to the already known volatile species. Bulk fluid analysis on quartz concentrates showed the charnockites to be higher in $N_2$, $CH_4$ and $H_2O$ but lower in $H_2$ in comparison to the gneisses. Ar and $CO_2$ do not show significant differences between both rock types. The strong melting point depression of the carbonic fluids in the gneisses can be correlated with the higher $H_2$ content in the fluid phase.

The mechanism of charnockite-gneiss transformation is discussed on the basis of field observations, petrological and fluid inclusion data. (Authors' abstract)

KLEMD, Reiner, 1987, A mineralogical and mineral chemical study of Archean granites bordering the Witwatersrand Basin: PhD thesis, unpub., Rand Afrikaans Univ., Johannesburg, S.A., 263 pp.

Hydrothermally altered Archaean granitic rocks (surface and boreholes) have been altered in two styles, each comprising several stages. The earlier style involved pervasive propylitization and sericitization. The second style was vein controlled, involving the development of: 1) K-feldspar veins; 2) muscovite-chlorite-quartz veins; 3) quartz-carbonate veins, and 4) chlorite-hematite veins.

All alteration was associated with low grade pyrite mineralization, plus sphalerite, molybdenite, chalcopyrite, wurtzite and other sulphides, and Th, U, and REE-rich carbon nodules and free gold with similar compositions to their detrital counterparts in the reefs of the Witwatersrand Basin. This feature lead to the suggestion that hydrothermally altered granitic rocks could have been a source for the Witwatersrand Basin. However, age determinations and the identification of connate brines as being responsible for some of the alteration and mineralization suggest post-Witwatersrand depositional alteration ages. Meteoric and/or metamorphic fluids may also have been responsible for some of the mineralization and alteration. (From the author's abstract)

Several daughter minerals* were identified: anhydrite, muscovite, calcite, orthoclase, apatite, rutile, hematite and various mixed chlorides occurred in fluid inclusions in quartz and pyrite of the Witwatersrand conglomerate. In one place, cassiterite daughter minerals were found, indicating a derivation from hydrothermal or pegmatitic sources. Most of these daughter minerals were also found in fluid inclusions in quartz grains of the investigated granite. A direct comparison of fluid inclusions in quartz pebbles with those in quartz of the granites is tenuous. But the fluid inclusions do indicate environmental conditions and it is evident that Shepherd (1977), Halbauer and Kable (1979), Cochran (1982) and A.E. Schoch (unp. work) described similar or identical features in fluid inclusions in Witwatersrand quartz pebbles and opalescent quartz grains, to those found during the present investigation of secondary fluid inclusions in magmatic quartz. Also, when comparing the investigated daughter minerals, similarities become even more obvious. (From the author's text, p. 116)

*Most of these are in fact accidentally trapped and not daughter minerals (pers. comm. R. Klemd, March 9, 1988, and his pp. 85-86))

KLEMD, R., HALLBAUER, D.K. and BARTON, J.M., Jr., 1987, Fluid inclusion evidence for unusual alteration processes in Archaen granitic rocks along the northwestern edge of the Witwatersrand Basin (abst.): Int'l. Symp.

on Granites and Associated Mineralizations, Salvador, Bahia, Brazil, Jan. 21-31, 1987, Extended Abstracts, p. 289-291. First author at Chamber of Mines of South Africa, Res. Org., P.O. Box 91230, Johannesburg, 2006, S.A.

Two hydrothermal fluids, one of higher and the other of low salinity, could be identified in fluid inclusions. These fluids most probably were of a connate and meteoric nature, respectively. Th ranged from ~100 to ~300°C; Tm ranged from -9 to +4°C (clathrate) and -26 to -14°C. See also previous item. (E.R.)

KLEMM, W., STRAUCH, G. and THOMAS, R., 1987, Mineral forming fluids - A study on fluid inclusions from hydrothermal minerals, in Wand, U. and Strauch, G., eds., Isotopes in Nature: Proc. 4th Working Meeting, Leipzig, Sept. 1986, Berlin, Akademie-Verlag, p. 409-421. First author at Bergakademie Freiberg, Sektion Geowissenschaften, Gustav-Zeuner-Strasse 12, DDR-9200 Freiberg, FRG.

Extending from the Variscan orogenesis to Mesozoic age the mineralization in the Erzgebirge is characterized [by a series of] different stages. Investigating the fluid inclusions of minerals formed and deposited as well in granitic rocks as in high to epithermal vein mineralizations the development of the mineral forming fluids can be recognized in these different stages. In this way we have studied fluid inclusions of quartz, fluorite, barite, and carbonates using the determination of the isotope variations of H and O and the chemical composition of the inclusion compounds as well the thermobarogeochemical methods. The results are discussed [in terms of] cooling the hydrotherms by stages. (Authors' abstract)

KNAUSS, K.G. and WOLERY, T.J., 1987, The dissolution kinetics of quartz as a function of pH and time at 70°C (abst.): GSA Abst. with Programs, v. 19, p. 395.

KNAUTH, L.P., HOVORKA, S.D. and FISHER, R.S., 1987, Isotope geochemistry of fluid inclusions in relation to sedimentology and bromide geochemistry of halite in the Palo Duro Basin, Texas (abst.): American Current Research on Fluid Inclusions, Jan 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). First author at Dept. Geol., Arizona State Univ., Tempe, AZ 85287.

Three groups of brine inclusions have been identified in halite of the San Andres Formation and Artesia Group of the Palo Duro Basin using integrated data from stable isotope analyses of the inclusions, Br analyses of the solid halite, and sedimentologic studies of the bedded salt:

(1) Inclusions holding evaporated sea water. Br concentrations in halite from the San Andres units 4 and 5 rise from 60 ppm (initial halite precipitated from evaporating sea water) to 120 ppm toward updip facies positions. Delta O-18 and Delta D values of these inclusions decrease along a hooked sea water evaporation trajectory (Knauth and Beeunas, 1986). Petrographic textures indicate that some halite was dissolved in the brine pool prior to evaporation for each cycle of sea water incursion, but this was too minor to significantly affect the geochemistry. The cycles begin with normal marine and hypersaline carbonates, indicating good communication with the marine environments to the south.

(2) Second cycle brines produced by evaporation of mixed meteoric-marine water. Some cycles in the Artesia Group lack carbonates, have halite which averages 20-32 ppm Br, and fluid inclusion isotopic signatures suggesting a major marine component. Anhydrite beds thicken down depositional dip toward marine environments also suggesting a marine and/or mixed meteoric-marine contribution. Because of the low bromide, these halites are interpreted as partly 2nd cycle marine dominated ephemeral brine pools.

(3) *Second cycle brines produced by meteoric water dissolution of halite.* Halite from the Tansill and Seven Rivers cycle 3-B (Artesia Group) have chevron zoned inclusions which plot isotopically near the meteoric water line, has Br concentrations of 6-20 ppm, and is interbedded with terrestrial clastics. These data indicate that meteoric water flooded dry halite flats, dissolved halite, and reprecipitated halite after evaporation.

We conclude that the isotopic analysis of fluid inclusions in halite, when integrated with other geochemical and sedimentologic data, can be used to unravel the controversial origin and depositional history of halite in the saline giants. (Authors' abstract)

KOCH, B.C., HUTCHINSON, R.W. and FREE, Bernhard, 1987, The Gold King precious metal deposit, Silverton caldera San Juan volcanic field, southwest Colorado (abst.): Geol. Soc. Am. Abst. with Programs, v. 19, p. 287. First author at Dept. Geol., Colorado Sch. Mines, Golden, CO 80401.

The Tertiary (27.5 m.y.) Silverton caldera is a nonresurgent trap door collapse structure, which contains a hinge zone formed in its northern part by the collapse mechanism. Significant precious and base metal deposits occur along ring faults, hinge zone fractures, and NE-faults of the apical Eureka Graben (27.5-22.5 m.y.), which extends northeastward to the Lake City caldera (22.5 m.y.).

The Gold King deposit, in the north center of the caldera, follows steeply SE- and NE-dipping, NE-trending subsidiary fractures of the Eureka Graben and NW-trending hinge zone faults. Hessite, calaverite, and other telluride minerals occur with free gold in flat, 30-45° NW- and NNW-dipping, 1-4' wide veins yielding up to 80 oz Au/st, and 35 oz Ag/st. Primary fluid inclusions indicate temperatures from 275° to 281°C for the deposition of milky quartz hosting the precious metal minerals at an elevation of 11,830'. The adjacent Sunnyside deposit yields base and precious metals at 11,800'. Other neighboring mines, at least 200' lower in elevation, contain base metals only.

Predominantly meteoric-derived hydrothermal solutions ascended through alloclastically fractured, ferruginous Precambrian formations and overlying Tertiary caldera fill, 10 to 15 m.y. after the Silverton caldera collapse. Due to the southward dipping caldera roof, solutions were funneled northward into hinge zone fractures and the Eureka Graben fault system.

Epithermal, precious metal deposition was due to the breakdown of reduced Au-bisulfide complexes during boiling, increasing oxygenation and mixing with fresh meteoric water. (Authors' abstract)

KOEBERL, Christian, 1987, Volatile elements in Muong Nong type tektites and in impact glasses from the Zhamanshin (USSR) crater: Clues to the origin of tektites (abst.): EOS, v. 68, p. 1344.

KOELLNER, M.S., SPRY, P.G. and RICHARDSON, C.K., 1987, Chemical and thermal changes in the ore fluid during deposition at the Denton mine, Cave-in-Rock fluorspar district, Illinois (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 731. Authors at Dept. Earth Sci., Iowa State Univ., Ames, IA 50011.

The Illinois-Kentucky fluorspar district contains numerous vein type deposits and larger bedded replacement deposits containing fluorite with lesser amounts of sphalerite, galena, and barite. Fluid inclusion, paragenetic, and stable isotope studies were undertaken to determine the chemical and thermal changes in the fluids responsible for ore deposition at the Denton bedded replacement deposit and to combine these data with information from other mines to help develop a regional picture of ore deposition.

Fluid inclusion T in banded fluorite range from 118.5 to 146.0°C, and salinities fall between 19.5 to 22.5 NaCl equiv. wt. %. Th measurements on fluid inclusions in each band indicate that the T was relatively constant over the early part of the paragenesis (around 129°C), and then there was an increase of 8 to 12°C across bands of purple and blue fluorite in the outer part of the crystal. T measurements made on individual marker bands in fluorite crystals from across the mine suggest that there may have been a very small T change (on the order of 2-3°C) close to large solution collapse breccia zones.

S isotope data for sulfides show a range in $\delta^{34}S$ from -6 to +6 per mil. Sulfate sulfur values are very heavy (+53 to +87 per mil) and suggest two different sulfur sources. $\delta^{13}C$ and $\delta^{18}O$ measurements on zoned calcite crystals indicate that some of the carbon may have come from limestone host rocks; the carbon values become very light (-9 to -12 per mil) in the outer zones indicating that some of the very late $CO_2$ may be from the degradation of organic matter. The data from the Denton mine along with those measured for the Deardorff and Hill mines suggest that the ore fluid was a saline meteoric water dominated basinal fluid. (Authors' abstract)

KOHNEN, M.E.L. and SCHOLTEN, S.O., 1987, Fluid inclusions study of the Mount Isa Inlier, Australia (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 155. Authors at State Univ. Utrecht, Inst. Earth Sci., Boedapestlaan 4, 3508 TA Utrecht, The Netherlands.

This fluid inclusion study was carried out on quartz samples collected from the main tectonic structures of the Mount Isa Proterozoic Inlier in Queensland, Australia. The geology of the Mount Isa Inlier is characterized by a pattern of N-S trending bands, 1-30 km wide and up to 150 km long, with contrasting stratigraphy and metamorphic history, that are separated by complex fault and shear zones. The areas that were studied form parts of the Kalkadoon-Leichhardt basement succession and the western sedimentary succession. Major mineralizations occur in the Inlier, especially near Mt. Isa where one of the worlds largest Cu and Ag-Pb-Zn deposits is found. Throughout the Mount Isa Inlier numerous minor deposits of Au-Cu occur.

During and after the formation of the Mount Isa Basin hypersaline conditions prevailed, with brines containing up to 30 wt.% $CaCl_2$. Leaching of the basement volcanic and igneous rocks by these hypersaline fluids could have released enough metals to produce mineralizing solutions. The contents of the inclusions were studied by means of microthermometry, SEM/EDS study of the residues from evaporation of opened inclusions, gas analyses and carbon isotopes analyses.

It is possible to distinguish between the major deformation phases;

The fluid system, especially during D1, can be characterized as an open system with an increasing salinity with the depth. The D1 brines, in the basement, were concentrated $NaCl-KCl-CaCl_2-FeCl_2-MgCl_2-AlCl_3$ fluids with a salinity of 17-20 wt.% (Na, K)Cl and 20-24 wt.% (Ca, Fe, Mg)$Cl_2$. During D1, homogeneous $CO_2-H_2O-CH_4-N_2-NaCl$-bearing fluids were introduced in these brines.

During D2 also two different fluids coexisted, a NaCl-KCl-bearing brine and a $H_2O-CO_2-N_2-CH_4-NaCl$-bearing fluid. In D2 quartz veins of the sedimentary area a third kind of fluid is represented by $CO_2-CH_4-H_2O$-bearing fluid inclusions. These inclusions have high $CH_4$ contents and the $CO_2$ in these inclusions has a high $^{13}C/^{12}C$ ratio.

The D2 and D3 brines were NaCl-KCl-bearing fluids with salinities of respectively 17-22 eq. wt.% NaCl and 7 eq. wt.% NaCl in the basement area.

The Au-Cu mineralizations in the sedimentary area are formed during D1. They are the result of mixing of the saline D1 fluids with oxygenated shallow groundwater. Such mixing may have occurred in faults which were formed during thrusting. The significant difference in salinities of fluid inclusions in the mineralized zones and fluid inclusions in the non-mineralized zones of the D1 thrusts can be used as an exploration tool. (Authors' abstract)

Note - This abstract was a late addition and hence is not in the bound volume of abstracts. (E.R.)

KOIVULA, J.I. and FRYER, C.W., 1987, Chalcopyrite in peridot: A first observation: J. Gemm., v. 20, no. 5, p. 272-273.

This paper describes, for the first time, inclusions of the copper-iron sulphide chalcopyrite in peridot [from Arizona]. The peridot host was analyzed for traces of copper to determine if copper might be playing a role in the coloration of this gem. No copper was detected. (Authors' abstract)

KOKIN, A.V., 1987, Fossil mineralized waters of a gold-ore deposit in connection with the problem of its genesis (southeastern Yakutiya): Geologiya i Geofizika, v. 28, no. 9, p. 70-77 (in Russian; translated in Soviet Geol. & Geophys., v. 28, no. 9, p. 64-70).

For the first time, the composition of fossil waters and inclusions in minerals and country rocks has been studied at a Au-ore deposit in southeastern Yakutiya. Coincidence of the composition of inclusions in ore quartzes with the gas composition of the deposit's fossil waters and similarity of microingredient composition of the waters and Au-ore bodies provides a basis for suggesting that the main source of the Au-ore deposit's material was sedimentary country rocks of Early-Permian age containing above-clarke concentrations of Au, arsenic, Pb, Zn, and Cu. The Au-ore deposit's fossil waters are seen as products of exhausted paleothermal springs preserved in its structure 100 million years ago. (Author's abstract)

KOLDUNOV, M.F., ROMANOV, M.F. and FILIMONOV, D.A., 1986, Contribution to theory of optical decomposition. Determination of inclusion concentration from experimental data: Dokl. Akad. SSSR, v. 289, p. 856-859 (in Russian). Authors at Sci.-Research Inst. Organic Byproducts & Dyers, Moscow, USSR.

The paper presents the mathematical description of the theoretical reaction of particles (inclusions) in a transparent medium with light beam and its experimental verification with use of the laser beam and polymethacrylate layer. Potentially of certain use for detection of differences in features of very small inclusions in minerals. (A.K.)

KOMOR, Steve, VALLEY, J.W. and BROWN, P.E., 1987, First petrologic results from deep drilling in the Siljan Ring structure, Sweden. Petrography and fluid inclusion data (abst.): EOS, v. 68, p. 468-469. Authors at Dept. Geol. & Geophys., Univ. Wisconsin, Madison, WI 53706.

The Siljan Ring in central Sweden is a Devonian age impact crater with an excavation diameter of 45 km. Within the crater are exposed two types of Dala granites (Siljan and Jaerna types, both 1.65 BY old), and subordinate cross-cutting dolerite dikes of Precambrian age. Both granite types contain qtz, Kspar, clots of biot and/or amph, plag and sphene, and accessory mag, rutile, apatite, and zircon; compared to the red Jaerna granite, Siljan granite is poorer in quartz, contains more plag, and is greyish-red to grey. Decorated planar elements in qtz, some resembling kink bands, are believed to be impact generated and to require pressures of 75-200 kbar. Dolerites contain plag, cpx and ol in a subophitic texture. Seven shallow drill holes (maximum depth 689 m) and a deep hole (projected total depth ~7500 m) were drilled in the astrobleme to investigate its hydrocarbon potential. Siljan granite is present from 0-1400 m in the deep hole; below 1400 m Jaerna granite is found. Two feldspar separates from Siljan granite yield $\delta^{18}O$ of 8.6-9.1‰, two from Jaerna granite both yield 7.7‰ and one whole rock Jaerna analysis is 7.5‰ (SMOW). Impact generated cracks in the granite provide pathways for fluid migration. At shallow depths (<1000 m) cracks are filled primarily by calcite. With increasing depth calcite abundance decreases and chlorite and epidote are the predominant crack-healing minerals. Fluid inclusion (Fl) trails are common in qtz. Peak pressure-corrected homogenization (vapor to liquid) temperatures for Fl's are 350-400°C. Salinities in Fl's are mostly <2 wt. % NaCl equivalent, but range up to 23 wt. %. The inferred trapping temperatures and salinities are consistent with hydrothermal circulation of meteoric waters. Fl's are observed in qtz grains with planar shock elements, suggesting hydrothermal activity is post-impact because fluid inclusions would have been destroyed by stresses necessary to generate the planar element. The heat source for hydrothermal activity is probably the impact itself because no post-impact igneous activity is known, and present exposures are within 2 km of maximum burial depths. (Authors' abstract)

KOPP, O.C., MISRA, K.C., LINKOUS, M.A. and PARIS, T.A., 1987, The Sweetwater sphalerite-fluorite-barite district: An unusual Appalachian Mississippi Valley-type deposit (abst.): Abstracts, SEPM annual midyear meeting 20-23, Aug. 1987, v. 4, p. 44. First author at Dept. Geol. Sci., Univ. Tenn., Knoxville, TN.

Limited measurements of presumably P fluid inclusions suggest that much of the sphalerite and fluorite in the Sweetwater district precipitated from a fluid of somewhat lower T (Th = 90-120°C) and significantly lower salinity (Tm = -6 to -15°C; corresponding salinity = 9.2 to 18.8 wt% NaCl eq.) than sphalerite of the Mascot-Jefferson City MVT zinc district in east Tennessee. The variation in the fluid characteristics and ore-gangue paragenesis between these two districts which lie along the same strike belt and in identical stratigraphic horizons, may be explained by lateral migration of ore fluids along a paleoquifer. (From the authors' abstract)

KORMUSHIN, V.A., 1987, The nature of microinclusion heterogenization (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 61-62. Author at Inst. Geol. Sci., Acad. Sci. of Kazakh SSR, 480100 Alma-Ata, Kalinin St. 69-a, USSR.

The temperature of the appearance of a gas bubble or of some other phase [on cooling a homogenized inclusion] is taken as the temperature of heterogenization [$T_{het}$]. The T of microinclusion heterogenization is always lower than that of homogenization. For a given microinclusion the $T_{het}$ is constant and unchangeable when this phenomenon is reproduced repeatedly.

To elucidate the conditions of mineral crystallization it is more essential to know not the absolute value of the $T_{het}$ but the temperature difference ($\Delta T_{hh}$) between the $T_{hom}$ and the $T_{het}$.

$$\Delta T_{hh} = T_{hom} - T_{het}$$

It is of common knowledge that the strength of fluid (Z) is equal to pressure at the moment of fluid rupture and as applied to microinclusions it is defined by the formula

$$Z = P - K\alpha\Delta T_{hh},$$

where P - the P in a microinclusion at the T of heterogenization;

K - the modulus of the fluid volume elasticity;

$\alpha$ - the difference between the coefficients of volumetric expansion of the fluid and the mineral.

Investigations of the phenomenon of heterogenization of gas-liquid inclusions in ore quartz of rare-metal deposits in Kazakhstan has made it possible to establish the fact that the $\Delta T_{hh}$ of microinclusions varies within wide ranges from units to 20-50 and seldom over 100°.

Thus, heterogenization as a change of the phase state of microinclusions, firstly, indicates the P value in microinclusions at the moment of the gas bubble appearance and, secondly, it reflects peculiarities of the chemical composition and concentration of some of the components when heterogenization in microinclusions is fixed by the melt crystallization, the appearance of enclosed minerals or the isolation of some kind of fluid. (From the author's abstract)

Note: This paper was not presented at the meeting. (E.R.)

KORMUSHIN, V.A. and POLYVYANNY, E.Ya., 1987, The determination of the absolute age of mineralization by microinclusions in minerals (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 63-64. First author at Inst. Geol. Sci., Acad. Sci. of Kazakh SSR, 480100 Alma-Ata, Kalinin St. 69-a, USSR.

Gas-liquid inclusions in non-K-bearing minerals (quartz, fluorite and others) of endogenic deposits are of special value for mineralization dating. These minerals are widely spread and plenty of microinclusions are to be found in them. According to chemical analysis and cryometric method data the K content can be as high as 10 and even more of mass %; argon (Ar-40 and Ar-36) isotopes of measurable quantities are found in them as well.

Ar-40 in microinclusions is of double nature. Firstly, it is radiogenic, having been accumulated since sealing due to radioactive decay of K and, secondly, it is introduced. Ar-36 is of atmospheric nature, i.e., it is introduced by vadose water.

The assessments of K content (61) and that of isotopic Ar (22) in quartz inclusions from rare-metal deposits in Kazakhstan have shown that K is $0.04\text{-}4.54 \cdot 10^{-3}$ wt% of mineral. The Ar-40 content varied from 0.087 to $55 \cdot 10^{-11}$ g/g of mineral. The obtained data on Ar-40 correlate with the K content in inclusions with regard for the age of intrusive rocks which enclose ore veins genetically spatially associated with intrusion. This fact confirms the possibility to define the mineralization age. In doing so it is necessary to take into account different behavior of Ar and K when they are extracted from inclusions. Argon as a gas is an easily and most completely extracted element. K in inclusions is dissolved in the liquid phase, therefore in case of incomplete opening of an inclusion (most common) it is retained in the inclusion cavity. Its extraction is not complete at Td. (From the authors' abstract)

Note: This paper was not presented at the meeting. (E.R.)

KOROTAEV, M.Yu., 1987, Highly concentrated fluid melts in the formation of ore fields: Vestnik Moskovskogo Univ. Geologiya, v. 42, no. 2, p. 49-57 (translated in Moscow Univ. Geol. Bull, v. 42, no. 2, Allerton Press, 1987, p. 48-55). Author at Moscow Univ., USSR.

Presented is a survey of experimental and geological data which indicate the participation of highly concentrated-melt solutions [evidence from multiphase inclusions] in the formation of ore deposits. (Author's abstract)

KORZHINSKY, M.A., 1987, Calcium-iron ratio in chloride supercritical fluid in equilibrium with skarn mineral associations: Geokhimiya, 1987, no. 2, p. 203-220 (in Russian; English abstract).

KOSTÖLANYI, Ch., BERTRAND, J.M., KRIER, G., and KOHLER, A., 1987, Microanalytical study of inclusions in zircons from the Anfeg granite (Algeria) (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 65-66 (in French; translation by R.J. Bodnar). First author at CREGU, BP 234, 54501 Vandoeuvre lès Nancy Cedex, France.

The inclusions in zircon were identified by electron microprobe and laser microprobe mass analysis (LAMMA). The most comon inclusions are apatite; others are zircon, quartz, feldspars and Ca and Fe silicates. Some inclusions are enriched in U and Th. (From the authors' abstract)

KOSTYRKO, A.A., 1987, Study of fluid inclusions in minerals of metamorphic rocks of the Kola Peninsula: Mineral. Paragenezisy Metamorf. i Metasomat. Porod. Apatity, 1987, p. 95-102 (in Russian; translated in Ref. Zh., Geol., 1987, Abstr. No. 7V212). (C.A. 108: 4144q)

KOSZTOLANYI, C., MULLIS, J. AND WEIDMANN, M., 1987, Measurements of the phase transformation temperature of gypsum-anhydrite, included in quartz, by microthermometry and Raman microprobe techniques: Chem. Geol., v. 61, no. 1/4, p. 19-28.

Full paper for abstract in Fluid Inclusion Research, v. 18, p. 217, 1985. (E.R.)

KOTEL'NIKOVA, Z.A., KOTEL'NIKOV, A.R. and SAMOVAROV, Yu.V., 1986, Data from fluid inclusions and geothermobarometry on the metamorphic history of the Khankai Massif: Geokhimiya, 1986, no. 8, p. 1101-1112 (in Russian; translated in Geochem. Internat., v. 24, no. 3, p. 39-50).

See Fluid Inclusion Research, v. 19, 1986, p. 234.

KOVALENKO, N.I., RYZHENKO, B.N., BELYUKHANOVA, T.K. and BARSUKOV, V.L., 1986, Solubility of cassiterite in HF solutions* and forms of tin transportation by supercritical fluids: Dokl. Akad. Nauk SSSR, v. 290, no. 1, p. 211-214 (in Russian). Author at Inst. Geochem. & Anal. Chem. of Acad. Sci. USSR, Moscow, USSR.

The paper presents an experimental study of cassiterite solubility and forms of tin transportation in acid fluoride solutions at 500°C, P 1000 atm under fixed redox conditions and a comparison of the role of F and Cl during Sn migration in post-magmatic solutions. (A.K.)

*Translation of the table of contents into English in "Doklady" gives here erroneously "hafnium solutions." (A.K.)

KOVALENKO, V.I., SOLOVOVA, I.P., RYABCHIKOV. I.D., IONOV, D.A., BOGATIKOV, O.A. and NAUMOV, V.B., 1987, Fluidized carbon dioxide-sulfide-silicate media as agents of mantle metasomatism and megacrysts formation: Evidence from a large druse in a spinel-lherzolite xenolith: Phys. Earth Planet. Inter., v. 45, no. 3, p. 280-293.

KOWALLIS, B.J., WANG, H.F. and JANG, B.-A., 1987, Healed microcrack orientations in granite from Illinois borehole UPH-3 and their relationship to the rock's stress history: Tectonophysics, v. 135, p. 297-306. First author at Dept. Geol., Brigham Young Univ., Provo, UT 84602, USA.

Oriented granite cores from the Illinois borehole UPH-3 contain planes of secondary fluid inclusions, which represent healed microcracks. They record the orientation of a paleostress field, with the maximum stress in the horizontal plane oriented to the NNW about 90° from the present stress field orientation. These bubble planes probably formed while the granite was still quite warm (>400°C) during initial cooling, uplift, and unroofing of the granite prior to deposition of younger overlying Cambrian sediments. The bubble planes have a much more uniform orientation than the open microcracks, which formed by stress-relief when the core was removed from the borehole. (Authors' abstract)

KOZHAKHMETOV, E.M. and KURMANBAEV, E.A., 1987, Crystallization characteristics of acid magmatic rocks of different facies: Vestn. Akad. Nauk Kaz. SSR, 1987, no. 3, p. 78-80 (in Russian).

KOZLOVSKY, Ye.A., ed., 1987, The Superdeep Well of the Kola Peninsula: Springer-Verlag, Berlin (original Russian edition ©1984, Kol'skaja sverchglubokaja, Nedra, Moscow), 558 pp.

Contains a brief description of the fluid and melt inclusions found in various rocks in the core. (H.E.B.)

KOZŁOWSKI, Andrzej, 1987, Allegedly magmatic tourmaline from the Strzegom environs: Archiwum Mineral., v. XLII, no. 2, p. 95-100 (in Polish; English abstract). See next item.

KOZŁOWSKI, Andrzej and METZ, Paul, 1987a Inclusions in the rock-forming tourmaline from the Strzegom massif, Poland (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 67. Authors at Mineral.-Petrogr. Inst. der Univ., Wilhelmstrasse 56, D-7400 Tübingen 1, West Germany.

Aplite dikes in the metamorphic cover (amphibolites, schists, graphite quartzites) of the Variscan granitoid massif Strzegom having the following composition (vol. %): 45-54 K-spar or60ab40 to or95ab5, 10-15 plagioclase ab90an8or2 to ab99.5or0.5, 33-39 quartz, 2-3 tourmaline $(Na_{0.86}K_{0.02}Ca_{0.03}Mg_{0.18})_{1.09}(Fe_{2.45}Mg_{0.21}Mn_{0.04}Al_{0.30})_{3.00}xAl_{6.00}B_{3.06}(Si_{5.96}Ti_{0.06})_{6.02}O_{27}[(OH)_{2.60}F_{0.45}O_{0.95}]_4$ and 0.5-1 biotite + muscovite + andalusite + sillimanite (muscovitized) + garnet alm67spess33 to alm80spess20. Tourmaline and garnet were described as magmatic minerals (Puziewicz 1981), but tourmaline commonly (Fig. 1A & B) and garnet sometimes (Fig. 1C) have features typical of metasomatic minerals. Tourmaline bears P tubular crystal inclusions, originally filled by feldspar + quartz, but then refilled by water solution with the complete recrystallization of the silicate phases (Fig. 2A & B) or with their partial alteration (Fig. 2C & D). Such inclusions may be determined erroneously as filled by a crystallized hydrous melt. P $LH_2O$ inclusions (but not partly refilled like the inclusion in Fig. 2E) coeval with the previous ones (Fig. 2C & F) yielded Th 340-355°C, Te -19 to -21°C, Tm -3.6 to -2.5°C, thus total salts, mainly NaCl, 4.1-5.9 wt.%. Five pure $CO_2$ inclusions showed triple point at -56 ± 1°C, Th +30.6 ± 0.1°C (control during each run on the melting point of spectrographically pure gallium +29.8°C) in liquid, hence the $CO_2$ density was 0.5 g/cm$^3$. P determined from the above data equals 770-810 bar and Th + ΔT is 410 to 450°C. Few pairs of $LH_2O>G$ and $LH_2O<G$ inclusions formed from boiling solution were found with Th 390-400°C, proving the local P decrease to 250-260 bar. Also three pairs (Q, R & S, Fig. 3) of the coeval inclusions formed from the two-phase fluid ($CO_2$-rich liquid, 51-60 mole % $CO_2$ plus $H_2O$-rich liquid, 11-14 mole % $CO_2$) were recognized. Their Th were 360-399°C, indicating P of the tourmaline origin 730-800 bar. Thus, the studied tourmaline should be considered as hydrothermal-metasomatic. (Authors' abstract)

Note: See original volume for figures. (E.R.)

KOZŁOWSKI, A. and METZ, P., 1987b Gases in sub-liquidus fluid inclusions in phenocrysts in volcanic rocks from Poland (abst.): Terra Cognita, v. 7, no. 2-3, p. 142. Authors at Min.-Petr. Inst. of Univ., Tübingen, FRG.

Gas components: $CO_2$, $CH_4$ (other light hydrocarbons inclusively), $N_2$ (eventual noble gases inclusively), $H_2$ and "acid gases" A.G. (total of $SO_2$, $H_2S$, $Cl_2$, etc.) were determined in individual melt inclusions and in coeval gas inclusions in olivine phenocrysts from the Tertiary basaltoids (basanites, basalts, nephelinites) of the Lower Silesia area, in quartz from the Permian ignimbrites and rhyolites, the same area, and from the Carboniferous pyroclastic sediments of the Holy Cross Mts., and in augite from the Tertiary andesites of the Pieniny Mts.

The gas composition varies essentially between the $CO_2$ and $N_2$ end members with a participation of other gases up to 20 mole %. From the liquid $CO_2$ inclusions the P during the olivine phenocryst formation in basaltoids at Th of melt inclusions (1200-1300°C) was estimated to be 3 to 5 kbar. The possible behavior of gases in melts and their role as well as the depth of the olivine phenocrysts formation are discussed. (Authors' abstract)

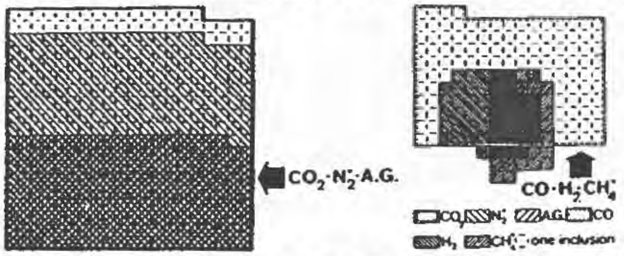


Figure. Coexistence of gases in inclusions in olivines; the field of CO, etc., occurs completely within the range of the $CO_2$ field.

KOZŁOWSKI, A. and METZ, P., 1987c, Conditions of the crystallization of the basaltoid minerals from Wilcza Mt., Lower Silesia (abst.): Fort. der Mineral., v. 65, p. 105.

Mid-Miocene basanites and sodic foidites have the following average modal composition (vol. %): olivine 8.6, Ti-augite 49.1, Fe-Ti oxides 5.4, labradorite 0.9, nepheline 16.1, glass + analcite 19.9 (Smulikowski and Kozlowska-Koch, Arch. Min. 40, 1, 53, 1984). These basaltoids contain rarely spinel (wt. %, $Cr_2O_3$ 30, $Al_2O_3$ 36, MgO 15, $Fe_3O_4$ 19), which may be partly the relics from ultramafic nodules. Reequilibration of melt with spinel during olivine crystallization (increase of $fO_2$, decrease of the Cr and Mg contents in melt) yielded outer rims of titanomagnetite ($Cr_2O_3$ 5, $Al_2O_3$ 4, MgO 3, $TiO_2$ 21, $Fe_3O_4$ 67); melt inclusions in olivine of this stage have Th 1330-1290°C and the coeval inclusions of liquid $CO_2$ (Th +24.8°C in liquid $\rightarrow$ $CO_2$ density 0.71 $g/cm^3$) indicated Pt during the olivine crystallization ca. 4.3 kbar. Thus the estimated depth of origin of the olivine and the titanomagnetite part of the spinels was about 14 km.

Ti-augite, which crystallized partly with the late olivine but essentially after it, bears silicate melt inclusions with Th 1280-1100°C, and globular sulfide (pyrrhotite) melt inclusions, crystallized after trapping. Gases in inclusions in olivine and in augite of this stage consist (in vol. %) of $CO_2$ 83-88, CO 0-3, $N_2$ 10-12, "acid gases" i.e., the total of $H_2S$, $SO_2$, $Cl_2$, $F_2$, $NH_3$ 0-7. The occasional presence of the sulfide melt and CO indicates low $fO_2$ in magma. Labradorite yielded few Th values of melt inclusions in the ranges 1150-1080°C and nepheline 1120-980°C. The average chemical composition of the parent melt in the homogenized inclusions in olivine was that of the sodic foidite close to basanite: $SiO_2$ 40.23, $TiO_2$ 2.93, $Al_2O_3$ 12.05, total Fe and FeO 11.78, MnO 0.19, MgO 11.95, CaO 12.85, $Na_2O$ 3.52, $K_2O$ 1.44, $P_2O_5$ 1.36 (mean values of the three analyses made with an electron microprobe). During the crystallization of the daughter minerals in the melt inclusions in olivine, the residual melt compositions changed to basalt and benmoreite (all rock names after Le Bas et al., J. Petrol. 27, 3, 745, 1986). (Authors' abstract)

KOZŁOWSKI, Andrzej and METZ, Paul, 1987d, Melt inclusion aspects of the studies of the central-European volcanic rocks (abst.): Abstracts of Conf. of Societa' Italiana di Mineralogia e Petrologia, Pisa, 1987 (unpaginated).

Upper Paleozoic and Tertiary rocks [map in original abstract deleted] yielded the following homogenization temperatures (°C) of the P melt inclusions in (mostly) phenocrysts: rhyolite - Holy Cross Mts. (tuffs, Carboniferous), in quartz 790-810; Sudetes (incl. ignimbrites, Permian), in quartz 1200-1340; trachyte - Sudetes (Tertiary), in Na-K-spar 1100-1230; andesite - Pieniny Mts. (Tertiary), in augite 1210-1320, in hornblende 970-1140, in plagioclase 1160-1390(?); Visegrad (Tertiary), in augite 1250-1310, in hornblende 1030-1160, in plagioclase 1250-1390(?); basaltoids - Lower Silesia (Tertiary), in olivine 1180-1340, in clinopyroxene 970-1300, in plagioclase 1000-1280, in nepheline 910-1280; Vogelsberg (Tertiary), in olivine 1190-1360, in clinopyroxene 1090-1300, in plagoiclase 1000-1300.

Pressure of the liquidus olivine crystallization in the Sudetian basaltoids, determined from the coeval melt and liquid carbon dioxide inclusions ranges from 3.0 to 5.1 kbar, suggesting the depth of the olivine crystallization from 10 to 17 km. In olivine phenocrysts P gas inclusions coeval with the melt ones contain almost pure $CO_2$ (gas analyses of the individual inclusions), but gas bubbles in melt inclusions have variable and sometimes significant admixtures of $N_2$ and/or CO, $CH_4$, $H_2$. Inclusion gases in augite from the Pieniny andesite and in Na-K-spar from the trachyte do not consist of pure $CO_2$ but they contain from 10 to 35 mole % of other gases. Acid melts contain mostly gases of $CO_2$-$N_2$ composition, very high in $N_2$ in inclusions from heterogeneous (gas + melt) trapping in quartz from ignimbrites. The evolution of the inclusion melt during crystallization of the dms is also discussed. Melt compositions of the homogenized inclusions are close to the bulk chemical compositions of the fresh rocks containing the host minerals (analyses of melt inclusions by the electron microprobe method). (Authors' abstract)

KRASNOZHINA, Z.V., VLASENKO, V.I., KRAVCHUK, Z.I. and ZVENIGORODSKAYA, T.M., 1987, Mineral parageneses and evolution of the sulfur isotopic composition of fluids in the Ak-Jilga tin ore deposit (the southeastern Pamirs) [USSR]: Dok. Akad. Nauk Ukr. SSR, Ser. B., 1987, no. 6, p. 16-19 (in Russian; English Summary). Authors at Inst. Geol. Nauk, Kiev, USSR.

Results from detailed studies of cassiterite-containing parageneses from quartz-greisen and aposkarn-sulphide ores of the Ak-Jilga deposit are reported in the paper. It is shown that high pH and $fO_2$ gradients existed in the ore deposition region during the formation of tin ores. Isotopic composition of sulphur in sulphides varies in a narrow range, $\sigma^{34}S\Sigma s = -2$‰. Insignificant relief of the isotopic sulphur composition in sulphides deposited in paragenesis with needle cassiterite in the aposkarn metasomatites is induced by neutralization and oxidation of sulphur-containing acid reduced solutions. Sulphur of the final mineralization stages has a mixed source. (Authors' Summary)

KRAUSE, W.B. and BRODSKY, N.S., 1987, Intracrystalline brine inclusion motion for Palo Duro Unit 5 salt from the Mansfield No. 1 borehole in Oldham County, Texas: Office of Nuclear Waste Isolation, BMI/ONWI-663, 136 pp. First author at RE/SPEC, Inc., Albuquerque, NM, USA.

A microscope equipped with a hot stage was used to monitor intracrystalline migration of natural fluid inclusions in Palo Duro Basin Unit 5 salt from the Mansfield No. 1 borehole in Oldham County, Texas. Steady-state velocities are determined for 65 inclusions between 0.04 mm and 0.82 mm in size subjected to T gradients between 200 K/m and 1440 K/m at T of 45°C to 202°C. Inclusion velocity increased with increasing inclusion size, mean salt T, and T gradient. Two models that predict brine inclusion velocity as a function of T, T gradient, and inclusion size are used to analyze the data. The models are simplified due to uncertainties in properties that depend on brine chemistry and T, such as the equilibrium salt concentration of the brine. The simplified models are then fitted to the data and the fitted parameters are used to estimate the threshold T gradient below which inclusions do not migrate. The threshold T gradients determined in this study are in reasonable agreement with other values reported in the literature. Since values of the fitted parameters depend on the chemical composition of the brine, it is necessary to determine the model parameters and threshold T gradient for each repository site. (Authors' abstract)

KRAVCHUK, I.F., MALININ, S.D., DORFMAN, A.M. and SENIN, V.G., 1987, Experimental study of distribution of petrogenic elements between the silicate melt and water-salt fluid at 900°C and 2 kbar: Geokhimiya, 1987, no. 2, p. 192-202 (in Russian; English abstract).

Constants of the exchange reactions and partition ratios of Na, K, Ca, Fe, $Cl^-$ between the silicate melt (natural granite and albite and their artificial analogs) and water-salt fluid (NaCl and KCl) have been determined in experiments at 900°C and 2 kbar. It has been found that values of the constant for the Na-K exchange reaction for all the studied systems are invariable (1.65 ± 0.25) and independent of T in the 750-900°C range. The obtained experimental data indicate that fluids in equilibrium with silicate melts should have a complex salt composition. (Authors' abstract)

KREULEN, Rob, 1987, Thermodynamic calculations of the C-O-H system applied to fluid inclusions: Are fluid inclusions unbiassed samples of ancient fluids?: Chem. Geol., v. 61, p. 59-64. Author at Inst. Earth Sci., Dept. Geochem., Univ. Utrecht, 3508 TA Utrecht, The Netherlands.

In graphite-buffered C-O-H systems P, T and $CO_2/CH_4$ ratio fix the partial P of all the gas species. The relation between $CO_2/CH_4$ ratio and $H_2O$ content of the fluid was calculated for 300°, 400°, 500°, 600°, 700° and 800°C and P of 500, 1000, 2000, 5000 and 9000 bar. It appears that water-deficient fluid compositions can only occur at very high or at very low $CO_2/CH_4$ ratios.

Many of the data published on $CO_2$ inclusions in medium- and high-grade metamorphic terranes are incompatible with the calculated diagrams. Possible explanations are discussed. The assumption that fluid compositions trapped in inclusions are generally preserved needs further investigation. (Author's abstract)

KREULEN, R., KONNERUP-MADSEN, J. and ROSE-HANSEN, J., 1987, Carbon isotope characteristics of methane in fluid inclusions and of bituminous materials in the alkaline Ilímaussaq complex (south Greenland) (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 69. First author at Utrecht Univ., Inst. Earth Sci., 3508 TA Utrecht, The Netherlands.

Fluid inclusions in minerals from peralkaline nepheline syenites and associated hydrothermal veins from the Ilímaussaq complex in south Greenland are very rich in reduced gases (predominantly $CH_4$). In addition, the various rock types in the complex contain smaller amounts of solid bituminous materials along intergranular fractures.

The presence of reduced gases is considered to reflect the fullfilment of three basic conditions during final solidification of the Ilímaussaq complex: (1) low oxygen fugacities, approaching those defined by the synthetic MW buffer reaction; (2) a wide T range of crystallization and a low-T solidus; and (3) retention of volatiles during solidification.

Analysis of the $\delta^{13}C$ compositions of $CH_4$ and bulk amount of bituminous materials in both the nepheline syenites and hydrothermal veins have been performed. $\delta^{13}C$ values for $CH_4$ extracted from fluid inclusions vary between -1.0 and -6.3‰, and a pronounced trend towards isotopically lighter values during differentiation of the Ilímaussaq complex is observed. The $\delta^{13}C$ values of the bulk amount of bituminous material (including fluid inclusion gases) extracted from the same rock samples are close to 7‰ lighter than those of the $CH_4$ within the fluid inclusions.

The C isotope characteristics strongly suggest a non-biogenic origin of the C (and $CH_4$) in the reduced gases in the Ilimaussaq complex. The analyses do, however, not appear to indicate any genetic relationships between the $CH_4$ in the fluid inclusions and the bituminous material in the rocks, and different sources for the two types of carbonic material are suggested. (Authors' abstract)

KRISHNASWAMI, S. and SEIDEMANN, D.E., 1987, Comparative study of $^{222}$Rn, $^{40}$Ar, $^{39}$Ar and $^{37}$Ar leakage from rocks and minerals: Implications for the role of nanopores in gas transport through natural silicates: Geochimica Cosmo. Acta, v. 52, p. 655-658.

KROHN, M.D., ALTANER, S.P. and HAYBA, D.O., 1987, Distribution of ammonium minerals at Hg/Au-bearing hot spring deposits (abst.): Program with Abstracts, Symp.: Bulk Mineable Precious Metal Deposits of the Western United States, April 6-8, 1987, Geol. Soc. Nevada, p. 58.

KRONENBERG, A.K., DENNIS, P.F., GILETTI, B.J. and KIRBY, S.H., 1987, Oxygen diffusion in quartz at high water pressures (abst.): EOS, v. 68, p. 422. First author at Geophys. Dept., Texas A&M Univ., College Station, TX 77843.

The diffusion rates of oxygen in $\alpha$-quartz parallel to the c-axis have been investigated at elevated water pressures ($P(H_2O$ = 400-1420 MPa) in the temperature range T = 700°-900°C and at confining pressures $P_C$ = 620-1520 MPa. Single crystals of Brazilian quartz were annealed (over times ranging $t = 2.46 \times 10^3 - 2.33 \times 10^4$s) in the presence of an $^{18}$O-enriched fluid of limited volume, derived from a mixture of $Mg(OH)_2$, MgO, and $H_2O$, so as to limit silica dissolution and reprecipitation.

Concentration profiles of $^{18}$O versus depth in annealed samples, measured using ion microprobes with both $Ar^+$ and $O^-$ primary beams, are characterized by an initial plateau in $^{18}$O associated with a reprecipitated $SiO_2$ surface layer, followed by smoothly varying $^{18}$O concentrations reflecting solid-state diffusional exchange. Diffusion coefficients determined from the ion microprobe results using the two primary ion beams are in excellent agreement ($D_2 = [1.2 \pm 0.4] \times 10^{-18} m^2/s$ and $[4.8 \pm 0.1] \times 10^{-17} m^2s$ at T = 700°C, $P(H_2O)$ = 400 MPa and T = 900°C, $P(H_2O)$ = 1420 MPa, respectively) and are greater than those reported for $\beta$-quartz over the same temperature interval at $P(H_2O)$ = 100 MPa (Dennis, 1984, Giletti and Yund, 1984) by factors of 2 to 3. The rates of diffusional transport of oxygen under these elevated water pressures remain far below those of hydrogen with D values 6 to 7 orders of magnitude smaller than those for hydrogen (Kronenberg et al., 1986) under equivalent conditions. (Authors' abstract)

KRUMHANSL, J.L. and STEIN, C.L., 1987, Fluid inclusions in halite from the lower Salado Formation near Carlsbad, New Mexico (abst.): American Current Research on Fluid Inclusions, Jan 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). First author at Geochem. Div., Sandia Nat'l. Lab., Albuquerque, NM 87185.

Fluid inclusions from a bedded salt horizon in the lower Permian Salado Formation in the Delaware Basin, southeastern New Mexico, were sampled for this study. Samples were collected at a depth of ~2150', in a horizon consisting primarily of recrystallized halite, with minor anhydrite occurring as thin layers ("marker beds"). Other trace minerals are dispersed randomly throughout the salt; these include quartz, polyhalite, gypsum, K-feldspar, magnesite, and clays. Numerous large fluid inclusions (frequently several mm on an edge) are common in the halite, as well as fragments of unrecrystallized salt containing microscopic (<10 µm) fluid inclusions in primary, chevron structures. The large inclusions were sampled by individual extraction of the fluids, which were then analyzed for Ca, Mg, K, and Na (by emission spectroscopy), and Cl, Br, and $SO_4$ (by ion chromatography). Samples of halite from the adjacent lithology were also examined petrographically and by x-ray diffraction. 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 early diagenetic reactions, dominated by 1) the alteration of calcium sulfate (as gypsum or anhydrite) to polyhalite, and 2) the alteration of calcium carbonate (as calcite or aragonite) to magnesite.

Other brines from this formation were also 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) suggest that these are intergranular brines with compositions that were determined, over a much longer time scale than that required by the fluid inclusions, by dehydration of gypsum, dewatering of detrital clays, and uptake of Mg during clay diagenesis. (Authors' abstract)

KRUPP, R.E. and SEWARD, T.M., 1987, The Rotokawa geothermal system, New Zealand: An active epithermal gold-depositing environment: Econ. Geol., v. 82, no. 5, p. 1109-1129.

KRUSTEVA, M. and TODOROV, T., 1987, Mineral thermometry studies for the sulfide-fluorite ore deposit of Jugovo, central Rhodopes: Geokhim., Mineral. Petrol., v. 23, p. 54-63 (in Russian). Authors at Geol. Inst., 1113 Sofia, Bulgaria.

Th of fluid inclusions in quartz, fluorite, barite, calcite, and gypsum from the Jugovo deposit indicate that mineral formation occurred in 3 mineralization stages: molybdenite-pyrite-quartz, quartz-barite-fluorite, and quartz-carbonate. The overall T range of mineral formation in the ore deposit was calculated as 50-350°. The sep. mineral parageneses, however, were deposited over considerably narrower T ranges, often with T recurrence at the beginning of successive mineralization stages. Another characteristic of the ore deposit is well manifested linear T zoning in the deposition of first-generation quartz. (C.A. 107: 220699c)

KUBICKI, S. and RYKA, W., 1987, Carbonatites of the alkaline-ultramafic intrusion of Tajno: Proc. of the First Sem. on Carbonatites and Alkaline Rocks of the Bohemian Massif and Ambient Regions, L. Kopecky, ed., publ. Geol. Survey, Prague, p. 11-21. Authors at Geol. Inst., Rakowiecka 4, 00 975, Warszawa, Poland.

Presents limited fluid inclusion decrepitation and homogenization data on various constituent minerals. (H.E.B.)

KUEHN, C.A. and ROSE, A.W., 1987, Temporal framework and fluid evolution at the Carlin gold mine, Eureka County, Nevada (abst.): American Current Research on Fluid Inclusions, Jan 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Authors at Pennsylvania State Univ., University Park, PA 16802.

Detailed logging of >15,000 ft. of core in the East Ore Body, with emphasis on temporal relationships of veinlet development and spatial distribution of alteration associated with gold mineralization, has allowed the development of a framework from which to evaluate major changes in fluid chemistry between pre-, syn- and post-ore fluids at Carlin. Constraints on the P-T-X conditions through time have been established by crushing tests and detailed low-T petrographic, heating/freezing and laser Raman microprobe studies. Early formed stages of the paragenesis inherit a record of later fluids as planes of S inclusions, whereas later stages lack any record of earlier fluids.

Hydrocarbon mobility and maturation pre-dates gold mineralization and is probably a Mesozoic event unrelated to gold emplacement. High bulk-density $CH_4$ (± $CO_2$) fluid inclusions are trapped in pre-ore hydrocarbon stage quartz + calcite veinlets along with highly saline aqueous inclusions. This "brine-methane" immiscibility occurred at 155° ± 20°C, 1.1 ± 0.2 kb and reflects metagenesis of local concentrations of organic matter under near geostatic P conditions. Pre-gold dikes cut high-carbon zones and are locally enclosed within mineralized jasperoid. Pre- to syn-mineralization quartz veins cut altered dikes and contain low-salinity $H_2O$-$CO_2$ inclusions which record fluid immiscibility at 230 ± 25°C and P >0.5 kb. Gold mineralization is associated with dissolution of carbonate and silicification of reduced, argillaceous carbonates while the fluid was in the stability field of illite, pyrite and pyrobitumen. Late ore-stage, post-jasperoid veinlets with calcite + barite ± As, Sb sulfides and sulfosalts contain low-salinity aqueous inclusions with sufficient $CO_2$ to form clathrate upon freezing, and to be detected by laser Raman microprobe. Preliminary work on the ore stage silicification, which has been bracketed between two stages showing evidence of dissolved $CO_2$, suggests gold mineralization occurred while the fluid was in the one-phase field. Additional compositional and P data will be required to P correct to the true P-T conditions of mineralization. The presence of a non-boiling, $CO_2$-bearing ore fluid suggests the geologic conditions of ore formations may not reflect the near surface environment typical of modern day hot springs. (Authors' abstract)

KUMAR, A., 1987a Volume properties of aqueous electrolytes. 1. Examination of apparent molal volume data by the Pitzer model: J. Chem. Eng. Data, v. 32, p. 106-109. Author at Inst. Phys. Chem. & Electrochem., Univ. Karlsruhe, D 7500 Karlsruhe, FRG.

Literature data on the densities of aqueous single electrolyte solutions are analyzed by the virial coefficients model of Pitzer. The Pitzer coefficients obtained for apparent molal volumes are treated with temperature- and pressure-dependent equations. The density data used in this work cover the temperature range to about 200°C and pressure to about 400 bar. The Pitzer equations represent the apparent molal volumes of these solutions with excellent accuracy. (Author's abstract)

KUMAR, A., 1987b Volume properties of aqueous electrolytes. 2. Application of the Pitzer model in estimating apparent molal compressibility and expansibility: J. Chem. Eng. Data, v. 32, p. 109-112. Author at Inst. Phys. Chem. & Electrochem., Univ. Karlsruhe, D 7500 Karlsruhe, FRG.

The Pitzer model of virial coefficients is applied to the apparent molal compressibility and expansibility of aqueous single electrolyte solutions. Pitzer coefficients for several electrolyte solutions are given in the form of temperature-dependent equations. Also, these coefficients are applied for estimating the above properties in aqueous mixed electrolytes. The Pitzer equations can predict these properties with excellent accuracy. (Author's abstract)

KURILO, M.V., 1986, Regularities of distribution and connection with ore formation of vein carbonates in Donbass: Dokl. Akad. Nauk SSSR, v. 291, no. 1, p. 202-206 (in Russian). Author at Inst. Geochem. & Physics of Minerals, Kiev, Ukraine, USSR.

Alpine-type veins (of metamorphic origin) filled with quartz-carbonate-polymetal associations, commonly occur in rocks of the Carboniferous terrestrial coal-bearing series in Donbass. The composition of wall-rock carbonates from sandy-shales is as follows: siderite 65-70%, ankerite-dolomite 25-30% and calcite 5%; limestones consist of calcite or dolomite. Post-diagenetic formations bear only calcite ($CaCO_3$ 97-99.5%) as carbonate plus subordinate barite and/or pyrite, quartz and dickite. Fluid inclusion studies yielded the following data for the minerals of the Alpine type veins (T in °C, P in MPa, solution conc. in wt.%, gases in $cm^3/kg$ of mineral, the sequence of specimens from the lowest to the uppermost levels): a) quartz, calcite T 390-400, P 200, 5.5-7.5, CO 155-291, $CH_4$ 5-8, $H_2$ nil, $CO_2$ 5; b) quartz, calcite T 270-280, P 180, 4.0, CO 719-1061,* $CH_4$ 22-110, $H_2$ 10-20, $CO_2$ 5; c) quartz, calcite T 190-215, P 120, 3.5, CO 319-375, $CH_4$ 23-56, $H_2$ 10, $CO_2$ 9; d) calcite T 170-175, P 100, CO 867, $CH_4$ 36, $H_2$ 40; e) calcite T 140-150, P 80, 2.0, CO 166, $CH_4$ 17; f) calcite T 110-125, P 65, 1.5, CO 882, $CH_4$ 38, $H_2$ 10; g) calcite T 100, P 50, 1.5, CO 761, $CH_4$ 47, $H_2$ 10; h) calcite T 50-60, P 40, CO 600, $CH_4$ 16. P is determined from the overburden thickness. It is worth noting that content of $CO_2$ in inclusions is very low. Ore-bearing veins have different parageneses with inclusions in minerals yielding the following characteristics (units and sequence as above): Bobrikovo, quartz Th 253-403, P 105-86, 2.5-5.25, CO 74, $CH_4$ 4, $H_2$ 20, $CO_2$ 316; sphalerite Th 344-356, P 170-150, 2.9-9.8; siderite 271-300, P 125-80, 2.0-9.8; quartz Th 250-275, P 100, 4.5-5.5, CO 32, $CH_4$ 7, $CO_2$ 76; calcite Th 112-120, CO 55, $CH_4$ 25, $CO_2$ not determined; Nizhniy Nagol'chik, quartz Th 213-235, P 70-85, 1.5-4.8, CO 20, $CH_4$ 1, $CO_2$ 32; Esaulovka, quartz Th 215, P 70-55, 5.5, CO 15, $CH_4$ 4, $H_2$ 20, $CO_2$ 15; sphalerite Th 150-195, P 55, 2.6-7.0, calcite 126-130, CO 100, $CH_4$ 17, $CO_2$ not determined. In the orebearing veins $CO_2$ is the main gas component, frequently present as a separate L phase (P determined by Kalyuzhnyi's method); moreover, $N_2$ and $O_2$ appear in appreciable amounts. The most important change is the distinct decrease from carbonate to ore veins. Carbon-bearing gases were generated by coal metamorphism, $N_2$ and $O_2$ have atmospheric origin. (Abstract by A.K.) [* sic]

KURILO, M.V., 1987, Polymetallic ore mineralization in sedimentary metamorphosed beds of the Ukraine (genetic types, formation conditions, and typomorphism of minerals): Litol. Polezn. Iskop., 1987, no. 5, p. 58-69 (in Russian).

KURODA, Yoshimasu, WATANABE, Koji, NAGAI, Sumio and MATSUO, Sadao, 1987, Water involved in chloritization and sericitization in and around the Rendaiji mine, the Izu Peninsula, Japan: J. Japan. Assoc. Min. Petr. Econ. Geol., v. 82, p. 16-22. First author at Dept. Geol., Shinshu Univ., Matsumoto, 390 Japan.

The Au- and Ag-bearing quartz veins of the Rendaiji mine (now closed) in the southern part of the Izu Peninsula are associated with sericitization and silicification in the Miocene volcanic and pyroclastic formations which have also suffered from a regional chloritization. $\delta D$ values of the sericite and chlorite together with X(Fe) values of chlorite were determined. Based on the average measured $\delta D$ values of -64.5‰ of chlorite samples with the average X(Fe) (= Fe"/(Fe" + Mg)) value of 0.32 and the dependence of the D/H fractionation factor between water and chlorite on X(Fe), -4‰/0.1X(Fe) (Kuroda et al., 1976), we estimated the $\delta D$ value for the pure magnesian chlorite to be -52‰. The estimated value of -52‰ is precisely the same as the average $\delta D$ value of sericite of -52‰. Since there is no D/H fractionation between sericite and magnesian chlorite according to Kuroda et al. (1986b) and the formation T of the sericite and chlorite is estimated to be the same, the water responsible for both the sericitization and chloritization in the Rendaiji mine should be the same so far as the $\delta D$ value is concerned. Using the $\delta D$ value of sericite (average -52‰), we calculated the $\delta D$ value of the water participated in both the sericitization and chloritization to be -12‰ on the basis of the D/H fractionation factor experimentally determined by O'Neil and Kharaka (1976), or -25 ~ -28‰ based on that estimated by Marumo et al. (1980) from the natural samples. The $\delta D$ value of the water estimated above is definitely higher than that of the contemporary local meteoric water. The $\delta D$ value of the water extracted from fluid inclusions in the quartz associated with sericitization, -53 ~ -63‰, is much lower than that of the water associated with sericitization. (Authors' abstract)

KURZ, M.D., GARCIA, M.O., FREY, F.A. and O'BRIEN, P.A., 1987, Temporal helium isotopic variations within Hawaiian volcanoes: Basalts from Mauna Loa and Haleakala: Geochim. Cosmo. Acta, v. 51, p. 2905-2914.

KUSAKABE, M. and MATSUBAYA, O., 1986, Volatiles in magmas, volcanic gases, and thermal waters: Bull. Volc. Soc. Japan, v. 30, 2nd Series, p. 267-283 (in Japanese; English abstract).

KUTZ, K.B. and SPRY, P.G., 1987a A stable isotope and fluid inclusion study of Upper Mississippi Valley (UMV)-type base metal occurrences (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 736. Authors at Dept. Earth Sci., Iowa State Univ., Ames, IA 50011.

Over 60 occurrences of minor UMV-type mineralization surround the main UMV district. Similarities exist between the mineralogy, geological setting, and some geochemical aspects of the main UMV district and the outlying occurrences. However, paragenetic, fluid inclusion, and stable isotope data suggest major differences in the genetic history of the outlying occurrences. Th for outlying sphalerite and calcite, range from 37°-115°C. The T are generally cooler than those reported for these minerals from the main UMV deposits (46°-220°C). Measured salinities from fluid inclusions in outlying calcites (16-18 equiv. wt. % NaCl) are higher than those from main district calcites (2-4 equiv. wt. % NaCl).

Values of $\delta^{34}S$ for outlying sulfates range from +21 to +31 per mil. This range is similar to that of the main UMV district (+22 to +36 per mil). Overall values of $\delta^{34}S$ for sulfides from 17 outlying occurrences range from -22 to +33 per mil. This contrasts with the +6 to + 30 per mil range exhibited by main UMV district sulfides. Although sulfides in the main UMV district formed from reduced seawater sulfate, sulfur isotope data suggest that some outlying sulfide occurrences formed from a mixture of reduced seawater sulfate and organically derived sulfur.

Values of $\delta^{13}C$ and $\delta^{18}O$ for outlying calcites (-9 to +5 per mil and +21 to +29 per mil, respectively) tend to be higher than main UMV calcites ($\delta^{13}C$ = -13 to -2 per mil; $\delta^{18}O$ = +17 to +23 per mil). Values of $\delta^{18}O$ for fluid inclusions in outlying mineralization (-8 to +6 per mil) are similar to main UMV values (-5 to +6 pe mil); however, values of $\delta D$ (-95 to -20 per mil) are lighter than main UMV values (-47 to +2 per mil). These isotopic values support a connate source for the mineralizing fluids. S, C, and O isotope data suggest that some outlying mineralization resulted from local diagenetic processes and are unrelated to events that formed the main UMV deposits. (Authors' abstract)

KUTZ, K.B. and SPRY, P.G., 1987b Geochemical aspects of outlying Upper Mississippi Valley (UMV)-type mineralization in Iowa, Illinois and Wisconsin: Proc. Iowa Acad. Sci., v. 94, no. 1, unpaginated. See previous item.

KUZNETSOV, A.D. and EPEL'BAUM, M.B., 1987, Eutectic relations in open systems with the completely mobile components: Moscow, "Nauka" Press, 108 pp. (in Russian; contents translated by A.Kozlowski).

Introduction (3)

Chapter 1. Present-day recognition of the influence of fluid components on phase relations during melting in silicate systems. Nature of the silicate systems (7). Experimental data on the influence of fluid components on eutectic relations in the granitic system (11). Theoretical models describing the influence of additional components on the liquidus relations (21). Quantitative evaluation of the acid-basic relations of melt with fluid in the system quartz-orthoclase-$H_2O$-HCl (29).

Chapter 2. Thermodynamics of eutectic relations in systems with completely mobile components. Peculiarities of the thermodynamic description of systems with completely mobile components (39). Thermodynamics and topology of the diagrams of melting of the systems with completely mobile components (54). Calculation of the liquidus surface with the presence of the completely mobile water (63).

Chapter 3. Fluid regime and eutectic relations in natural granite systems. Certain examples of appearance of the effect of the eutectic shift in $SiO_2$-rich magmatic systems (75). Analysis of the fluid regime during the formation of the Upper Paleozoic granite massifs of the Tokraukskoe synclinorium and its margins (Central Kazkhstan) (80).

Final remarks (97).

Literature (103).

KWAK, T.A.P., 1987, W-Sn skarn deposits and related metamorphic skarns and granitoids: Devel. in Ec. Geol., v. 24, 451 pp.

KWAK, T.A.P. and ABEYLSINGHE, P.B., 1987, Rare earth and uranium minerals present as daughter crystals in fluid inclusions, Mary Kathleen U-REE skarn, Queensland, Australia: Min. Mag., v. 51, p. 665-670. First author at Dept. Geol., La Trobe Univ., Bundoora, Victoria 3083, Australia.

At least six separate rare earth and uranium-bearing daughter crystals occur in fluid inclusions hosted by andraditic garnet from the Mary Kathleen REE-U ore skarn, Queensland, Australia. The daughter minerals are particularly high in La, Nd and Ce which reflects the relatively high concentration of these in the bulk ore ($La_2O_3$ = 33.5%, $Nd_2O_3$ = 9.1% and $Ce_2O_2$ = 51.5% of the 2.6 wt. % REE common in the ore). The host garnets themselves contain up to 7600 ppm REE and 5 to 2700 ppm U. The energy-dispersive spectra (EDS) are consistent with the following minerals: a (Y, Ce, U, Ca, Fe, Nb, Ta) mineral; a (Ca, Fe, Ce) carbonate(?) mineral; a (Fe, Ca, Y, Ce, Nb, Ta) mineral; a possible carbonate of La, Mn and Nd; a chlorite of Mn and La as well as a possible chloride or oxychloride of K, Mg, Mn and La. Their occurrence infers that relatively high concentrations of REE and U prevailed in the original, oxidized, concentrated (30-70 wt. % total dissovled salts), high-T (550-670°) ore solutions. Their presence as daughter crystals may be due to the fact that $CaCl_2$ is a dominant salt in the solutions and that the latter's solubility was sufficiently high to 'salt out' the less soluble REE-U components. (Authors' abstract)

KWAK, T.A.P., TAYLOR, R.G. and PLIMER, I.R., 1986, Occurrence and genesis of primary tungsten deposits in Australia, in Geology of tungsten, Inter. Geol. Correl. Prog. Proj. 26 "MAWAM," A.A. Beus, ed., p. 217-244. First author at Dept. Geol., La Trobe Univ., Bundora, Victoria, Australia. (Continued)

Concentrates on the major occurrences and includes discussion of relevant fluid inclusion data. (H.E.B.)

KYLE, J.R., HARDWICK, J.F., STANDEN, A.R. and REED, M.H., 1987, Geological and geochemical controls of metal precipitation in epithermal systems, western San Juans, Colorado (abst.): Geol. Soc. Am. Abst. with Programs, v. 19, p. 288. First author at Dept. Geol. Sci., Univ. Texas, Austin, TX 78713.

Precious and base metal concentrations in the Silverton area in the western San Juans are the result of geothermal systems focused along structural zones related to mid-Tertiary caldera development. The most economically important deposits are the Au-rich epithermal veins along the apical graben faults of the San Juan-Uncompaghre caldera complex, e.g., Sunnyside, Scotia-Vanderbilt. Other epithermal deposits occur along radial faults near and outside of the structural margin of the nested San Juan-Silverton calderas. Base metal-rich replacement deposits with local calc-silicate concentrations were formed where Paleozoic carbonate rocks were intersected by the epithermal fluid conduits. Large blocks of the Mississippian Leadville Formation carbonates within the andesitic volcanic strata of the San Juan Formation were locally replaced by base metal-rich ores at the Pride-of-the-West deposit. The mineralized material occurs within a megabreccia unit of the Sapinero Mesa Tuff that slumped from the oversteepened southern margin of the San Juan caldera. Replacement of carbonate matrix and clasts of the Eocene Telluride Conglomerate adjacent to vein structures on the northwestern margin of the San Juan-Silverton caldera complex also resulted in the formation of sulfide concentrations, e.g., Idarado and Camp Bird.

Fluid inclusion data for these deposits indicate that mineralization principally occurred over a range of about 250 to 290°C from dilute solutions commonly containing less than 2 wt % NaCl equivalent. Homogenization temperature and freezing point depression data for the same inclusions suggest a variety of precipitation mechanisms, including dilution, cooling, and boiling, were involved during the different paragenetic stages of the deposits. Simultaneous, multi-phase chemical equilibria calculations suggest that gold precipitated from S-deficient waters in these epithermal systems when enough aqueous sulfide was precipitated in minerals to remove sulfide from the gold bisulfide complex. (Authors' abstract)

KYLE, J.R., POSEY, H.H. and FISHER, R.S., 1987, Sulfide mineralization in Permian strata of the Palo Duro Basin, Texas (abst.): Abstracts, SEPM annual midyear meeting 20-23, Aug. 1987, v. 4, p. 45. First author at Dept. Geol. Sci., Univ. Texas at Austin, Austin, TX.

Filling T and compositions were determined from fluid inclusions in coarse-crystalline sphalerite within Wolfcampian carbonates penetrated in three Palo Duro Basin wells. Mineralization T are higher than both the current formation T and T generated by sustained heating of deeper formations as indicated by vitrinite reflectance and other thermal indices (Ruppel, 1985; Dutton, 1986). In addition, inclusion fluids are almost two times more saline than current formation water.

The most significant intersection is a 5-ft fusilinid wackestone interval at about 3930 ft depth in DOE well Donley County #1 Sawyer. Twinned sphalerite crystals to 2 cm are tightly enclosed in clay-rich carbonate zones. Th for P 2-phase fluid inclusions in sphalerite range from 50 to 74°C (mean = 60°C) and are consistent within individual growth bands. T of final ice melting range from -17.5 to -18.8°C, indicating a fluid composition of 20.8 to 21.8 wt % NaCl eq. (4.6 to 4.8 molal). Initial melting T for inclusion fluids range from -26 to -28°C and are indicative of the presence of ions other than Na. Current formation waters are 32°C and are dominantly Na-Cl brines with a TDS content of about 141,000 mg/L (2.5 molal).

Hydrologic modeling of the Palo Duro Basin (Senger and others, in press) indicates that basin tilting initiated in the Miocene significantly increased flow rates through the basin. In its present configuration, there is potential for fluid flow into the basin from the west and south (Smith and others, in press). These observations compared wtih the fluid inclusion data indicate that warm brines were introduced into the lower Permian strata, but that the heat contribution was insufficient to affect organic maturation indices. Mineralization may have taken place from relatively warm and concentrated brines during deep burial of the Permian strata, whereas current fluids represent cooled and diluted products of late-stage basin flushing. (Authors' abstract)

KYLE,P.R., WRIGHT, A. and KIRSCH, I., 1987, Ultramafic xenoliths in the late Cenozoic McMurdo volcanic group, western Ross Sea embayment, Antarctica, in Mantle Xenoliths, P.H. Nixon, ed.: John Wiley & Sons, p. 287-293. Authors at Dept. Geosci., New Mexico Inst. Mining & Tech., Socorro, NM 87801, USA.

Suggests that the abundant, secondary fluid inclusions [silicate melt and $CO_2$?] observed in clinopyroxene may represent the fluid responsible for the metasomatism and formation of phlogopite. (H.E.B.)

LABOTKA, T.C. and NABELEK, P.I., 1987, The water/rock ratio and fluid infiltration in the contact-metamorphic aureole of the Notch Peak stock, Utah (abst.): EOS, v. 68, p. 1527.

LAGUNA MORALES, J.E., 1987, Microthermometric and isotopic study of fluid inclusions of the "Veta Blanca," Bella Vista mine, Miramar, Costa Rica: Third geologic conf. of Costa Rica, Sept. 24-25, 1987, p. 48 (in Spanish).

LAL, D., WACKER, J.F., POREDA, R. and CRAIG, H., 1987, Diffusion of helium in diamonds and implications for primordial helium in the earth (abst.): Meteoritics, v. 22, p. 437-438. First author at Chem. Dept., Univ. California, San Diego, La Jolla, CA 92093.

We have used two methods to measure diffusion coefficients of helium in diamond. From these data, we calculate a diffusion coefficient (D) of $1.4 \pm 0.6 \times 10^{-10}$ cm$^2$sec$^{-1}$.

What diffusion coefficient is required for diamonds to retain He for 4.5 Gyr? For a 1 mm radius diamond, D needs to be $<1 \times 10^{-20}$ cm$^2$sec$^{-1}$. Our measured values are many orders of magnitude greater than this. Thus, our results cast severe doubts on the hypothesis that diamonds can provide direct information on the primordial isotopic composition of helium in the Earth. (From the authors' abstract)

LAMB, W.M., 1987, Metamorphic fluids and granulite genesis: PhD dissertation, Univ. Wisconsin, Madison, WI, 234 pp.

Granulite-facies rocks often share certain characteristics, including: (1) metamorphism under conditions of low fugacities of water, (2) a depletion in large-ion-lithophile (LIL) elements, and (3) peak metamorphic P requiring deep crustal burial, and T ranging from 650 to 1000°C. Ideas concerning the formation of granulites generally fall into three categories: (1) removal of $H_2O$ and LIL elements by partitioning them into partial melts that are removed by intrusion to shallow crustal levels, (2) infiltration of $CO_2$ to dilute $H_2O$, and (3) metamorphism of rocks dehydrated prior to the peak of metamorphism. The work summarized here suggests that granulites in the Adirondack Mountains of New York formed by magmatic processes (processes 1 and 3).

Amphibole and biotite equilibria in samples from the southern Adirondacks require peak metamorphic $\alpha H_2O \sim 0.2$, while in other rocks peak metamorphic $\alpha CO_2 \sim 0.2$. These gradients in fluid activities argue against the infiltration of a pervasive $CO_2$-rich fluid.

C-O-H fluid calculations show that peak metamorphic oxygen fugacities >0.5 log bars more reducing than the graphite-$CO_2$ oxygen buffer require a fluid phase with $XCO_2 <0.2$. A review of peak metamorphic oxygen fugacity data shows that at least some granulites were not metamorphosed in the presence of a $CO_2$-rich fluid. Furthermore, these same data suggest that fluid-absent metamorphism may be common in granulites.

The presence of $CO_2$-rich fluid inclusions in a number of granulite facies terranes is thought to support the idea that granulites form via the pervasive infiltration of $CO_2$. $CO_2$-rich inclusions are also found in samples from the Adirondacks. However, these inclusions occur in rocks that contain fluid-buffering mineral equilibria that require low $XCO_2$, and therefore they cannot contain representative samples of the peak metamorphic fluid and were probably trapped after the peak of metamorphism yielding information about post-metamorphic P-T-X during uplift and cooling. (Author's abstract) See adjacent items

LAMB, W.M., BROWN, P.E. and VALLEY, J.W., 1987, Post-metamorphic $CO_2$-rich fluid inclusions in granulites: Evidence from the Adirondack Mountains, N.Y. (abst.): American Current Research on Fluid Inclusions, Jan 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated).

LAMB, W.M., VALLEY, J.W. and BROWN, P.E., 1987, Post-metatmorphic $CO_2$-rich fluid inclusions in granulites: Contrib. Mineral. Petrol., v. 96, p. 485-495. First author at Dept. Geol, Texas A&M Univ., College Station, TX 77843, USA.

In granulite-facies samples from the Adirondack Mountains, NY, estimates of peak-metamorphic $CO_2$ fugacities based on mineral equilibria are not consistent with estimates based on data for high-density, $CO_2$-rich fluid inclusions. Of the 21 Adirondack samples investigated for this study, all contain $CO_2$-rich inclusions. Inclusions occur in quartz, apatite, and garnet. They range in size from 3 to 50 µm and are without visible $H_2O$. In a few of the inclusions, freezing point determinations and preliminary Laser Raman spectroscopy show the presence of small amounts (<3%) of other fluids ($N_2$ and $H_2S$). $CO_2$ liquid-vapor homogenization temperatures are between -46 and +31°C, corresponding to densities between 1.14 and 0.5 gm/cc. Some of these densities are consistent with peak-metamorphic entrapment (1.06 to 1.1 gm/cc).

Peak-metamorphic fluid compositions in these samples are inferred from fluid-buffering equilibria that restrict the fugacity of $CO_2$ ($fCO_2$) directly (i.e., calcite + quartz + wollastonite) or buffer the fugacity of oxygen ($fO_2$). Assemblages that buffer $fO_2$ are important because knowledge of $fO_2$ places an upper limit on $fCO_2$. In 13 of the 21 samples, estimates of peak-metamorphic fluid compositions based on these equilibria show that the mole fraction of $CO_2$ ($XCO_2$) in equilibrium with the rock was low, in some cases less than 0.2.

The contradiction of mineral equilibria and fluid inclusion data shows that the inclusions record post-metamorphic conditions. At present, there are no criteria to distinguish these "primary appearing" $CO_2$-rich inclusions from those found in other granulite-facies terranes. Therefore, inferences of pressure-temperature conditions and peak-metamorphic fluid compositions based on fluid inclusions must be viewed with caution. (Authors' abstract)

LAMBERT, I.B. and ETMINAN, H., 1987, Biogeochemistry and origins of sediment-hosted base-metal sulphide deposits: Bur. Mineral Resources, Geology, and Geophysics [Australia] Yearbook, 1987, p. 89-93.

Includes data on Pillara and Wagon Pass Pb-Zn deposits including isotopes, Th, Tm and organic GC/MS. (E.R.)

LANDAIS, P. and CONNAN, J., 1986, Source rock potential and oil alteration in the uraniferous basin of Lodève (Hérault, France): Sci. Géol., Bull. de 'Univ. L. Pasteur de Strasbourg, v. 39, p. 293-314. First author at Centre de Recherches sur la Géol. de l'Uranium, BP 23, 54501 Vandoeuvre-les-Nancy, France.

Major uraniferous mineralizations (post-fault ore) of the Permian from the Lodeve Basin are associated with migrated organic matter in reservoir facies (faults, joints, silts, cinerites). The kerogen of the dolomitic black shales is oil-prone (mixed to sapropelic type) and has reached the threshold of intense oil genesis. The study of Autunian oils shows that original oils may be altered by different processes: extensive biodegradation with intense attack of alkanes and aromatics (oxidizing pathway), genesis of a chloroform insoluble phase without obvious bidegradation (non-oxidative pathway). This chloroform insoluble organic fraction may represent more than 90% of the total bitumen. A tentative explanation for these observations has been proposed by referring to microthermometric data obtained on aqueous fluids trapped in Autunian carbonates. These data show two types of fluids: meteoric waters and brines. Meteoric waters have brought the microorganisms responsible for the biodegradation of oils in some cases whereas saline brines, interacting with oils, may have led to genesis of chloroform insoluble bitumen without any biodegradation in other cases. (From the authors' abstract)

LANDEFELD, L.A., SILBERMAN, M.L. and O'LEARY, R.M., 1987, Comparative geochemistry of lode gold deposits in the Mother Lode, California and Archean greenstone terranes (abst.): Program with Abstracts, Symp.: Bulk Mineable Precious Metal Deposits of the Western United States, April 6-8, 1987, Geol. Soc. Nevada, p. 57. First author at Univ. of Western Ontario.

The results to date indicate no systematic, direct variations of Au with trace elements and degree of $CO_2$ metasomatism. (From the authors' abstract)

LANDIS, G.P., HOFSTRA, A.H., LEACH, D.L. and RYE, R.O., 1987, Quantitative analysis of fluid-inclusion gases - Applications to studies of ore deposits (Extended abst.): U.S. Geol. Survey Circular 995, p. 38-39.

Quantitative methods of fluid-inclusion gas analysis using a quadrupole mass spectrometer have been applied to the study of ores from the Coeur d'Alene district, Idaho; Mississippi Valley-type (MVT) deposits, Missouri, Arkansas, and Kansas; the Creede district, southern Colorado; and wood tin deposits, southern New Mexico.

Analyses are obtained from samples previously studied by fluid-inclusion petrographic and microthermometric methods and constrained by a geologic framework. While under vacuum, inclusion gases are released either by mechanical crushing of host material or by thermal decrepitation. Controlled thermal ramp heating coupled with real-time multiple ion monitoring are used to profile gas release as a function of T. These profiles define discrete fluid-inclusion populations that can be distinguished from adsorbed-desorbed gas release, "matrix" gas, and the thermal decomposition of host minerals. Matrix gas collectively refers to the following sites of gas entrapment in the host minerals: submicrometer-sized fluid inclusions, domain boundaries, microstructures, crystal defects, and gas dissolved in the crystal. Chemical reactions of gases due to heating are evaluated easily. Sharply defined spikes representing sudden release of gas from single or multiple fluids inclusions are superimposed upon the thermal profiles. Quantitative analysis of these "bursts" permits detailed study of ore fluid chemistry at the level of individual fluid inclusions. Analyses of gas mixtures from discrete fluid-inclusion populations tightly constrain ore genesis models.

Gas data are quantified from the partial P of each gas determined in the mass spectrometer and the P-V-T relations of the gas mixture in the inlet system. The following parameters are applied for each gas in a M x N matrix solution: ionization fragmentation, gas sensitivity, and kinetic adsorption-desorption on vacuum surfaces. Rapid, highly sensitive, and precise analyses are possible with a minimum detectable partial P of $8 \times 10^{-15}$ mbar, a partial P sensitivity of $8 \times 10^{-9}$ (that is, 8 ppb), a maximum scan rate of 100 µs per atomic mass unit (AMU), over a range of 0-255 AMU, and an electrometer dynamic range of five orders of magnitude. All instrument control is enabled by assembly and FORTRAN codes on a PDP 11/73 computer with 4 MByte memory and 110 MByte Winchester disk capacity. Any gas species with major atomic mass unit peaks within the range of the instrument can be detected. The present system is calibrated for 32 primary gases and light hydrocarbons, including $H_2O$, $CO_2$, $N_2$, $O_2$, $H_2$, He, Ar, $CH_4$, $H_2S$, $SO_2$, N-O gases, $NH^3$, HF, and HCl, and common organics up to $C_6$. Total relative analytical precision of 1-3 percent is typical. A separate gas chromatograph-mass spectrometer is used to identify more complex organic spectra.

The following results are obtained from the above studies of ore systems: (1) Fluid inclusions in Zn-rich veins from Coeur d'Alene contain greater concentrations of $CH_4$, short chain hydrocarbons, and $N_2$ than in younger Ag-rich veins in which $CO_2$ is dominant. Reduced fluids in Zn-rich veins probably were derived from devolitalization reactions of sediments containing organic matter and $NH_4$-bearing phyllosilicates. Changes in P-T, $fO_2$, and loss of volatiles by gas phase separation may have generated a more oxidized $CO_2$-rich fluid for the young Ag veins. (2) The most abundant gases determined in samples from studied MVT's are $CO_2$, $N_2$, and $CH_4$. The hydrocarbon content of these fluids is low (<0.1 mole percent) and consists largely of $CH_4$ with traces of $C_2H_6$. Water- and $CO_2$-rich inclusions combine to yield bulk analyses of several mole percent $CO_2$. The $CO_2$-rich (>20 mole percent) individual inclusions represent a period of local $CO_2$ effervescence during host rock dissolution and sulfide deposition. The thermal maturity and low concentration of hydrocarbons together with the high $CO_2$ content suggest that these ore-forming fluids are highly evolved basinal brines. (3) The gas studies of epithermal ores from the Creede district, combined with existing extensive detailed geologic and geochemical data, provide strong constraints on the sources of fluids and the role of mixing and boiling during ore deposition. The presence of variable amounts of organic gas species throughout the paragenesis points to a significant input from caldera moat sediments in the hydrothermal process. (4) The data from the Black Range tin occurrences confirm a magmatic orign for the ore fluids and permit study of the evolution of magmatic fluids during the period of ore deposition. (From the authors' abstract)

LANDIS, G.P. and RYE, R.O., 1987, Reconnaisance gas chemistry of the Creede, Colorado, hydrothermal system (abst.): Geol. Soc. Am. Abst. with Programs, v. 19, p. 288. Authors at U.S. Geol. Survey, MS 963, Fed. Center, Denver, CO 80225.

The gas chemistry of the Creede epithermal vein system is highly variable in time and space. The gases are significant indicators of the sources and evolution of fluids in the veins and at depth. They also constrain processes leading to mineral precipitation. Each major stage of mineralization is characterized by a specific gas chemistry which may have been modified locally by mixing or boiling. Fluids from all paragenetic stages, including those from the high-T (up to 310°C) and high-$fO_2$ (hematite stable) main stages, contain a complex (and as yet poorly-characterized) mixture of alkanes, alkenes, and aromatic hydrocarbons. These hydrocarbons must have been derived from progressive thermal degradation or pyrolysis of moat sediment organic matter. Additional gas species detected in variable and commonly disequilibrium amounts include $CO_2$, $H_2S$, $SO_2$, $N_2$, $H_2$, and Ar. The relative abundances of the sulfur gas species clearly do not reflect equilibrium, consistent with the observation of sulfur isotope redox disequilibrium in the system. The persistence of the organic species and disequilibrium gas compositions in the fluids indicate lack of attainment of complete chemical equilibrium in the system. (From the Authors' abstract)

LANE, T., 1987, Setting and origin of shoestring sphalerite deposits, Lower Ordovician St. George Group, Daniel's Harbor, western Newfoundland (abst.): Abstracts, SEPM annual midyear meeting 20-23, Aug. 1987, v. 4, p. 47. Author at Dept. Earth Sci., Memorial Univ. of Newfoundland, St. John's, Newfoundland, Canada, A1B 3X5.

After Middle Ordovician burial and P solution-related dolomitization, and prior to Middle Paleozoic uplift, heterogeneous dolostones were episodically fractured, partially dissolved and cemented along karst breccia bodies, faults and folds. During a burial maximum between 1000 and 3000 m (at a conodont CAI of 2-1/2) warm to hot, saline brines (100° to 180°C Th at 18 to 30 eq. wt. % NaCl) migrated both vertically up chimney feeders and laterally along complexes. Non-radiogenic isotopic leads imply a partial metal source 2000 m below in or near a high grade metamorphic segment. Deep dolostone chimney feeders at major fracture intersections contain (1) deep early sulphides, (2) hot TPFI Th's (160° to 180°C) and (3) positive $^{34}S$. Evidence of mixing between metal rich fluids and formational brines includes (1) solution fronts, (2) zebra fabrics, (3) varied TPFI compositions and (4) variable $^{34}S$ isotopes. (From the author's abstract)

LANE, T. and JAMES, N., 1987, Coarse dolostone/sphalerite complexes: Lower Ordovician St. George Group, Daniel's Harbor, western Newfoundland (abst.): Abstracts, SEPM annual midyear meeting 20-23, Aug. 1987, v. 4, p. 47. First author at Dept. Earth Sci., Memorial Univ. of Newfoundland, St. John's, Newfoundland, Canada, A1B 3X5.

Coarse dolostone complexes with sphalerite form extensive stratabound bodies within, and local discordant bodies across the Catoche Formation, a predominantly limestone unit within the St. George Group. These dolostones are the final stage in a complex history of limestone diagenesis and dolomitization. These lithologies were buried to depths of 1000 to 3000 m and tectonically fractured, creating extensive porosity and permeability, particularly along the margins of karst breccias. The tectonic fractures interconnected with faults which tapped deep brines (18 to 30 eq. wt. % NaCl, 100 to 180°C Th) in or near the basement. Fluid P were elevated beneath impermeable dolostone caprocks. (From the authors' abstract)

LANG, Dianyou and ZHANG, Xingjun, 1987, Geological setting and genesis of the Jiashengpan Pb-Zn-S ore belt, Inner Mongolia: Mineral Deposits, v. 6, no. 2, p. 39-54 (in Chinese; English abstract). Authors at 105 Geol. Party of Bureau of Geol. & Min. Res. of Inner Mongolia, Buiyanhua Gommvne, Urad Front Banner, Inner Mongolia.

Presents data for chemical analysis of inclusion fluids in quartz, pH, and Eh. (H.E.B.)

LANG, J.R., YIN, Guan and EASTOE, C.J., 1987, Oxygen isotope composition of sulfate in early stage veins, Mineral Park porphyry copper-molybdenum system, Arizona (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 739. First author at Dept. Geosci., Univ. Arizona, Tucson, AZ 85721.

Oxygen isotope analyses were performed on anhydrite from the stage AM and AC veins of the Mineral Park porphyry copper-molybdenum deposit. The results show that the $\delta^{18}O$ (anhydrite) values from the early, molybdenite-bearing stage AM veins range from 9.5 to 9.8 per mil. The values in the later, chalcopyrite-rich stage AC veins range from 15.3 to 19.7 per mil. In both vein stages the pressure-corrected T from primary fluid inclusions in quartz range from 360 to 420°C and are in good agreement with T obtained from the sulfur isotope fractionation of coexisting anhydrite-pyrite. The salinity of stage AM veins averages about 5 NaCl eq. wt% while stage AC veins contain 45 wt% NaCl + KCl. Calculated $\delta^{18}O$ signatures of water in equilibrium with the anhydrite are 4.8 to 6.8 per mil in the stage AM veins and 9.1 to 15.5 per mil in the stage AC veins.

The distinctly different $\delta^{18}O$ ranges of the two vein types indicate fluids of different origin or evolution for the two vein stages. The data are consistent with a magmatic source for the stage AM waters. Possible fluid sources for the AC veins include formation waters that equilibrated with surrounding metamorphic rocks, or magmatic fluids that were modified during an episode of liquid-vapor separation. (Authors' abstract)

LANGE, R.A. and CARMICHAEL, I.S.E., 1987, Densities of $Na_2O$-$K_2O$-CaO-MgO-FeO-$Fe_2O_3$-$Al_2O_3$-$TiO_2$-$SiO_2$ liquids: New measurements and derived partial molar properties: Geochim. Cosmo. Acta, v. 51, p. 2931-2946.

LANZIROTTI, Antonio, 1987, Developing gas geothermometers for high temperature metamorphic fluid inclusions (abst.): American Current Research on Fluid Inclusions, Jan 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Author at Dept. Geosci., New Mexico Inst. Mining & Tech., Socorro, NM 87801.

Metamorphic terranes commonly exhibit a change in the equilibrium composition of fluids generated during metamorphism as a function of metamorphic grade. A prime example is the 'Geotraverse' of Frey through the Swiss Alps. With increasing grade we generally see a change from C-O-H-rich fluids to $CO_2$-rich fluids. Attempts were made to derive gas geothermometers for those terranes in which it seemed that fluid equilibrium had been preserved and P inclusions were present. The geothermometers were constructed around the chemical reaction which seemed to be primarily responsible for controlling the fluid composition in the particular area of interest. For example, a carbon oxidation reaction was employed for fluids from graphitic schists. By calculating Gibbs' Free Energies at various high T, we curve-fit an equilibrium constant expression in terms of T. We can then write the equation in terms of partial pressures using high T fugacity coefficients. The equation for graphite oxidation becomes:

$$5.6409 - \frac{5104.663}{T} = \log(1.271\ pCO_2) + 2\log(1.269\ pH_2) - 2\log(0.656\ pH_2O)$$

where the partial pressure is in bars and the temperature in Kelvin. Similar equations can be constructed for fluids derived from decarbonation or silicate hydration reactions. Applying these geothermometers to actual metamorphic terranes which appear to contain equilibrium fluids, for example the Khatada Lake Complex, B.C., or the 'Systeme du Graphite,' Madagascar, yields T which are in good agreement with those derived from mineral pairs (± 50°C). When applied to terranes in which the fluids are not in equilibrium with each other, for example those which have seen extensive decrepitation, or with the surrounding lithologies, through influx of fluids from other regions, significant deviations can be seen between the fluid geothermometers and T from mineral pairs. The Pecos Baldy area of New Mexico is a good example (± 400°C). (Author's abstract)

LAPIQUE, F., CHAMPENOIS, M., CHEILLETZ, A. and BOULLIER, A.M., 1987, An interactive image analysis system for quantitative geometric analysis in mineralogy, petrology, fluid inclusions and structural geology (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 159. Authors at Centre de Recherches Pétrogr. & Gépchim., CRPG-CNRS, B.P. 20, 54501 Vandoeuvre-lès-Nancy Cedex, France.

The CRPG Image Analyzer system is based on an IBM PC, XT, AT or compatible microcomputer, which is used for storage and treatment of video data provided by a high resolution RGB video camera. The camera can be mounted on reflected or transmitted light microscopes, or binocular zoom microscopes.

Optional programs, developed in the fields of mineralogy, petrology, fluid inclusions or structural geology, perform the calculation of parameters such as surface fraction, point count analysis, histograms of distribution, shape factors, orientation distribution or finite strain ellipsoid determination. Automatic image analysis using a digital image processor and image analysis software is now being added to this interactive Image Analysis system. This complete image processing system represents a new advance in the quantification of visual information in earth sciences. (From the authors' abstract)

Note - This abstract was a late addition and hence is not in the bound volume of abstracts. (E.R.)

LAPUSHKOV, V.M., 1987, Method of determining homogenization temperature of gas-liquid inclusions in materials: USSR Patent SU 1300359 A1 (in Russian).

LARIONOV, N.N., NASTASIENKO, E.V., SMOLYANSKII, P.L. and SOMOV, M.M., 1987, A new type of sellaite-fluorite mineralization: Mineral. Zh., v. 9, no. 2, p. 22-25 (in Russian). Authors at Vses. Nauchno-Issled. Geol. Inst., Leningrad, USSR.

Steep-dipping veins of sellaite-fluorite associations occur in the Lower Riphean carbonaceous-argillaceous schists at the exocontact of gabbro-diabase dikes in southern Urals (USSR). Light-grey and transparent grains of fluorite have gas-liquid inclusions containing K 3.7, Na 3.8, Ca 7.9, Mg 1.8, $Cl^-$ 8.5, and $HCO_3^{2-}$ 33.0 g/L; these inclusions have Th 105-120°. A low-T hydrothermal origin is proposed for this ore mineralization. (From C.A. 108: 170913r)

LARSON, P.B., 1987, Stable isotope and fluid inclusion investigations of epithermal vein and porphyry molybdenum mineralization in the Rico mining district, Colorado: Econ. Geol., v. 82, p. 2141-2157. Author at Dept. Geol., Washington State Univ., Pullman, WA 99164-2812.

The Rico mining district, western San Juan Mountains, Colorado, contains epithermal vein deposits, carbonate replacement deposits, and a large zone of porphyry-style Mo mineralization. Historically, the vein and replacement deposits have produced significant amounts of Ag, Pb, and Zn, with minor Au and Cu. All the mineralization formed nearly contemporaneously about 5 m.y. ago. (...) The porphyry Mo mineralization is 1,500 m beneath the surface. The epithermal veins occur above and peripheral to the porphyry mineralization. Widespread high-silica, alaskite porphyry dikes were also emplaced at the same time as the porphyry mineralization and are probably related to the source intrusion for Mo mineralization and the heat source for the hydrothermal system that produced the epithermal and replacement deposits. Fluid inclusions in quartz from the veins have Th 200° to 300°C and yield salinities less than 5 eq. wt % NaCl. The δD values of quartz inclusion fluids (-112 to -121‰) and calculated $\delta^{18}O$ values of fluids in equilibrium with the quartz (-3 to -17‰) show that the epithermal vein fluids were $^{18}O$-shifted meteoric waters. Vein samples with large $^{18}O$ shifts also exhibit very saline fluid inclusions, indicating that the fluids which experienced the greatest degree of water-rock interaction contain the highest concentration of dissolved components. The porphyry fluid (δD = -90 to -104‰, $\delta_{18}O$ = +2‰) was derived from mixed magmatic and meteoric sources. P inclusions in the porphyry veinlets homogenize to both liqud and vapor in the range 350° to 420°C, suggesting that boiling occurred during their formation. Trains of S inclusions are abundant in the veinlets and show that a later lower T fluid encroached upon the porphyry system. No evidence for mixing of magmatic and meteoric fluids was found in any of the epithermal veins. The porphyry mineralization formed early in the history of the Rico hydrothermal system. Epithermal vein formation occurred later than the porphyry mineralization, and the meteoric-hydrothermal fluid collapsed into the porphyry core of the system during the retrograde stages of the hydrothermal system. (Author's abstract)

LARSON, P.B. and TAYLOR, H.P., Jr., 1987, Solfataric alteration in the San Juan Mountains, Colorado: Oxygen isotope variations in a boiling hydrothermal environment: Econ. Geol., v. 82, p. 1019-1036. First author at Dept. Geol., Washington State Univ., Pullman, WA 99164-2812.

Uses literature data on fluid inclusions from these camps. (E.R.)

LASAGA, A.C., 1987, Modeling metamorphic fluid compositions: The kinetic factor (abst.): EOS, v. 68, p. 1528.

LATORRE, C.O. and VATTUONE de PONTI, M.E., 1986, Presence of barite crystals in a basalt of Misiones Province: Revista de la Asoc. Argentina de Mineral., Petrol., Sediment., v. 17, no. 1-4, p. 1-10 (in Spanish; English abstract).

Crystals of barite deposited on a chalcedony layer in cellular basalts have 0.035% Sr and are near to the pure species. $^{87}Sr/^{86}Sr = 0.7059 \pm 0.0003$ normalized for $^{86}Sr/^{88}Sr = 0.1194$. Th of fluid inclusions was 157.3-236.0°C. This suggests a volcanic or an hydrothermal process and would have a common origin with basalt, being the mineral formed in a latter volcanic event. (E.R.)

LAUL, J.C. and SMITH, M.R., 1987, Disequilibrium study of natural radionuclides in hot brines (190°-165°C) from the Salton Sea Geothermal Field (analog study) (abst.): EOS, v. 68, p. 439. First author at Pacific Northwest Lab., P.O. Box 999, Richland, WA 99352.

The study of natural radionuclides of the uranium and thorium series in groundwaters can provide information on retardation parameters of radwaste radionuclides and their analogs in an unlikely event of a breached salt repository. The temperature around the radwaste canister is expected to be about 200°-150°C. For far-field (40°-20°C) results, we have studied site-specific briny groundwaters from the Palo Duro Basin and observed certain trends (radionuclide spectrum). For near-field (200°-150°C) studies, hot brines from the SSGF provide representative matrix waters as the temperatures and salinity of the SSGF brines cover the range of temperatures and salinity expected in a salt repository.

As part of the Salton Sea Scientific Drilling (SSSD) project, organized by W.A. Elders, we participated in consortium studies. We report results of natural radionuclides in hot brines from port 4 (190°C) and port 5 (165°C) of Zone 1 (6227-6166 ft) of the SSGF well. Our findings are as follows.

The concentrations of radionuclides (except for Pb) in the SSGF brines are very low relative to their host rocks and lie in the same range as observed in the Palo Duro brines. The overall radionuclide spectrum (except Pb) in the SSGF brine is similar to that observed in the Palo Duro brines. Radium does not appear to be retarded in deep brines. Relative to radium, $^{234}U$, $^{230}Th$, $^{228}Th$, and $^{210}Po$ are highly retarded by factors of $10^4$ to $10^5$. Uranium, like Th, is in the +4 state and thus suggesting a reducing environment of the aquifer. The $^{210}Pb/^{226}Ra$ ratio is high (1.7), while this ratio is extremely low in the Palo Duro brines. High $^{210}Pb$ in the SSGF brine suggests that lead exists as a highly soluble chloride complex in hot brines. The overall behavior of natural radionuclides in terms of their retardation factors, sorption/desorption behavior and their associated kinetics (except for Pb) in the near-field is similar to that in the far-field. (Authors' abstract)

LAYNE, G.D., SPOONER, E.T.C. and LONGSTAFFE, F.J., 1987, Mineralogical, fluid inclusion and stable isotope studies of the JC tin skarn, Yukon (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 742. First author at Dept. Geol., Univ. Toronto, Toronto, Ont., Canada M5S 1A1.

The JC skarn is a tin deposit (~1.25 m.t. at 0.54% Sn) hosted by Mississippian sediments on the southwest flank of the Seagull batholith in south-central Yukon Territory. Multiple stages of skarn formation have resulted in the following stable mineral assemblages, stage I; stanniferous andradite (<0.02-0.62% Sn) + hedenbergite, stage II; stanniferous Fe-amphibole (0.06-0.48% Sn) + magnetite, stage IIA; stanniferous Fe-amphibole + pyrrhotite + chalcopyrite + sphalerite, stage III; stanniferous epidote (0.09-0.58% Sn) + quartz + calcite + axinite + stanniferous Al-sphene, stage IIIA; muscovite + Fe-chlorite + calcite, stage IV (early veins); beryl + quartz + tourmaline or danalite, stage IV (main stage); biotite + quartz + fluorite + arsenopyrite + cassiterite, stage V; late stage veins and breccias of calcite + pyrite + marcasite. Primary fluid inclusions in stage III epidotes show a Th range of 343-420°C, salinities of 20.0-0.27 wt.% and $CaCl_2/NaCl$ ratios of between 11.2 and 14.4. Primary inclusions in stage IV cassiterite have a Th range of 362-482°C, salinities of 24.7-33.3 wt% and $CaCl_2/NaCl$ ratios of between 0.6 and 7.6. Stable isotope analyses of carbonate and silicate minerals are consistent with a predominantly magmatic origin for fluids at stages I and II and mixing of magmatic fluids with a significant, but variable, amount of meteoric water at stage III. Stage IV fluids were predominantly magmatic in nature. Some silicate samples show evidence of reequilibration with later, lower T (<400°C) fluids of stage V. (Authors' abstract)

LEACH, D.L., GOLDFARB, R.J. and HOFSTRA, A.H., 1987, Fluid inclusion characteristics of the Juneau gold belt, southeastern Alaska (abst.): Geol. Soc. Am. Abst. with Programs, v. 19, p. 398. Authors at U.S. Geol. Survey, Box 25046, Denver Fed. Center, Denver, CO 80225.

The Juneau gold belt comprises a group of mineral deposits that extends for more than 200 km along the western side of the Coast Range Batholith in southeastern Alaska and includes Alaska's two largest lodge gold producers, the Alaska-Juneau and Treadwell deposits. Fluid inclusion studies of samples for the Alaska-Juneau, Kensington, and Sumdum Chief mines, as well as from several small prospects, have been made to determine the temperature, pressure, and chemical composition of the ore-forming fluids. Samples from the Treadwell deposit have so far been found to be unsuitable for fluid inclusion study.

Fluid inclusion studies of gold-bearing samples show that ore deposition throughout the gold belt occurred at temperatures between 200°C and 325°C and at pressures in excess of 1 kb. The ore fluids had low salinities, less than 5 equivalent wt. percent NaCl, and variable gas contents. Gas compositions of the fluid inclusions, determined by microthermometry, mass spectrometry, and laser Raman spectrography, show $CO_2$ to be the dominant gas, with minor amounts of $CH_4$, $N_2$, and $H_2S$. Estimates of the bulk mole percent $CO_2$ for the ore-forming fluids range from 30 to 60 percent for the Alaska-Juneau deposit to less than 5 percent for many of the smaller deposits.

Fluid immiscibility (boiling) was clearly a major control on gold deposition at the Alaska-Juneau deposit. The fluid immiscibility is thought to be responsible for the intense hydrofracturing of the metasedimentary host rocks and for the abundance of quartz-carbonate veining. At other mines along the gold belt which contain lower gas contents, evidence for fluid immiscibility is lacking and the intensity of veining is much less developed. Wall rock interaction may have been the most important control on ore deposition for these systems. (Authors' abstract)

LEACH, D.L., GOLDFARB, R.J. and LIGHT, T.D., 1987, Fluid inclusion constraints on the genesis of the Alaska-Juneau gold deposit, in Elliott, I.L. and Smee, B.W., eds., Geoexpo/86: Exploration in the North American Cordillera: Assoc. of Explor. Geochem. Pub., p. 150-159.

See previous item. (E.R.)

LEACH, D.L., LANDIS, G.P. and HOFSTRA, A.H., 1987, Gas contents of Mississippi Valley-type ore fluids: Implications for ore genesis (abst.): American Current Research on Fluid Inclusions, Jan 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Author at U.S. Geol. Survey, P.O. Box 25046, Denver Federal Center, Denver, CO 80225.

A quadrupole mass spectrometer was used for quantitative analyses of gas from fluid inclusions in ore and gangue minerals from Mississippi Valley-type deposits in Missouri, Arkansas, Kansas, and Oklahoma. The gases in the ore and gangue minerals help characterize the ore-forming fluids and can be used to interpret the geochemical processes leading to ore deposition. Analyses show that the total gas liberated from 5- to 10-gram samples heated from 100° to 350°C is predominantly $H_2O$ and has anomalously high $CO_2$ contents of up to 6 mole % and small amounts (generally $<0.1$ mole %) of other gases, including $H_2S$, $SO_2$, $N_2$, Ar, $CH_4$, and other short-chain hydrocarbons. Comparable bulk $CO_2$ contents were obtained by both thermal decrepitation and room-T crushing methods. Both show $CO_2$ contents that would be an order of magnitude greater than the amount that would be soluble in a saline aqueous fluid under the P-T conditions of ore deposition ($T < 150°C$ and fluid $P < 200$ bars).

Controlled thermal ramp heating was coupled with real-time multiple ion monitoring to profile gas release as a function of T on samples as small as 100 mg. These profiles define gas release from fluid inclusion populations that can be distinguished from adsorbed/desorbed gas, thermal decomposition of the host mineral, gas chemical reactions, and matrix gas. Matrix gas sites include submicron-size fluid inclusions, domain boundaries, and crystal defects. Superimposed upon the profiles are sharply defined spikes representing sudden release of gas from individual or multiple fluid inclusions. Quantitative analyses of these "bursts" enable detailed study of ore fluid chemistry at the level of individual fluid inclusions. The thermal profile data show that the majority of the $CO_2$ released by thermal decrepitation resides in $CO_2$-rich fluid inclusions. Many of these inclusions are nearly pure $CO_2$ with small amounts of $H_2S$, $SO_2$, $N_2$, Ar, and short-chain hydrocarbons. Other $CO_2$-rich inclusions containing variable amounts of $H_2O$ may record heterogeneous trapping of a two-phase fluid. $H_2O$-rich fluid inclusions (<99 mole % $H_2O$) contain less than 0.5 mole % $CO_2$ and minor amounts of $H_2S$, $N_2$, Ar, and short-chain hydrocarbons.

Based on the results of the gas analyses and field relationships, we propose that the episodic mixing of a metal-bearing brine with a local source of reduced sulfur resulted in sulfide mineral deposition. This reduced the pH of the ore fluid. The common presence of abundant marcasite in these carbonate-hosted deposits indicates the pH of the ore fluid was locally as low as 1 to 3. Rapid dissolution of the host rocks during ore deposition caused $CO_2$ effervescence in the ore zones. The ore fluid and the evolved $CO_2$ are recorded by the two populations of fluid inclusions. (Authors' abstract)

LEACH, T.M. and MUCHEMI, G.G., 1987, Geology and hydrothermal alteration of the north and west exploration wells in the Olkaria geothermal field, Kenya: Proc. 9th NZ Geother. Workshop 1987, Univ. Auckland, NZ, p. 187-192. First author at Chartered Min. Services and GENZL.

Th values on liquid-rich inclusions in quartz, calcite and rhodochrosite range ~200-300°C, and "vapor-rich and $CO_2$-rich" inclusions were found, suggesting 2-phase trapping. Th decreases with depth in the 2 wells, from either deposition while the system was heating, or an influx of cool fluids, probably the latter. (E.R.)

LeANDERSON, P.J. and MUNOZ, J.L., 1987, Relationship between rock type, metamorphic grade, and fluid-phase composition in the Grenville Supergroup, Limerick Township, Ontario: Can. Mineral., v. 25, p. 485-498.

LEE, H.K., KIM, S.J. and CHOI, S.G., 1987, Occurrence of electrum from the Namseong gold mine: J. Korean Inst. Mining Geol., v. 20, no. 4, p. 223-234 (in Korean; English abstract).

Th for quartz ranges from 225° to 355°C. (E.R.)

LEE, J.K.W., ONSTOTT, T.C. and HANES, J.A., 1987, A laser microprobe investigation of argon distribution in biotite and hornblende: A comparison with conventional $^{40}Ar/^{39}Ar$ step-heating spectra (abst.): EOS, v. 68, p. 1514.

LEE, Y.I. and FRIEDMAN, G.M., 1987, Deep-burial dolomitization in the Ordovician Ellenburger Group carbonates, west Texas and southeastern New Mexico: J. Sed. Petrol., v. 57, no. 3, p. 544-557. First author at Dept. Geol. Sci., College of Natural Sci., Seoul Nat'l. Univ., San 56, Shinrim-dong, Kwanak-Ku, Seoul 151, Korea.

From western Texas and southeastern New Mexico, core samples of shallow subtidal and peritidal carbonates in the Ellenburger Group (Lower Ordovician) were examined to investigate the effects of deep burial on diagenesis. At present, the burial depth of samples ranges from 6,000 ft (1.5 km) to 23,000 ft (7.0 km).

Below 10,000 ft (3.0 km) carbonates are exclusively dolostones, showing evidence of deep-burial dolomitization such as the presence of coarse crystalline dolomite, xenotopic texture, homogeneous cathodoluminescence, high fluid-inclusion Th, and light oxygen-isotope compositions.

Locally, neomorphism of older, fine crystallline dolomite occurs; howeever, the preservation of depositional textures in coarse crystalline, xenotopic dolomite indicates a nonobliterative replacement origin in deep-burial environments. Millimeter-size crystals of euhedral saddle dolomite commonly fill vugs and fractures.

The $Mg^{+2}$ ions in the nonferrous dolomites are probably derived from basinal brines via high porosities and fractures. Higher temperatures and longer reaction times coupled with the addition of $Mg^{+2}$ ions from circulating waters are apparently responsible for deep-burial dolomitization. (Authors' abstract)

LEEDER, O., THOMAS, R. and KLEMM, W., 1987, Einschlüsse in Mineralen (Inclusions in minerals), 1st edition, 180 pp., 67 ill., 23 tables, 335 references: Leipzig, Deutscher Verlag fur Grundstoffindustie (in German).

This first book in the German language on the studies of the inclusions is a compact review of the history of the method, physicochemical basis, methods and possibilities of application of the studies of inclusions in minerals. It presents the thermobarometric approach (measurements of Th, determinations of P, cryometry and decrepitography) as well as the determinations of the chemical composition of the parent solutions, water content, gas composition and isotopic characteristics. The book is addressed essentially to mineralogists, petrologists, the investigators of the ore- and non-ore raw material deposits, but also to chemists, silicate technologists and specialists of some other branches of material technology. (Authors' annotation translated by A.K.)

LEMARCHAND, Fabienne, VILLEMANT, Benoît and CALAS, Georges, 1987, Trace element distribution coefficients in alkaline series: Geochimica Cosmo. Acta, v. 51, p 1071-1081.

LEROY, J.L, ANIEL, Brigitte and POTY, Bernard, 1987, The Sierra Pena Blanca (Mexico) and the Meseta Los Frailes (Bolivia): The uranium concentration mechanisms in volcanic environment during hydrothermal processes, in B. Poty and M. Pagel, eds., Concentration Mechanisms of Uranium in Geol. Environ.-A Conf. Rept. Uranium, v. 3, p. 211-234. First author at G.S. C.N.R.S.-C.R.E.G.U., B.P. 23, F-54501, Vandoeuvre-lès-Nancy Cédex, France.

It is postulated that an intense hydrothermal activity [and vapor phase crystallization], probably of prolonged duration, in rocks displaying primary enrichment of labile U, is essential to form volcanogenic U deposits of the type found in Mexico. (From the authors' abstract)

LESPINASSE, Marc, 1987, Relations between fluid inclusion trails, fluid circulation and rock alteration in granitic environment: A tool for fluid chronology (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 147-148. Author at CREGU et GS CNRS-CREGU, BP 23, 54501 Vandoeuvre-les-Nancy Cedex, France.

Within the last few years, much work has been done on microcrack propagation mechanisms, spatial distribution, and relation with local stress axis. Most cracks appear to be extensional fractures (mode I cracks) propagated roughly parallel to the local maximum stress axis. However, geometric description of fracturing is not sufficient to establish a chronology between the different stages of regional paleostressfields. It was necessary to perform a new method of investigation relating fracturing with deformational events (responsible of the fracturing) and the nature of filling of the microfractures. Thus, we have focussed on a particular microstructural marker, the fluid inclusion (FI) trails.

In a major study, Tuttle (1949, J. Geol., v. 57, p. 331) has shown that trails of FI are oriented in a coherent manner relative to the regional structure. Thus it should be possible to discriminate between trails (i.e., between different generation of fluids) and to relate them to the regional history of the rock, using them as a structural marker for the bulk brittle deformation of the area (Lespinasse and Pecher, 1986, J. Struct. Geol., v.

8, p. 169; and Pecher et al., 1985, Lithos, v. 18, p. 229). This approach has been tested in two granitic areas in the N.W. of the French Massif Central. (The Le Bernardan open pit and the La Crouzille Uranium district.)

The hydrothermal dissolution of magmatic quartz is the main alteration process of the granites in those area. It is shown that the percolation of hydrothermal fluids occurs through a dense set of fractures on all scales. But geometric description of fracturing is not sufficient to relate the different stages of fluid percolation to the quartz dissolution. Simultaneous studies of the orientation of FI trails in space and microthermometric characteristics of their inclusion show that:

(1) Planes of FI (FI trails) have similar orientations to that of other extensional cracks; they are mode I cracks formed parallel to the average direction of $\sigma_1$, and perpendicular to the average direction of $\sigma_3$ in the bulk rock. Planes of FI would provide, in the absence of (or in addition to) mesostructural markers, a practical way of constructing extension direction trajectories.

(2) According to the direction, several generations of fluids are distinguished as a function of their physico-chemical characterisitcs (P, V, T) which correspond to the different stages of hydrothermal activity. FI trails can be used to establish the chronology of both faulting during a regional geological evolution. Considering the quartz dissolution, the P-T-X conditions of the process were estimated. They give arguments in favor of the effect of density changes in the fluid itself as a satisfactory explanation of the mechanisms of the fluid undersaturation with respect to quartz.

Thus, one can use the physico-chemical differences in the included fluids to separate different sets of trails; or, on the other hand, it should be possible to use trails to relate the different stages of fluid percolation to a regional succession of deformational events. (Author's abstract)

LESPINASSE, M. and CATHELINEAU, M., 1987, Relations between microfissuration, fluid circulation and rock alteration in granitic environment: A tool for palaeostress field chronology (abst.): Terra Cognita, v. 7, no. 2-3, p. 127. Authors at CREGU et GS CNRS-CREGU, Vandoeuvre-les-Nancy, France.

See previous item. (E.R.)

LEU, A.-D. and ROBINSON, D.B., 1987, Equilibrium phase properties of selected carbon dioxide binary systems: n-pentane-carbon dioxide and isopentane-carbon dioxide: J. Chem. Eng. Data, v. 32, p. 447-450.

LEUNG, I.S., 1987, Moissanite-sanidine intergrowth occurs in diamond containing griquaitic inclusions (abst.): EOS, v. 68, p. 444. Author at Dept. Geol. & Geography, Herbert H. Lehman College, City Univ. of New York, Bronx, NY 10468.

Three moissanite (SiC) crystals occur in a natural diamond 2 mm in size. Because of their intense deep green color, they appear transparent only under very bright illumination. The largest moissanite crystal is interpenetrated by an equal amount of sanidine. The latter is transparent and colorless, forming globular, pear-shaped, and elongate blebs. These shapes possibly represent drops of potassic, silica-rich immiscible melt from which sanidine grew simultaneously with the crystallization of moissanite. On the surface of this intergrowth (180 μm in size) are two crystals of anhydrite ($CaSO_4$) and many minute grains of magnesiocalcite and pyrrhotite.

Included in the same diamond are several other minerals: olivine, garnet, omphacitic clinopyroxene and hercynite. The olivine also contains two inclusions of its own, chromite and phlogopite. Garnet has the composition $Alm_{36}GR_{35}Py_{29}$. Compositions of garnet and clinopyroxene are similar to those existing in eclogite, whereas, the multi-phase inclusion of olivine-chromite-phlogopite is characteristic of peridotite. The occurrence of both eclogite and peridotite suites of minerals in a single diamond had never been observed before. This new assemblage of coexisting diamond inclusions resembles the mineralogy of a mantle eclogite known as griquaite.

Moissanite, an extremely rare mineral, has been found in diamond-bearing kimberlites in Siberia and China. Natural occurrence of the moissanite-diamond equilibrium assemblage may have significant implications for interpreting temperature, pressure, silica contents, fugacities of oxygen and carbon dioxide existing in the earth's mantle. (Author's abstract)

LEUNG, I.S. and PENG, Mingsheng, 1987, Moissanite from diamond-bearing kimberlite in Shandong, China: Geol. Soc. Am. Abstracts with Programs, v. 19, p. 744-745.

LEUNG, I.S. and TREVES, S.B., 1986, Fluid inclusions in olivine in a basanite flow from Ross Island, Antarctica: Antarctic J., 1985 Review, v. 20, no. 5, p. 23-25 (cover shows "Volume 19;" dated 1985 but published 1986). First author at Dept. Geol. & Geography, Herbert H. Lehman College of City Univ. New York, Bronx, NY 10468.

Olivine crystals occurring in the basanite are xenocrysts derived from disintegration of olivine nodules incorporated in the lava flow. Abundant carbon dioxide inclusions as well as silicate-melt (glass) inclusions are found in olivine some of which even contain NaCl-bearing water solution or dense mixture of gases.

SEM study of melt inclusions indicate that there is direct correlation between increasing degree of crystallization in the included melt globule and depletion of silicon, concomitant with enrichment of iron in the residual melt. Dm chromite and a smaller crystal of pyrrhotite which contains minor amounts of Zn and Cu are reported, as well as apatite, sanidine, ilmenite, and spinel as possible dms. Liquid immiscibility may have been involved. (E.R.)

LI, Binglun and SHI, Gang, 1987, Physicochemical parameter charts for gases in fluid inclusions: Geochemistry, v. 6, no. 1, p. 44-52 (in English). Authors at Inst. Geol., Acad. Sinica.

A great wealth of analytical data for fluid inclusions in minerals indicate that the major species of gases in fluid inclusions are $H_2O$, $CO_2$, CO, $CH_4$, $H_2$ and $O_2$. Three basic chemical reactions are supposed to prevail in rock-forming and ore-forming fluids:

$$H_2 + 1/2\ O_2 = H_2O,$$
$$CO + 1/2\ O_2 = CO_2,$$
$$CH_4 + 2\ O_2 = CO_2 + 2H_2O,$$

and equilibria are reached among them. $\lg f(O_2) - T$, $\lg f(CO_2) - T$ and Eh - T charts for petrogenesis and mineralogenesis in the supercritical state have been plotted under different P. On the basis of these charts $f(O_2)$, $f(CO_2)$, Eh, equilibrium T and equilibrium P can be readily calculated. In this paper some examples are presented to show their successful application in the study of the ore-forming environments of ore deposits. (Authors' abstract)

LI, Cundeng, 1987, A tentative discussion on geologic characteristics and genesis of fine-grained gold deposits in southwestern Guizhou: Mineral

Deposits, v. 6, no. 3, p. 49-56 (in Chinese; English abstract). Author at Bureau Geol. & Min. Res. Guizhou Province, Huishui County, Guizhou.

Au deposits in this area occur in Triassic and Permian sediments. Pyrite from Banqi and Yata deposits has $\delta^{34}S$ value of +5.9 - +16.6‰; $\delta^{18}O$ value of quartz and calcite varies in the range of +9.61 - +26.07‰; the inclusions in pyrite, quartz and stibnite have Td and Th 180-290°C, salinity 7.01-48.00% and pH value 6.28-6.41.

Based on characteristics of ore deposits, geochemical data on rocks and various analyses, the author considers that ore materials must have been derived from the strata, and the gold deposits genetically belong to leaching type of mesothermal-epithermal underground brine of crustal series. (From the author's abstract)

LI, Zhaolin, 1987a Formation temperature determination by using melt inclusions in accessory minerals in granite (abst.): Abstracts, Inter. Symp. on Petrogenesis and Mineralization of Granitoids, Dec. 7-10, 1987, Guangzhou, China, p. 151.

LI, Zhaolin, 1987b A new method of rock-forming temperature determination of melt inclusions in accessory minerals of igneous rocks: Scientia Sinica, Ser. B, v. 30, no. 9, p. 986-993 (in English). Author at Dept. Geol., Nanjing Univ.

The quenching + oil immersion method first developed in this work is an effective means of determining the Th of melt inclusions in accessory minerals, and provides us with a new way to look into the T in the initial stage of rock-forming process. In addition to the description of the new method, some applications to granites are discussed in this paper. (From the author's abstract)

LICENCE, P.S., TERRILL, J.E. and FERGUSSON, L.J., 1987, Epithermal gold mineralization, Ambitle Island, Papua New Guinea: Pacific Rim Congress 87, 26-29 August, 1987, Australasian Inst. Mining & Metallurgy, Victoria, Australia, p. 273-278. First author at City Resources PNG Inc., P.O. Box 2174, Lae, Papua New Guinea.

The prospect is still an active geothermal area with current boiling in the zone tested.

Studies of fluid inclusions in vuggy epithermal calcite show the boiling zone is a recent feature, probably still active.

The Th data fit the boiling point with depth curve with respect to the current water table.

Anhydrite appears to be of two generations; one gave fluid inclusion Th concordant with the boiling point with depth curve while the other gave significantly higher T, probably attributable to the relict porphyry alteration. (From the authors' abstract and text)

LIEBLER, G.S., 1987, Geology and gold mineralization at the Picacho mine, Imperial County, California (abst.): Program with Abstracts, Symp.: Bulk Mineable Precious Metal Deposits of the Western United States, April 6-8, 1987, Geol. Soc. Nevada, p. 53. Author at P.O. Box 70958, Reno, NV 89570.

Native gold occurs in open-space quartz fillings in close association with pyrite and its oxidized derivatives. Fluid inclusions in veinlet quartz indicate precipitation from very dilute (1 wt% NaCl eq) fluids at a minimum T in the range of 201° to 226°C.

The hydrothermal system at Picacho was probably initiated and sustained by thermal energy related to mid-Tertiary igneous activity. Temperature and salinity data from fluid inclusion studies suggest mineralization occurred in a meteoric water-dominated epithermal system. This mineralizing event occurred during and after detachment faulting, which provided open spaces for fluid circulation. (From the author's abstract)

LIEWIG, Nicole, CLAUER, Norbert and SOMMER, Frederic, 1987, Rb-Sr and K-Ar dating of clay diagenesis in Jurassic sandstone oil reservoir, North Sea: AAPG Bull., v. 71, no. 12, p. 1467-1474.

LINDBLOM, S., 1987, Evidence of fracturing and fluid movements in granite from Finnsjön, Sweden, derived from inclusions in fracture-filling calcite and prehnite: Chem. Geol., v. 61, no. 1/4, p. 241-251.

Full paper for abstract in Fluid Inclusion Research, v. 18, p. 243-244, 1985. (E.R.)

LINDBLOM, Sten, 1987, Fluid inclusion and organic geochemistry in association with gold deposition (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 71. Author at Ore Res. Group, Dept. Geol., Univ. Stockholm, S-106 91 Stockholm, Sweden.

Epithermal Au deposits are found in a variety of forms associated with Cenozoic igneous activity in the Basin and Range provinces in the western United States. Au may occur in relatively high concentration in quartz veins or as submicroscopic disseminations in a sedimentary or volcanic host rock. The geologic environment is often little disturbed by later metamorphism. Fluid inclusions and organic geochemistry may offer primary evidence for ore deposition.

The present study indicates an ore-forming environment characterized by a salinity of 0.6 to 1.7 eq. wt. % NaCl and a formation T of 200-300°C in fluid inclusions from quartz and barite. Later stages may involve the same fluids at lower T. Carbonaceous host rocks, either rich in carbonate or silica, have a total organic C content of 0.1 to 5 wt. %. They yield an extractable bitumen fraction ranging from 0.2 to 2 mg/g solid sample. Liquid and gaseous hydrocarbons were also found in fluid inclusions in close association with the ores. Although probably not a major cause of Au deposition, the evidence suggests that the organic matter may play an important role in localizing the ore in certain deposits.

The above related recent deposit studies are contrasted with old Precambrian Au deposits in Sweden. These also have a primary igneous affiliation but are overprinted by varying degrees of metamorphism. A comparison is of interest because of the occurrence of $CO_2$-inclusions and organic matter in both types of deposits. Although in widely different settings Au deposition may have been affected in similar ways in dissolution-precipitation reactions. It is suggested that the relatively recent Au deposits in Nevada may give significant information as to the nature of the ore formation in earlier Precambrian deposits in a more metamorphosed environment. (Author's abstract)

LINDBLOM, Sten, RANKIN, A.H. and THOMPSON, Michael, 1987, Fluid inclusion analysis by the decrepitation-ICP method of quartz association with mineralization in the Baltic Shield (abst.): American Current Research on Fluid Inclusions, Jan 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). First author at Geol. Inst., Stockholms Univ. S-106 91, Stockholm, Sweden.

Quartz fluid inclusions have been analyzed by the decrepitation-ICP method. The quartz samples originate from eight distinct mineralization districts in Sweden. The geologic setting varies from an almost pristine sedimentary environment in the Laisvall sandstone Pb-Zn deposits to highly metamorphosed rocks in the Saxberget skarn deposit.

Major components Na, K and Ca give variable but interpretable information about crystal fluids involved in ore deposition and subsequent metamorphism. K/Na and Ca/Na ratios are very consistent even at very low salt concentrations in the inclusion fluids. Feldspar contamination does not affect the ratios.

Zn/Na and Cu/Na may be used as a guide to ore in different environments.

Microthermometry and other geochemical data are supported by the D-ICP data in the present study. It is suggested that the technique is well situated to: (a) find targets for further study and exploration; (b) delineate geochemical boundaries between rock uints within an ore district; and (c) trace solution paths to mineralization. (Authors' abstract)

LINDLEY, I.D., 1987, The discovery and exploration of the Wild Dog gold-silver-copper deposit, East New Britain, P.N.G.: Pacific Rim Congress 87, 26-29 August, 1987, Australasian Inst. Mining & Metallurgy, Victoria, Australia, p. 283-286. Author at CR PNG Inc., P.O. Box 536, Rabaul, PNG.

The Wild Dog gold-silver-copper deposit represents a new ore-deposit type in Papua New Guinea. The telluride vein mineralization is associated with a Tertiary caldera and has similarities with that from the Baguio district, Philippines, Vatakoula, Fiji, and the San Juan Mountains, southwestern Colorado.

Four types of silicification have been defined. Early replacement silica (Stage I) is typically fine-grained and forms the bulk of the veins; Th are in the range 290-320°C. This silica is extensively crosscut by a barren, banded white microcrystalline (Stage II) quartz with Th in the range 270-275°C. Crosscutting both Stage I and II silica is a clear crystalline quartz (Stage III) which is intimately associated with a mineralized dark, fine-grained sulphide bearing silica (Stage IV). Th for the Stage III silica range from 235-250°C. The mineralized Stage IV silica has associated high-sulphidation state copper minerals and Te minerals including native Te and several Au-Ag and Bi tellurides. (From the author's abstract and text)

LIU, Bin, 1987, Immiscible fluid inclusions as geothermometer and geobarometer: Kexue Tongbao (Sci. Bull.), v. 32, no. 10, p. 978-982. Author at Dept. Geotech. Engrg., Shanghai Tongji Univ.

A review of the use of modified Redlich-Kwong equations to calculate pressure from fluid inclusions of $CO_2$ and $CO_2$-saline $H_2O$. (E.R.)

LIU, Congqiang, 1987, Geochemistry and genesis of the Yendonggou lead-zinc-silver deposit: Mineral Deposits, v.6, no.4, p.53-61 (in Chinese; English abstract). Author at Inst. Geochem., Acad. Sinica, Guiyang, Guizhou.

The Yendonggou Pb-Zn-Ag deposit was formed by an earlier Ag mineralization period composed of three stages, followed by a Pb-Zn period of two stages.

The isotopic evidence (Pb, S, O, H, C) yields the following conclusions: 1. the deposit has an age of 1300 Ma; 2. the ore-forming metals and sulfur came from the upper mantle or from the deep crust; and 3. the ore-forming fluids of earlier mineralization period were derived from a mixture of meteoric and magmatic water while the fluids of later mineralization period merely from meteoric water.

According to the data of fluid inclusions and the thermodynamic analysis, the Ag mineralization ranged at least from 180°C to 320°C and the salinity from 5 to 15 wt. % eq.; the T of lead-zinc 130°C to 280°C, 2 to 8 wt. % NaCl eq., and P ≈ 200 x $10^{15}$ Pa[sic]; the fugacity [of unstated species] of the two periods, $10^{-42}$ atm. to $10^{-38}$ atm., and pH, ≈ 4.5 to 5.6. (Author's abstract)

LIU, Xiaoshan, WU, Chengyu and HUANG, Biaq, 1987, Origin and evolution of the hydrothermal system in Nannihu-Sandaozhuang molybdenum (tungsten) ore deposit, Luanchuan county, Hunan province: Geochimica, no. 3, p. 109-207 (in Chinese; English abstract). Author at Dept. Geol., Nanjing Univ.

Thorough studies of the Th, P and chemical compositions of fluid inclusions and the stable isotopes of hydrothermal minerals (quartz, calcite, pyrite and molybdenite) have thrown light on the evolution trend of the molybdenum-bearing hydrothermal system which originated from a magmatic process and underwent significant mixing with meteoric waters in the later stages of hydrothermal activities. (Authors' abstract)

LIU, Yingjun, SUN, Chengyuan and SHA, Peng, 1987, Geochemical studies of the formation of gold deposits in the Shaoxing-Longquan uplift zone, Zhejiang Province: Geochemistry, v. 6, no. 4, p. 309-321 (in English). Authors at Dept. Geol., Nanjing Univ.

Four analyses are given (decrepitation-extraction method) for quartz contemporaneous with Au, for $CO_2$ and $CH_4$, and for K, Na, Ca, Mg, Fe, Au, F, Cl and Σs. The T (Th?) was 260 to 350. The Au contents were in the range $10^{-5}$ - $10^{-6}$ moles/kg $H_2O$ (0.6-4 ppm). P was estimated, from Th, salinity and $CO_2$, to range from 270-600 atm. (E.R.)

LOCUTURA RUPEREZ, J. and TORNOS ARROYO, F., 1987, Origin of the F(Ba + Pb) mineralization from the Colmenar de Arroyo area (Spanish central system): Boletín Geol. y Minero., v. 98, p. 680-694 (in Spanish; English abstract). Authors at IGME. Ríos Rosa, 213. 28003 Madrid, Spain.

Geological and thermodynamical studies on a barite-fluorite (Pb-Zn-Cu) lode contribute to genetic interpretation of such kind of deposits in the Spanish central system.

The ore minerals grew near the FMQ buffer, in progressive lower T [fluid inclusion data] (from 270 to 120°C) with associated salinity increase (0 to 12% NaCl eq.). Oxygen and sulfur fugacities remained near pyrite-hematite-magnetite buffer. (From the authors' abstract)

LOFERSKI, P.J., ARCULUS, R.J. and KUSHIRO, I., 1987, Silicate melt inclusions from the island arc volcanics of Japan (abst.): EOS, v. 68, p. 463. First author at Dept. Geol. Sci., Univ. Michigan, Ann Arbor, MI 48109.

An unusually large number of silicate melt (glass) inclusions occur in plagioclase and clinopyroxene phenocrysts in the island arc basalts and andesites from Japan. Such inclusions can provide unique petrologic information because they are direct samples of the melt from which their host phase grew. We have begun a detailed study of an andesite from Hakone. Plagioclase phenocrysts contain discrete, rounded, brown glass inclusions that range from 1-100 µm across. The inclusions occur in concentric growth zones in plagioclase, and are more abundant in the calcic ($An_{75}$) than the sodic ($An_{65}$) bands. Each melt inclusion contains at least one spherical vapor bubble, some of which enclose minute sulfide grains (Cu and Cu-Fe, based on EDA spectra), implying strong partitioning of those components into the vapor phase. Rare daughter phases in the glass are clinopyroxene and Fe-Ti oxide. The inclusions in clinopyroxene are less numerous, about 20 µm across, and commonly contain a minute daughter Fe-Ti oxide grain and a vapor bubble.

The glass in plagioclase is rhyolitic (up to 76 wt.% $SiO_2$) and has unusually high $Na_2O/Na_2O + K_2O$ ratios (0.6 to 0.9), which decrease with increasing silica content, probably as a result of sodic plagioclase precipitation on inclusion walls. Glass in clinopyroxene is lower in FeO, $K_2O$, $Na_2O$, and higher in $Al_2O_3$ and $SiO_2$ possibly indicating entrapment of a later melt. Other samples from Hakone, Fuji, Iwate, and Myoko show a variety of glass textures in plagioclase. The inclusions may be concentrated in the cores, rims, or concentric growth zones in different phenocrysts in a sample, suggesting different times of entrapment. Some plagioclase contains an interconnected boxwork-like network of glass, implying extremely rapid skeletal growth.

Many samples contain previously-unreported fluid (liquid + vapor bubble) inclusions embedded in the glass, implying vapor saturation and unmixing of the fluid after melt entrapment in plagioclase. The fluid inclusions appear to be primary, and initial heating experiments indicate dominantly aqueous compositions. Continuing study of the melt and fluid inclusions is expected to shed light on the following: a) the evolution of the magmatic-hydrothermal fluids, and b) the extent of magma mixing in the Japan island arc volcanics, because distinct liquids may be preserved as melt inclusions. (Authors' abstract)

LOFSTROM, D.M. and SHELTON, K.L., 1987, Fluid inclusion and stable isotope studies of W-Sn-Ag deposits, Silver Mine District, southeast Missouri: Progressive meteoric water inundation of a magmatic hydrothermal system (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 748-749. Authors at Dept. Geol., Univ. Missouri-Columbia, Columbia, MO 65211.

The W-Sn-Ag deposits of the Silver Mine District, St. Francois Mountains, southeast Missouri occur within quartz veins and greisen associated with the Precambrian age Silvermine granite. Mineralization was deposited in four stages: greisen and early vein (wolframite-cassiterite), main sulfide (base-metal and silver sulfides), and barren late quartz. Fluid inclusion data suggest W-Sn deposition occurred between 380° and 250°C from fluids with salinities of 20.0 to 5.0 wt % NaCl eq. Base-metal and silver mineralization (Ag-tennantite, antimonpearceite, berryite) was deposited between 270° and 150°C from fluids with salinities of 23.3 to 1.0 wt % NaCl eq. Fluid inclusion evidence of boiling indicates P of <100 to ≈350 bars, consistent with a depth of mineralization near 1.25 km under P conditions that alternated between hydrostatic and lithostatic.

H and O isotope values of hydrothermal fluids show a progressive decrease in deuterium and $^{18}O$ with increasing paragenetic time, from greisen and early vein stages ($\delta D = -52$ to $-81$ per mil; $\delta^{18}O = 5.2$ to $4.2$ per mil) to main sulfide stage ($\delta D = -81$ to $-102$ per mil; $\delta^{18}O = +3.5$ to $-5.3$ per mil). These values suggest progressive inundation of a magmatic S-Sn hydrothermal system by Pb-Zn-Ag-depositing meteoric waters. The abrupt change in hydrothermal fluid stable isotope compositions following the early vein stage suggests tungsten deposition was possible only under low w/r ratio conditions. As w/r ratios increased during meteoric water inundation, only metals which were transported as chloride or sulfide complexes (Cu, Pb, Zn, Ag) continued to be deposited. (Authors' abstract)

LONDON, David, ZOLENSKY, M.E. and ROEDDER, Edwin, 1987, Diomignite: Natural $Li_2B_4O_7$ from the Tanco pegmatite, Bernic Lake, Manitoba: Canadian Mineral., v. 25, p. 173-180. First author at Sch. Geol. & Geophys., Univ. Oklahoma, Norman, OK 73019, USA.

Diomignite, $Li_2B_4O_7$, occurs as a clear, colorless, tetragonal dm (30 μm in maximum dimension) in fluid inclusions in spodumene from the Tanco pegmatite, Bernic Lake, Manitoba. Its identity was established by several analytical techniques, and confirmed by the identical Gandolfi X-ray-diffraction pattern for diomignite and synthetic $Li_2B_4O_7$. Optical properties are: uniaxial (-) for diomignite and synthetic $Li_2B_4O_7$; $\omega$ = 1.612(2), $\epsilon$ = 1.554(2), $\delta$ =0.058(4) for synthetic $Li_2B_4O_7$. Geometrical properties are: a 9.470(4), c 10.279(5) Å, refined in the space group $I4_1cd$; V(cell) = 921.83(5) Å$^3$, Z = 8, V(mole) = 69.397 cm$^3$, D(calc) = 2.437 g/cm$^3$. The strongest five X-ray lines [d in Å(I, hkl)] are: 4.07 (100,112), 2.662 (60,123), 3.495 (50,022), 2.587 (40,132), and 2.045 (40,332). Natural diomignite and $Li_2B_4O_7$ synthesized at high P and T commonly appear trigonal or cubic in form. The rhombohedral or cubic appearance can be reconciled with the tetragonal space-group by the pseudocubic shape of the diomignite cell (c/a ≃ 1), by the generation of 2 pseudomirrors with rotation about a three-fold pseudoaxis, and by angular intersections of [0k0] $\wedge$ [hkl] of ~60°. The $Li_2B_4O_7$ component (as diomignite) served as a flux to depress solidus T, to increase silicate-$H_2O$ miscibility, and to enhance the solubilities of ore-forming incompatible lithophile elements in late-stage pegmatitic fluids at Tanco. (Authors' abstract)

LORAND, J.P., 1987, Cu-Fe-Ni-S mineral assemblages in upper-mantle peridotites from the Table Mountain and Blow-Me-Down Mountain ophiolite massifs (Bay of Islands area, Newfoundland): Their relationships with fluids and silicate melts: Lithos, v. 20, p. 59-76. Author at Lab. Minéral. du Muséum Nat'l. d'Histoire Naturelle de Paris, Unité Assoc. au CNRS No. 286, 61 Rue Buffon, 75005 Paris, France.

Microstructural criteria such as the absence of sulfide inclusions in olivine neoblasts demonstrate that the sulfide component postdates plastic deformation of the transition zone. The sulfide-enrichment pattern is thus ascribed to the percolation of a sulfur-saturated basaltic magma into residual dunite. (From the author's abstract)

LORAND, J.P. and COTTIN, J.Y., 1987, Na- Ti- Zr- $H_2O$-rich mineral inclusions indicating postcumulus chrome-spinel dissolution and recrystallization in the Western Laouni mafic intrusion, Algeria: Contrib. Mineral. Petrol., v. 97, p. 251-263. First author at Lab. Min. du Museum Nat'l. d'Histoire Naturelle de Paris, Unité Associée au CNRS no. 286, 61 Rue de Buffon, F-75005 Paris, France.

Disseminated cumulus chrome spinel in the lower-most olivine orthocumulates from the Western Laouni intrusion (Southern Hoggar, Algeria) contains inclusions of silicates enriched in Mg-Ti-Na and $H_2O$, and Fe-Ti (Zr) rich oxides, occurring either as numerous micro-inclusions or as large solitary cavities. Apart from kennedyite, all minerals included in chrome spinel form larger intercumulus crystals in the host rock as well. The micro-inclusions were trapped as the consequence of chrome spinel dissolving against the intercumulus liquid, 150 to 300°C below its liquid T. The solitary cavities are attributed to fluid-assisted solid-state recrystallization of chains of spinel crystals; the role of capillary fluids is demonstrated by both the hydrous nature of solid inclusions and a strong positive correlation between the amphibole content and the abundance of solid inclusions in the rock. Phlogopite locally showing similar optical orientation within and outside the inclusions indicates that spinel was still recrystallizing down to 950°C. In the range 1100-900°C determined for the formation of inclusions, chrome spinel probably trapped various combinations of crystals, liquids and fluids, the respective quantities of which varied greatly over distances of few tens of micrometers in a single spinel. The volume ratio of solids to liquids or to fluids must have been low enough to permit magmatic or hydrothermal reactions, which are otherwise never possible for the larger intercumulus crystals. Hence, the lack of olivine and clinopyroxene as inclusions in spinel while abundant in the host rock suggests that, as trapped, they completely reacted with the residual liquid to form phlogopite and pargasite respectively. Likewise, plagioclase and phlogopite have been enriched in Na against hydrothermal fluids to form albite and Na-phlogopite in the mineral inclusions. (From the authors' abstract)

LOREDO, Jorge, LUQUE, Carlos and GARCIA IGLESIAS, J., 1987, Formation temperature of mercury deposits in the Cantabrian Zone (Spain) (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 73-74. First author at Escuela de Minas, Independencia 13, 33004 Oviedo, Spain.

In the Cantabrian Zone (north of Spain) there are abundant and significant Hg deposits. They appear inserted in different stratigraphic levels from Cambrian to Carboniferous, although the greater part of them can be found in the Carboniferous materials, showing a clear tectonic control related to late Hercynian fractures.

The mineral paragenesis of these mineralizations is formed by pyrite, marcasite, realgar, orpiment, stibnite, sphalerite, galena, grey coppers, iron and manganese oxides, with quartz, fluorite, calcite, barite and kaolinite as gangue minerals.

The Tt of cinnabar is estimated from fluid inclusion studies in the transparent minerals of the paragenesis: sphalerite, quartz, fluorite and calcite, [whose] temporal relation with Hg sulfide is known by reflected light microscopy studies. Th was determined for minerals earlier and latter than cinnabar; as earlier minerals: quartz (135-125°C), fluorite (140-120°C), calcite (135-120°C), and as latter minerals: calcite and quartz occasionally (70-80°C).

In some deposits of "Picos de Europa Type" with Hg-rich sphalerite, this mineral shows contents in Hg that seems to indicate the presence of very small inclusions of primary cinnabar (Barbanson et al., 1985, Bull. Min., v. 108, p. 483). Th, and formation, of this sphalerite is in the range of 95-120°C (Loredo and Garcia Iglesias, 1984, VII Cong. Int. Min. Met., v. 1, p. 89).

The Hg mineralizations of the Cantabrian Zone show strong epithermal feature[s], and the connection with volcanic processes is probable. These mineralizations seem to originate from low-T hydrothermal solutions (80-120°C) circulating over late Hercynian fracture network in superficial zones, where the mixing of juvenile and vadose waters is frequent. (From the authors' abstract)

LOTTERMOSER, B.G., 1987, A fluid inclusion study of the Tourmaline Hill Granite, Umberatana, South Australia: Implications for hydrothermal activity and wallrock metasomatism: Mineral. & Petrol., v. 36, p. 135-148. Author at Dept. Geol., Univ. Newcastle, Australia.

Th and salinity data are documented for fluid inclusions present in quartz from a Paleozoic alkaline to peralkaline granite intrusion. A wide range of salinities (3.8 to 60.6 wt% NaCl eq.) and Th (25.8 to 537°C) indicates a sequential entrapment of different fluids, whereby the detected salinities decreased as a direct result of decreasing Th. Fluids were saturated with NaCl at 537°C and the development of hydrothermal solutions occurred at 1100 ± 300 bars. Hydrothermal activity and the release of volatiles, F and B, during granite crystallization resulted in phlogopitization and tourmalinization of intruded metapelites. Volatile degassing, the presence of hypersaline hydrothermal fluids and contamination on the periphery of the intrusives by aluminous sediments led to the transport of K, Rb, Li, Mg, Cs, Be and Ta via halogen complexes from the granite system into the metapelitic aureole. (Author's abstract)

LOUCKS, R.R., IRISH, N.F. and SOMMER, M.A., 1987, Topographically forced convection at Platoro, Colorado, indicated by fossil fluid pressure gradient recovered by fluid inclusion gas analysis and microthermometry (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). First author at Dept. Earth & Atmos. Sci., Purdue Univ., West Lafayette, IN 47907.

Oxygen and hydrogen isotopic evidence indicates that mid-Tertiary gold-silver mineralization in the Platoro district, San Juan Mountains, Colorado, developed in a meteoric-water-dominated hydrothermal system. As part of an extensive study of dissolved gas abundance, fluid P gradients, and fluid dynamic processes in fossil meteoric geothermal systems, the average vertical fluid P gradient in the Merrimac vein, Platoro district, has been reconstructed from heating/freezing data and analysis of $CO_2$, $CH_4$, and $H_2S$ in fluid inclusions (fi's) that trapped the liquid phase of boiling solutions. A 30-micron-diameter, 0.4 MW, Q-switched ruby-laser light pulse was fired down the vertical tube of an optical microscope to decrepitate in vacuo selected individual fi's, and the mol ratios $CO_2/H_2O$, $CH_4/H_2O$, and $H_2S/H_2O$ in liberated volatiles were analyzed by quadrupole mass spectrometry relative to certified gas mixture and mineral standards. Gas ratios were recast as gas partial P at mineralization T using high-precision trapping T and salinity data and appropriate Henry's Law coefficients. $H_2S$ was below the detection limit (ca. 0.005 molal) in all Platoro samples. The standard error of $P\Sigma = P(H_2O + P(CO_2) + P(CH_4)$ averages ± 2.3 bars (~6-7% of $P\Sigma$) in 13 drill core and surface samples. Linear regression of $P\Sigma$ versus sample depth yields $r^2 = 0.95$ and $dP\Sigma/dz = 0.174 \pm 0.025$ b/m ($2\sigma$) over the sampled vertical interval of 152 m.

This exceptionally steep fluid P gradient in the ore-bearing portion of the Platoro system may be compared with our similarly measured gradients $dP\Sigma/dz = 0.09$ b/m over $\Delta z = 725$ m in epithermal Ag veins at Topia, Durango, Mexico; $dP\Sigma/dz = 0.09$ b/m over $\Delta z = 287$ m in three veins of the Silver Monument system, Black Range, New Mexico; and $dP\Sigma/dz = 0.09$ b/m over $\Delta z = 381$ m in four veins of the St. Cloud epithermal Ag district, Black Range, New Mexico. Fossil dynamic fluid P gradients in these three systems in Mexico and New Mexico exceed hot-liquid-hydrostatic gradients by about 15% in each case and compare closely with typical values from down-hole measurements in drilled active meteoric geothermal systems and agree with gradients predicted by theoretical models that make no provision for topographically forced convection.

The radial fault/vein swarm that contains the Platoro mineralization is situated (above an inferred, unexposed stock) within the subsided caldera block, and the upflowing portion of the hydrothermal system is centered 3 km from the rim fault of the 25-km-diameter caldera. The mineralization post-dates the main episodes of caldera subsidence. We interpret the unusually steep dynamic fluid P gradient in the Merrimac vein to be not a local transient feature due to a permeability constriction, but rather to be a temporally and spatially persistent characteristic of the entire upflow column, with contributions by thermal buoyancy and topographic head. The latter could be large enough to explain the observed gradient if fluid recharge was predominantly from elevated regions along the caldera rim. (Authors' abstract)

LOUCKS, R.R. and SOMMER, M.A., II, 1987, Hydrodynamics in boiling hydrothermal upflow zones (abst.): EOS, v. 68, p. 1326. First author at Dept. Earth & Atmos. Sci., Purdue Univ., West Lafayette, IN 47907.

Vertical dynamic fluid P gradients in wide fissure conduits in three fossil meteoric geothermal systems of Tertiary age has been reconstructed over vertical intervals of 280 to 725 m from microthermometry and analysis of $CO_2$, $CH_4$, and $H_2S$ in quartz-hosted fluid inclusions (fi's) that trapped vapor-saturated liquids. A 30 μm-diameter, 0.4 MW, Q-switched ruby laser pulse was fired down the vertical tube of an optical microscope to decrepitate in vacuo selected individual fi's. Mole ratios of gas/$H_2O$ were analyzed by fast-scanning quadrupole mass spectrometry and recast as partial P using micothermometry data and appropriate Henry's Law coefficents. Regression of $P_\Sigma = P(H_2O) + P(CO_2) + P(CH_4) + P(H_2S)$ vs sample elevation above mean sea level yields P of mean vapor-pressure gradients with an average precision of ± 0.006 b/m (1σ). Mean hydrodynamic P gradients range from 8.7 to 9.1 b/100 m in the three extinct geothermal systems and exceed the maximum possible hydrostatic gradient in a boiling fluid column by 10-18% in each case.

Theoretical modelling, published down-hole gauge measurements in active geothermal systems, and our analytical results for fossil meteoric-water geothermal systems indicate that boiling fluid columns generally maintain internal P gradients much greater than hydrostatic and like expected gradients in cool downflow portions of the hydrothermal systems, as required for dynamic P equilibrium in the absence of significant topographic forcing of convective flow. Upflow conduits of exceptional permeability provide low viscous resistance to flow, hence a tendency to diminish P gradient, hence a "suction pump" flow focussing capacity for drawing fluid from the walls into the fissure that is especially developed if the fissure has a diminished hydrostatic component of the P gradient due to presence of suspended vapor. The tendency of fluid drawn into vapor-bearing fissures to entrain more fluid in its wake fosters a pattern of "parasitic" shallow groundwater convection wherein aerated, cool, surface water wells down between major upflow conduits, enters the faults over a range of depths (to >1 km) and mixes with boiling fluid rising in the faults, quenching vapor and contributing to the mass flux required to maintain a dynamic P gradient that balances that of cooler fluid outside the upflow channel. Wallrock alteration zoning, systematic gradients of upward decrease in salinity and δD and upward increase in $fO_2$ in the vapor-saturated fluid column in fissure veins of extinct geothermal systems at Chloride, New Mexico, and Topia, Durango, Mexico, document operation of the regime of parasitic groundwater convection, mixing, and dilution that accompanied boiling. (Authors' abstract)

LOWENSTEIN, T.K. and SPENCER, R.J., 1987, Syndepositional origin of potash evaporites in Permian Salado Formation, New Mexico: Fluid inclusion and textural evidence (abst.): Abstracts, SEPM annual midyear meeting 20-23, Aug. 1987, v. 4, p. 50. First author at Dept. Geol. Sci., State Univ. New York at Binghamton, Binghamton, NY 13901.

Sylvite (KCl) and carnallite ($KCl \cdot MgCl_2 \cdot 6H_2O$) in halite rocks of the Permian Salado Formation are interpreted as pore-filling cements because they occupy areas equivalent to the void spaces in modern, near surface halite deposits. The sylvite and carnallite cements are internally zoned, and with color-banding defined by tiny incorporated hematite crystals. The cements crosscut the stratigraphic boundaries of Salado Formation depositional sequences, so they are post depositional in origin. The timing of cementation has been determined from analysis of fluid inclusions in the associated halite frameworks. P fluid inclusions in chevron and cornet halite contain sylvite and carnallite dms. This establishes that syndepositional brines were at or near sylvite or carnallite saturation and that halite, sylvite and carnallite could have been produced from the same parent brines. Sylvite dms in inclusions in halite dissolve completely at T between 30°C to 100°C, documenting crystallization of halite in warm, shallow, surface waters of a salt pan. Upon desiccation of the salt pan, the level of these brines would drop below the sediment-air interface. The groundwater brines so produced would become, when cooled, highly supersaturated with respect to sylvite or carnallite, and capable of pervasive cementation. Monominerallic cements of sylvite or carnallite and the lack of associated halite cements suggests that T change (cooling) was responsible for cementation. The Salado sylvite and carnallite cements may occupy as much as 50% of the rock volume. When compared with porosity versus depth profiles of halite from modern salt-pan settings (Saline Valley, CA) the large volume of sylvite and carnallite constrains the depth of cementation in the Salado Formation to the uppermost few meters. (Authors' abstract)

LU, Huanzhang and FANG, Genbao, 1987, Fluid and melt inclusions in granites and related mineral deposits, south China (abst.): Abstracts, Inter. Symp. on Petrogenesis and Mineralization of Granitoids, Dec. 7-10, 1987, Guangzhou, China, p. 200-201. Author at Inst. Geochem., Acad. Sinica.

There are many granites and related mineral deposits in south China. The granites are of Precambrian, Caledonian, Hercynian, Indosinian and Yanshanian ages. Mineralizations of W, Sn, Nb, Ta, Cu, Mo, Pb and Zn are associated with granites of Yanshanian age (70-195 Ma) only. In this paper, we focus on the melt and fluid inclusions in these granites and related mineral deposits. (From the author's abstract)

LU, H.-Z and LIU, Congqiang, 1987a A discussion on mechanism of formation of stratabound ore deposits in China, a fluid inclusion study approach (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). First author at Sci. de la terre, Univ. Québec à Chicoutimi, Canada.

Based on geological studies on stratabound deposits in China. Authors did fluid inclusion research on that (including Pb, Zn, Au, Ag, U, Sb, Hg, W, quartz crystal and sparry calcite stratabound ore deposits in China) and attempt to approach the model of that type through the material sources, migration of fluids and conditions of mineralization.

The results are as follows: the ore-forming fluids (special $H_2O$) originated as a heated meteoric water that reacted with the wall-rocks and dissolved $Na^+$, Ca≠, $K^+$, $Cl^-$, $HCO_3^-$ and Mg≠ components. The ore-forming elements and other components, including sulfur, were also mainly derived from the wall-rocks. The ore-fluids belong to the Na-Ca-Cl-$HCO_3$ system with salinities ranging from 4 to 14 wt. % NaCl equivalent and densities from 0.9 to 1.0 g/cm$^3$. The deposits as we now see were formed at temperatures ranging from 150-250°C and pressures from 300 to 800 bars. Deposition may have been controlled by reaction with either organic matter or bacteria(sic). (Authors' abstract)

LU, Huanzhang and LIU, Congqiang, 1987b, A discussion on formation mechanism of stratabound ore deposits in China -- A fluid inclusion approach: Mineral Deposits, v. 6, no. 2, p. 16-28 (in Chinese; English abstract). Authors at Inst. Geochem., Acad. Sinica, Guiyang, Guizhou.

See previous abstract. (E.R.)

LUAIS, Béatrice, 1987, Silicate liquid immiscibility in groundmass and glassy inclusions of the basic andesites from Santorini (Aegean arc): Bull. Minéral., v. 110, p. 93-109. Author at Lab. Pétrol. Volcan., Centre Géol. et Géophys., U.S.T.L., Place E. Bataillon, 34060 Montpellier Cedex, France.

Immiscibility textures have been observed in basic andesites from the Skaros series, Santorini (Greece). They occur both in the groundmass as Fe-rich brown glassy globules enclosed in a Si-rich clear glass, and in plagioclase phenocrysts as minute Si-rich glassy globules within a Fe-rich brown glass. The clear glass exhibits a granitic normative composition with high Si, Al, Na and K contents whereas the brown glass is characterized by high Fe, T, Mg, Ca and Mn contents with a pyroxenite composition. The present study suggests that silicate liquid immiscibility is controlled in plagioclase phenocrysts by concentration gradients at the liquid-mineral interface, and in the groundmass by liquid composition (especially Ti). (Author's abstract)

LUCCHESI, Sergio and MAIORANI, Armando, 1987, Growth formation conditions of "three-stage" beryl crystals from Minas Gerais, Brazil: N. Jb. Miner. Abh., v. 157, no. 1, p. 1-18.

The study of the fluid and solid inclusions trapped in colorless beryl crystals from Minas Gerais, Brazil, allowed the clarification of the growth modalities of these crystals. Optical observations, X-ray diffraction, electron microprobe analyses and microthermometric determinations were performed. The fluid inclusions found in the cores of the crystals were characterized by an aqueous phase with high charge cations, while the three-phase fluid inclusions occurring in the middle and outer growth stages of the samples proved to consist of $CO_2$ and $H_2O$ with an $X(CO_2)$ of ~0.8 and a salinity between 1.5 and 5.1 wt. % NaCl eq. The solid inclusions were: beryl, muscovite, biotite, albite, talk, quartz and fluorite.

Hypotheses on the P-T growth conditions and on the development of the growth medium are put forward. (Authors' abstract)

LÜDERS, V. and MÖLLER, P., 1987, REE distribution pattern and fluid inclusions in fluorites of Harz Mts. (abst.): Fortschritte der Mineralogie, Bd. 65, Bhf. 1, p. 123 (in German). Authors in Berlin, FRG.

Contrary to veins in Upper Harz, some veins in Middle Harz and almost all veins of the Lower Harz contain fluorites as a vein mineral. In the region of Neudorf (GDR), fluorite occurs also in the sulfide parageneses of the main sulfide mineralization phase. The other fluorite occurrences are younger than the primary sulfide ore mineralization and form pre- to post-barite veins. All the studied fluorites have Tb/La-Tb/Ca atomic proportions typical of hydrothermal origin. The distribution pattern of lanthanoids shows three groups. Fluorites of the main sulfide mineralization have continuous change from light to heavy REE elements. The younger fluorites indicate distinctly lower contents of light REE than heavy ones, some locations have negative or postive Eu anomalies, indicating either reducing mineral-forming conditions or reaction of mineral-forming solutions with feldspars. The REE distribution in the younger fluorites may be interpreted as mobilization of the older fluorites. P fluid inclusions in the oldest fluorites indicate Th about 300°C (Leeder et al., 1972; Fluid Inclusion Research, v. 7, p. 122, 1974). Fluid inclusions in the younger fluorites bear solutions of high Cl content (4 to 5.5 M) and Th are 100-150°C. Similar data came also from the S fluid inclusions in the oldest fluorites, indicating the reworking of the older mineralization by highly saline low T solutions. On approaching to granite the salinity of the inclusion fillings increases. (Authors' abstract, translated by A.K.)

LÜDERS, V. and NEUMANN, M., 1987, Comparison of genesis of the carbonate-sulfide banded ores (Upper Harz/FRG and Nanisivik/Canada) (abst.): Fortschritte der Mineralogie, Bd. 65, Bhf. 1, p. 124 (in German). First author in Berlin, FRG.

The hydrothermal vein mineralization of the Upper Harz occurs in the folded Devonian and Carboniferous sediments, intruded by the Upper Carboniferous granites. The Pb-Zn deposit Nanisivik on Baffin Island (Canada) fills hydrothermal karst caves in Proterozoic dolomites. Both mineralizations typically bear banded carbonate-sulfide ores. Geochemical studies of isotopes of O, C and S, fluid inclusions, Ga/Ge ratio in ZnS and REE distribution in carbonates and in wall rocks indicate that the banded ores formed at least from two fluids: solution I - metal-rich fluid of deep origin with T >250°C; solution II - in Upper Harz: $H_2S$-rich, connected with the Middle Devonian black shales, in Nanisivik: $H_2S$ from $SO_4$-bearing surficial waters due to reduction in bituminous dolomites. Calcite in Upper Harz precipitated from solution I by cooling. Dolomites in Nanisivik are the deposit wall rocks. The precipitation of the banded ores in both cases results from cyclic changes from solution I to a mixture of solutions I and II, an back to solution I. In Upper Harz Eh generally did not reach a value to cause reduction of $Eu^{3+}$ to $Eu^{2+}$, whereas in Nanisivik Eu was bivalent, leading to negative Eu anomalies in the REE distribution pattern. (Authors' abstract, translated by A.K.)

LUETH, V.W., 1987, Mineralogic, petrologic, and fluid inclusion comparison of copper skarns in the Silver City mining region, New Mexico (abst.): Geol. Soc. Am. Abst. with Programs, v. 19, p. 316. Author at Dept. Geol. Sci., The Univ. Texas at El Paso, El Paso, TX 79968.

A comparative study of copper skarn deposits, in similar host rocks and adjacent to granitic intrusives of similar age, involved a porphyry-related skarn at Santa Rita (SR) and a barren stock skarn at Pinos Altos (PA). The skarn at the Continental Mine (CM) had characteristics similar to both "end-member" skarns and is considered intermediate.

Skarn distribution patterns, preservation of early stage skarn minerals at PA, endoskarn development, and discreet skarn zoning are consistent with previously described criteria differentiating skarn types. Mode of stock emplacement (passive at PA, forceful at SR and CM), sulfur fugacity (higher $fS_2$ assemblage at SR), oxygen fugacity ($-19>fO_2>-23$ at PA; $-23>fO_2>-25$ at SR), amount of garnet compositional variation (greatest at PA and CM especially with respect to spessartine), and the relative amounts of lead and silver sulfides (greatest at PA) were additional factors delineating between barren stock and porphyry skarns.

The observed differences between PA and SR are not best illustrated in the calcsilicate formation stage but in the retrograde mineralization stage. Garnet fluid inclusion homogenization temperatures (Th, 350 to 450°C), late stage garnet compositions (Ad 90 to 100), and quartz-sulfide vein temperature evolution (high saline, Th = 350°C to low saline, Th = 250°C) are remarkably similar. The amount of meteoric fluid component appears responsible for the major differences in the two types. PA displays the features indicative of a small scale, magmatic fluid dominant system while SR results from meteoric fluid infiltration on a large scale. (Author's abstract)

LUHR, J.F., 1987, Experimental sulfur solubility in anhdyrite- and pyrrhotite-saturated andesitic and basaltic melts (abst.): EOS, v. 68, p. 1541.

LUMPKIN, G.R. and CHAKOUMAKOS, B.C., 1987, Crystallization path and economic mineralogy of the Harding pegmatite, Taos County, New Mexico (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 751. Authors at Dept. Geol., Univ. New Mexico, Albuquerque, NM 87131.

The Harding pegmatite has been a major source of Be, Ta, Nb and Li ore minerals, during intermittent mining, 1919-1958. The mineral paragenesis is constrained by field relations, petrography and petrology. A P-T path of crystallization has been established from 1) experimentally determined liquidus and solidus, 2) isochores for $CO_2$-NaCl-$H_2O$ fluid inclusions, 3) metamorphic grade of the host rocks, and 4) pegmatite mineral equilibria.

The magmatic stage of crystallization ranged from 650° to 550°C at 3.3-3.5 kbar, followed by hydrothermal alteration (albitization, greisenization) as isobaric cooling continued to about 350°C. Fluid inclusions indicate that the fluid composition (mole %) evolved from 6$CO_2$:4NaCl to less than 1$CO_2$:10NaCl during crystallization. Early in the magmatic stage, major concentrations of beryl (Be) and columbite-tantalite (Nb, Ta) occurred in association with the appearance of spodumene late in the magmatic stage at 575-550°C. High-grade ore bodies occur in the quartz-lath spodumene zone. Uranium-rich microlite dispersed as millimeter sized grains in the microcline-spodumene zone constitutes low-grade ore. Additional microlite formed during the hydrothermal stage in the cleavelandite replacement unit and in pod-shaped lepidolite (Li) ore bodies. In nearby arroyos, small placers of columbite-tantalite were derived from occurrences in the wall zones. (Authors' abstract)

LUTH, R.W., 1987, Solubility mechanisms of fluorine in silicate liquids: The system CaO-$CaF_2$-$SiO_2$ (abst.): EOS, v. 68, p. 1541.

LÜTTGE, A., METZ, P., WALTHER, J. ALTHAUS, E. and HEINRICH, W., 1987, $CO_2$-$H_2O$ fluid inclusions in synthetic forsterite crystals (abst.): Fortschritte der Mineralogie, Bd. 65, Bhf. 1, p. 125 (in German). First author at Min.-Petr. Inst. of Univ. Tübingen, 7400 Tübingen 1, Wilhelmstrasse 56, FRG.

The studies of fluid inclusions were performed in products of the metamorphic-type reaction yielding forsterite and calcite, in a conventional hydrothermal apparatus:

1 tremolite + 11 dolomite $\rightleftarrows$ 8 forsterite + 13 calcite + 9$CO_2$ + 1$H_2O$.

The conditions of the experiments were: 1) 670°C, 5 kbar, 10-16 mole % $CO_2$ in fluid phase $CO_2 + H_2O$; 2) 720°C, 5 kbar, 40-44 mole % $CO_2$ in fluid phase $CO_2 + H_2O$. The obtained forsterite bears many 10-20 μm long fluid inclusions, filled with $CO_2$ and $H_2O$. Their composition was microthermometrically determined and compared with the $CO_2$-$H_2O$ proportions in fluid phases. Forsterite, formed under conditions 1), bears fluid inclusions with concentrations of $CO_2$ equal a) 8 ± 1 mole % and b) 26 ± 3 mole %[sic]. Forsterite crystallized under conditions 2) has inclusions with $CO_2$ content 5-15 mole % higher than $CO_2$ concentration in the initial fluid phase of the experiment. Thus in the experiments performed the fluid inclusions bear $CO_2$ concentrations exceeding the average $CO_2$ content in fluid phase used for the runs. This petrogenetically important conclusion may be explained if the above reaction goes through a dissolution-precipitation mechanism, where the places of nuclei formation of forsterite depend on $CO_2$ content in fluid phase (Heinrich et al., Cont. Min. Pet., v. 93, p. 215, 1986). The obtained results indicate that in the experiments local variations occurred in composition of the fluid phase. This helps to explain why fluid inclusions in natural forsterites frequently have variable composition. (Authors' abstract, translated by A.K.)

LUX, Gayle, 1987, The behavior of noble gases in silicate liquids: Solution, diffusion, bubbles and surface effects, with applications to natural samples: Geochimica Cosmo. Acta, v. 51, p. 1549-1560. Author at Charles Evans & Assoc., 301 Chesapeake Drive, Redwood City, CA 94063, USA.

Solubilities of noble gases in five natural silicate liquids as a function of temperature and partial pressure at 1 atm total pressure were determined and diffusion coefficients of the noble gases were measured in a tholeiite basalt at 1350°C. Solubilities of noble gases in silicate liquids obey Henry's law and are a strong function of composition and/or physical properties of the liquids. Solubility is greatest in less dense, more silica-rich liquids. Solubility is highest for the light gases and is related to the radius of the gas atom according to $K_i = a \exp(-br_i^2)$. Temperature dependence of solubility is weak, but in general solubility increases with increasing temperature yielding positive enthalpies of solution. Diffusion coefficients in a basalt liquid at 1350°C show more or less the same linear relationship with $r^2$ as solubility and are larger than what would be expected from extrapolation of values determined at lower temperatures. A large percentage of samples of andesite composition had bubbles that contained gas which was fractionated from the gas of the experiment. Concentrations of noble gases in samples equilibrated on Pt wire loops correlate with the surface/volume ratio, suggesting that surfaces of silicate liquids can accommodate more noble gases than the liquid proper. Solubility fractionation is a valid process to account for certain patterns in marine basalts. The density of silicate liquids appears to be a good predictor of noble gas solubility in these liquids. (Author's abstract)

LYAKHOV, Yu.V., 1987 Thermobarochemical zoning and conditions for formation of depth-different gold ore deposits: Dokl. Akad. Nauk SSSR, v. 297, no. 2, p. 437-441 (in Russian). Author at L'vov. Gos. Univ., L'vov, USSR.

A combination of geological, mineralogical, and thermobarogeochemical (multiphase inclusion) data indicates that processes of Au ore formation at different depths are characterized by specific physicochemical conditions and dynamics of regressive inversion in time and space. Shallow deposits of sulfide-poor ores formed under conditions of a sharp drop in P and of supersaturation, boiling, and strong degassing of solutions; the range in T and P was 370-50° and 20-1 MPa. Deposits at medium to large depth formed under more thermostatic conditions, over 500-50° and 120-20 MPa ranges. More extreme conditions of Au ore formation (540°, 300-200 MPa) were achieved only in gas-explosion phenomena or a very great depth. Evolution of the ore-forming processes occurred against a background of decreasing T, P, and concentration of strong acids (mainly $Cl^-$ and bases $Na^+$ and $K^+$) and increase in $HCO_3^-$, $Ca^{2+}$, and $Mg^{2+}$ concentrations in solutions. Thermobarogeochemical parameters which are definite indicators of Au ore mineralization include: a $CO_2$-$H_2O$ composition of the mineral-forming solutions, an increase in the concentration of Na and $Cl^-$ in solution during the productive stage, evidence of solution boiling, and a thermal regime of 270-190°. (C.A. 108: 41326c)

LYON, G.L. and HULSTON, J.R., 1987, Isotopic evidence for the origin of methane from New Zealand geothermal systems (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 753. Authors at Inst. Nuclear Sci., DSIR, Private Bag, Lower Hutt, New Zealand.

Most New Zealand geothermal fields have methane with $\delta^{13}C$ values between -24‰ and -28‰, and near constant helium isotope ratios of $^3He/^4He$ between six and seven times the atmospheric value. This methane may be derived from reduction of carbon dioxide or from underlying greywacke which has kerogen $\delta^{13}C$ of about -25‰.

However, at Mokai, methane has enriched and variable carbon isotope compositions. As the helium isotope ratios do not vary, these methane $\delta^{13}C$ values ranging from -27‰ to -14‰ imply that heavy methane is not necessarily related to the mantle source which supplies helium-3. The carbon and hydrogen isotopes of Mokai methane show that a mixture of two types of methane occurs, but without apparent chemical signatures except for quartz geothermometer T which increase with increasing carbon-13. The lighter component is similar to that of the other geothermal fields, which generally have higher gas contents. (Authors' abstract)

McCAFFREY, M.A., LAZAR, B. and HOLLAND, H.D., 1987, The evaporation path of seawater and the coprecipitation of $Br^-$ and $K^+$ with halite: J. Sedimentary Petrology, v. 57, p. 928-937. First author at Dept. Earth, Atmos. & Planet. Sci., Massachusetts Inst. Tech., Cambridge, MA 02139.

Brines and salt were sampled at the Morton Bahamas solar salt production facility on Great Inagua Island in the Bahamas. The brines were analyzed by ion chromatography to define more precisely than heretofore the evaporation path of seawater to the end of the halite facies. At Inagua, calcium carbonate begins to precipitate at a brine concentration of about 1.8 times that of seawater. Gypsum begins to precipitate at a brine concentration of 3.8 times seawater, and halite at a concentration factor of 10.6. Three of the most concentrated brines from Inagua (40 times seawater) were evaporated further in the laboratory. Magnesium sulfate first precipitated at brine concentrations about 70 times those of seawater, and potassium-bearing phases began to precipitate from these brines at concentrations greater than 90 times those of seawater.

The distribution coefficients of $Br^-$ and $K^+$ between brines and halite were determined by combining analytical data for the Inagua brines with measurements of the $Br^-$ and $K^+$ content of halites from Inagua and of halite which had precipitated from Inagua brines during storage. The observed average value of $D(Br^-)$ is 0.032, in good agreement with some of the previous measurements. The measured values of $D(K^-)$ are highly variable (0.001 to 0.021); $D(K^+)$ for halite precipitated early in the halite facies is in the vicinity of 0.015. (Authors' abstract)

McCAIG, A. and KNIPE, R., 1987, Microstructural and microchemical criteria for determining mass-transport mechanisms in deformed rocks (abst.): Terra Cognita, v. 7, no. 2-3, p. 131.

McCONVILLE, P. and REYNOLDS, J.H., 1987, Cosmogenic He in Sierra Leone Diamonds? (abst.): Eos, v. 68, p. 1514. Authors at Dept. Physics, Univ. California, Berkeley, CA 94720.

As part of our continuing effort to study noble gases in diamonds (Honda et al., J. Geophys. Res., in press) and in light of the recent detection of cosmogenic $^{10}Be$ in alluvial diamonds (Lal et al., 1987, Nature 328, p. 139-141), we have stepped-heated identical splits of finely-crushed Sierra Leone alluvial diamond. Results demonstrate the problems of identifying the source of high $^3He/^4He$ ratios in diamonds.

Both splits have similar noble gas concentrations and identical elemental and isotopic compositions. No Ne was detected above our system blank. Ar, Kr, and Xe concentrations were higher than other African diamonds, which may be attributed to adsorption of atmosphere during sample crushing. There also is evidence that radiogenic $^4He$ and $^{40}Ar$ were lost during sample preparation as a result of acid-dissolution of inclusions. The former contributed to the high measured $^3He/^4He \approx 300\ R_a$, but the major factor was the $^3He$ concentrations ($39\text{-}48 \times 10^{-12}$ cc STP/g), the highest ever measured in diamonds at Berkeley.

The alluvial origin of the diamonds and the absence of substantial trapped He are consistent with cosmic-ray spallation being the source of the high $^3He$ concentrations. We shall present additional data and results from other localities. (Authors' abstract)

McDONALD, B.W.R., 1987, Geology and genesis of the Mount Skukum Tertiary epithermal gold-silver vein deposit, southwestern Yukon Territory: M.S. thesis, Univ. British Columbia.

The Tertiary Mt. Skukum Au-Ag epithermal vein deposit occurs in andesitic volcanics. Major known mineralized zones occur within a regional halo of propylitic alteration centered on a fault-bounded graben. Each consists of steeply-dipping quartz-carbonate-sericite veins associated with major faults and rhyolite dikes which bound blocks of the graben. Precious metals occur as electrum and native Ag as grains averaging 15 to 20 microns in veins containing only trace amounts of sulphides. Fluid inclusions indicate that vein minerals were deposited from hydrothermal fluids averaging 313°C with an average salinity of 0.7 wt% NaCl eq. P inclusions show that depositional fluids existed under two P regimes; one close to hydrostatic, the other approaching lithostatic. Both reflect depths of deposition of about 470m below paleosurface. Variable fluid P reflecting similar depths of deposition combined with variable liquid to vapor ratios in P inclusions as well as abundant textural evidence of hydrothermal brecciation indicate that boiling was common during mineralization.

Oxygen and carbon isotope composition of minerals in the deposit and surrounding wall rocks indicate that depositional fluids were meteoric in origin with no contribution from magmatic sources. Large depletions in $O^{18}$ content of andesitic rocks in the deposit area indicate a miniumum water:rock ratio over the life of the deposit of 0.81:1.

Precious metals at the Mt. Skukum deposit were emplaced at relatively low T in a near surface environment by a circulating, meteoric water dominated, hydrothermal system driven by a heat source associated with the rhyolite dikes. Au leached from andesitic volcanic rocks and metamorphic and granitic rocks was precipitated with quartz and carbonate in permeable conduits such as fault zones, and breccia bodies. (From the author's abstract)

MACHEL, H.-G., 1987, Saddle dolomite as a by-product of stylolitization and thermochemical sulfate reduction (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 753-754. Author at Dept. Geol., Univ. Alberta, Edmonton, Alberta T6G 2E3, Canada.

Data from the Devonian Nisku reef trend in Canada include: (a) the amount of saddle dolomite increases downdip; (b) saddle dolomite occurs almost exclusively as cement below present hydrocarbon/water contacts; (c) saddle dolomite has grown around oil droplets; (d) carbon isotope ratios decrease upward from about +2 permil PDB within the water-saturated zone to about -10 permil PDB at the gas/water contact in one downdip location; (e) oxygen isotope ratios in the same interval decrease upward from about -6 to -8 permil PDB; (f) 87-Sr/86-Sr isotope ratios are 0.7114 to 0.7151, compared to 0.7089-0.7107 in the host rock dolomite; (g) boron contents are about 3.5 ppm compared to 7-50 ppm in the host rock dolomite; (h) fluid inclusion Th are 110-180°C; and (i) final melting T are equivalent to salinities of about 2.8 to 3.7 times that of seawater.

These data indicate that saddle dolomite formed in association with hydrocarbons at depths in excess of 3000 m from hypersaline brines that had interacted chemically with clastic rocks. The probable source of Mg was stylolitization of the host rock dolomite. In the downdip part of the study area, thermochemical sulfate reduction and concomitant hydrocarbon oxidation are responsible for increased amounts of saddle dolomite, negative carbon isotope ratios, and upward-decreasing stable isotope trends. Furthermore, thermochemical sulfate reduction may be representative of other processes that increase the precipitation rate and amount of saddle dolomite via an increase in carbonate alkalinity. (Author's abstract)

MACHEL, H.G., 1987, Saddle dolomite as a by-product of chemical compaction and thermochemical sulfate reduction: Geology, v. 15, no. 10, p. 936-940. See previous item.

MACHIDA, Minoru, OTSUBO, Tsutomu and FURUYADO, Akira, 1987, Disseminated type mineralization in the Tochibora ore deposits, Kamioka mine, Gifu prefecture, Japan: Mining Geol., v. 37, no. 2, p. 119-131. First author at Kamioka Mining & Smelting Co., Ltd., Kamioka, Yoshiki-gun, Gifu 506-11, Japan.

The Tochibora ore deposits of the Kamioka mine are mainly composed of skarn type Pb and Zn ore bodies which replace limestone.

The deposits are classified into four types; 1) pyrometasomatic Pb and Zn deposit (so-called Mokuji deposit), 2) mesothermal replacement Pb and Zn deposit (so-called Shiroji deposit), 3) Ag deposit and 4) disseminated type Pb and Zn deposit described in this paper.

Studies of fluid inclusion, wall rock alteration and mineral assemblage on the Tochibora ore deposits including the disseminated type mineralization were useful to make a conceptual genetic model for the ore deposits. (From the authors' abstract)

McINNES, B.I.A., 1987, Geology and precious metal evolution at Freegold Mountain, Dawson Range, Yukon: MS thesis, McMaster Univ., 230 pp.

The Au-bearing quartz veins at Freegold Mountain are high grade, low-tonnage deposits with grades ranging from 0.4 to 1.0 oz/t. Fluid inclusions from the lower portions of the Laforma mine have Th = 185°C with salinity ranging between 2 and 4.5 wt. % NaCl eq. A boiling zone has been detected above the deeper ore where fluid inclusions show extreme ranges in Th (165-430°C) and salinity (4-43 wt. % NaCl). Fluid inclusion waters have stable isotopic signatures indicative of meteoric water with $\delta D = -138$ and $\delta^{18}O = -18.4$. Boiling of the Laforma fluid has caused a shift towards heavier hydrogen and oxygen isotopic values, mineral deposition and appears to enhance Au precipitation over nonboiling zones. Stable isotopic evidence indicates that the paleoaltitude of Freegold Mountain during late Cretaceous time as south of the present day Yukon-B.C. border.

The Emmons Hill (Dart) prospect is a Au-bearing vein-breccia with mineral assemblages of barite, stibnite, marcasite, 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. This property shows marked similarities to acid-sulphate type precious metal deposits in New Zealand and western United States.

The deposit [Freegold Mountain?] formed by the explosive escape of volatile components evolved from the retrograde boiling of a silicic magma chamber. Au mineralization in the breccia is associated with pyrite and arsenopyrite formed ~300°C and salinities of ~4.5 wt. % NaCl. (From the author's abstract)

McKENZIE, D.P., 1987, The compaction of igneous and sedimentary rocks: J. Geol. Soc., London, v. 144, p. 299-307.

McKIBBEN, M.A., 1987, Fluid inclusions in metamorphosed Plio-Pleistocene evaporites from the Salton Sea geothermal system, Salton Trough rift zone, California (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Author at Dept. Earth Sci. & Inst. Geophys. & Planet. Physics, Univ. California, Riverside, CA 92521.

The Salton Sea geothermal field (SSGF) is located at the south end of the Salton Sea, associated with an arc of five Quaternary rhyolite domes (Helgeson, 1968; Muffler & White, 1969). The rocks penetrated by geothermal wells are mainly Plio-Pleistocene fluvial and lacustrine sediments deposited by the Colorado River delta. T >350°C and hypersaline Na-Ca-K-Cl brines with TDS >25 wt % are encountered at 2 km depth within this system. The deltaic sediments are metamorphosed to greenschist facies mineral assemblages: actinolite-quartz-epidote-biotite-andradite (McDowell & Elders, 1980). The water in the geothermal brines is partially-evaporated Colorado River water (Coplen, 1976). The hypersaline nature of the geothermal brines has been attributed to the near-surface dissolution of evaporites. White (1968) and Rex (1983) proposed that local meteoric recharge waters dissolved shallow evaporites formed from Colorado River water. They argue that the resulting cold, dense brine descended into the geothermal reservoir along rift-related fracture networks. Until recently, however, no recognized subsurface evaporites have been reported from drilling in the SSGF.

Fluid inclusions in the massive and breccia-cementing anhydrite from a new drill core range from simple liquid-vapor inclusions to multiphase inclusions containing over 50 volume % halide and carbonate crystals. The inclusions consistently homogenize at 291°C (98 measurements, $1\sigma \pm 9$) but show variable solid-liquid phase behavior. Te range from -48 to -35°C (9 measurements). Most inclusions show simple ice melting at -26 to -18°C (22 measurements). A few inclusions show ice melting at -24 to -25°C followed by hydrohalite melting at -15 to -14°C, while a few others show hydrohalite melting at -25 to -24°C followed by ice melting at -22 to -21°C. The multiphase inclusions have Tm NaCl ranging from 157 to >315°C (19 measurements). This variable phase behavior is consistent with the isothermal trapping of fluids with widely-varying salinities, some of which must have been saturated in halides at the time of trapping.

Saline brines are presently produced from depths a few hundred feet above the evaporites, at near 300°C and P near 1200 psi. The brines contain 212,000 ppm TDS, with 2.6 m NaCl, 0.7 m $CaCl_2$, 0.4 m KCl, 0.03 m $CO_2$ and 0.002 m $SO_4$. If the inclusion fluids have the same (Na + K)/Ca ratios as the produced brines, then their phase behavior can be approximated by a 70% NaCl-30% $CaCl_2$ brine in the NaCl-$CaCl_2$-$H_2O$ ternary system.

The fluid inclusion and textural data imply that thermal metamorphism of buried evaporites may have played a role in generating the high salinities of the geothermal brines in the SSGF. This thermal mechanism of generating saline brines from deep evaporites may be supplemental to previously-invoked mechanisms involving the cold dissolution of near-surface salt deposits. (From the author's abstract; references and diagrams omitted here.)

McKIBBEN, M.A., ANDES, J.P., Jr. and WILLIAMS, A.E., 1987, Ore-forming processes in the Salton Sea geothermal system, California: New insights from the SSSDP cores (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 766-767. Authors at Dept. Earth Sci. & IGPP, Univ. California, Riverside, CA 92521.

Two types of vertical ore-bearing fractures occur in the SSSDP drill-core (Table). Type 1 veins are completely filled and contain the paragenesis epidote + adularia + ankerite; CALCITE: sphalerite + pyrite + chalcopyrite ± galena ± pyrrhotite. They occur in rocks that show minimal alteration. Type 2 veins are open and contain the paragenesis EPIDOTE + quartz + chlorite; calcite; chalcopyrite + pyrite ± sphalerite ± galena; hematite. They occur in pervasively epidotized and chloritized rocks. Ejecta from well flow tests are Type 2 in character.

We interpret the Type 1 veins as an older vein set. Fluid inclusion Tt's indicate a much higher paleogeothermal gradient for the Type 1 veins, implying that the upper 1-2 km of this part of the geothermal system has cooled by as much as 100°C. The Type 1 veins probably formed when early volcanism fractured and heated the lithified, unaltered sediments, expelling heated, reduced connate fluids upward.

The Type 2 veins are forming now, at a sharp interface between deep metamorphic brine and shallow evolved groundwaters. Although the vein fluid inclusion data define an apparent increase in brine salinity with depth, brines currently produced from the geothermal system are bimodal in salinity: shallow brines are <10 wt% TDS and deep brines are >19 wt% TDS. The Type 2 veins must form by fluid interaction and oxidation in vertical fracture zones at the brine interface, when periodic magma intrusion and heating induce thermal upwelling of the deep brines.

Abundant inclusions may not form during more quiescent, long-term equilibration between static brines and host rocks. In contrast, vein inclusions record transient nonsteady-state mixing events, and must be used cautiously to interpret the dynamics of fossil geothermal systems. (Authors' abstract)

McKIBBEN, M.A., WILLIAMS, A.E., ANDES, J.P., Jr., OAKES, C.S., OKUBO, S. and ELDERS, W.A., 1986, Metamorphosed Plio-Pleistocene evaporites in the Salton Sea geothermal system, Salton Trough Rift, California (abst.): Geol. Soc. Am. Abstracts with Programs, v. 18, p. 690. Authors at Dept. Earth Sci., IGPP, Univ. California, Riverside, CA 92521.

Drillcore from a recent commercial production well in the central part of the geothermal system contains recrystallized, bedded anhydrite at 900 m depth. The anhydrite is often brecciated and locally remobilized into veins. Two-phase fluid inclusions in the bedded anhydrite homogenize at 299°C and have equivalent salinities of 23 wt % NaCl. Four-phase fluid inclusions contain halide dxls.

Flash-corrected analyses of brines from the well yield 212,813 ppm TDS, 153 ppm sulfate, and > 15-25 ppm sulfide. The brines are not as deficient in total sulfur as brines previously described from this system. The Na-K-Ca geothermometer yields a T of 296°C, agreeing with an estimated first-flash T of 293°C. Thermodynamic calculations at 300°C indicate that the brines are supersaturated in anhydrite.

The presence of recrystallized bedded anhydrite in equilibrium with the Salton Sea brines implies that evaporite deposits were important sources of brine salinity, as proposed originally by D.E. White in 1968. However, sulfur isotopic data suggest that the major source of sulfur for Fe-Zn-Cu-Pb ore mineralization in veins is magmatic. (From the authors' abstract)

MACKWELL, S.J. and KOHLSTEDT, D.L., 1987, Diffusion of hydrogen in olivine: Implications for the presence of water in the mantle (abst.): EOS, v. 68, p. 417. Authors at Dept. Materials Sci. & Engrg., Cornell Univ., Ithaca, NY 14853.

A series of high-pressure hydrothermal experiments is being performed on single crystals of San Carlos olivine to determine the rate at which water-derived species diffuse into the olivine. Experiments are being conducted at temperatures from 500 to 1000°C and confining pressures from 50 to 500 MPa with the oxygen fugacity buffered by either iron-wustite or nickel-nickel oxide powders. Infrared spectroscopic measurements indicate that the olivine specimens are totally penetrated by a water-derived species at 1000°C, yielding a diffusivity of greater than $10^{-10} m^2 s^{-1}$ . Some penetration has also been measured at temperatures as low as 800°C. The diffusivities measured so far are considerably faster than those determined for oxygen diffusion in olivine, suggesting that the mobile species are hydrogen ions. Such rapid diffusion of water-derived species at these moderate temperatures indicates that appreciable loss of water may occur from olivine grains during their ascent from the mantle. By comparison, the work of Tingle and Green (1987) and Watson (1986) shows that carbon is considerably less mobile and should be retained by the olivine. Consequently, mixed $H_2O$-C/CO/$CO_2$ fluid inclusions may be expected to lose hydrogen during ascent, yielding fluid inclusions enriched in $CO_2$, similar to those observed in xenoliths. (Authors' abstract)

McLIMANS, R.K., 1987, The petroleum reservoir environment: Techniques and applications of fluid inclusion studies (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated).

Knowledge of the diagenetic history of a potential petroleum reservoir is critical to successful exploration because diagenesis controls the preservation, creation, or destruction of porosity and permeability. During burial, diagenetic reactions occur between sediments and surrounding fluids in response to increases in T and P. Records of such processes are commonly preserved as fluid inclusions in pore-filling cements. Geothermometry of oil and brine inclusions are used to determine the timing and physicochemical environments of cementation and oil migration. The maturity, composition, alteration, and evidence for multiple migrations of oil are gained from two and three dimension analyses of fluorescence and decrepitation-gas chromatography of oils in fluid inclusions. Such techniques are used to study oil and brine inclusions synthesized in the laboratory as well as those that occur naturally in petroleum reservoir cements. A few applications of the methods are presented here.

The Wealden Basin, southern England, is an active exploration area owing to recent Conoco oil discoveries in the Middle Jurassic Great Oolite Formation. Fluid inclusion studies of oil and brine inclusions occurring in calcite cements have been used to determine the timing of cementation and oil migration, estimate oil maturities, reconstruct structural history by determining values of uplift, indicate the primary areas of the basin where oil migration and accumulation occurred, and develop a predictive diagenetic model.

For the Cretaceous Mishrif Formation, Dubai, the distribution of oil inclusions identifies a migration pathway. Geothermometry of oil and brine inclusions in the same cement crystals yield the P-T-X conditions for cementation and oil migration. Decrepitation-gas chromatography identifies several families of oil-filled inclusions from fresh oil to highly altered. (Author's abstract)

McMILLAN, K., CROSS, R.W. and LONG, P.E., 1987, Two-stage vesiculation in the Cohassett flow of the Grande Ronde Basalt, south-central Washington: Geology, v. 15, p. 809-812. Authors at Geosci. Group, Basalt Waste Isolation Project, Rockwell Hanford Op., Richland, WA 99352.

The Cohassett flow of the Grande Ronde Basalt contains two vesicular zones separated by 24 m of dense, sparsely vesicular basalt. The vesicular zones represent accumulations of upward-migrating bubbles sequentially frozen-in by the downward passage of the upper solidification front. The separation of the two zones suggests a hiatus in the exsolution of aqueous vapor from the lava. The flow-top vesicular zone formed during and immediately following emplacement of the flow from vapor bubbles nucleated during ascent and eruption, whereas the internal vesicular zone formed after emplacement from bubbles apparently nucleated at the lower solidification front. Homogeneous nucleation of vapor was probably initially driven by large oversaturation pressures in the erupting lava. After emplacement, heterogeneous nucleation of vapor was probably initiated by crystallization in the margins of the flow. (Authors' abstract)

McMILLAN, P., SMYTH, J.R. and AKAOGI, M., 1987, OH in β-$Mg_2SiO_4$ (abst.): EOS, v. 68, p. 1456.

McNEIL, A.M. and EDGAR, A.D., 1987, Sodium-rich metasomatism in the upper mantle: Implications of experiments on the pyrolite-$Na_2O$-rich fluid system at 950°C, 20 kbar: Geochim. Cosmo. Acta, v. 51, p. 2285-2294.

McNUTT, R.H., FRAPE, S.K., FRITZ, P., DOLLAR, P., JONES, M.G. and MACDONALD, I.M., 1987, Comparison of the $^{87}Sr/^{86}Sr$ ratios in brines from the Precambrian Shield and from the Michigan Basin (abst.): GAC-MAC, AGC-AMC Joint Ann. Mtg., Program with Absts., v. 12, p. 71. First author at Dept. Geol., McMaster Univ., Hamilton, Ontario L8S 4M1.

The chemistry of brines from Precambrian age rocks on the Canadian Shield and from rocks of Paleozoic age in the Michigan Basin show that samples from both areas are dominated by Ca, Na and Cl with significant contents of Br and Sr. The sedimentary basin brines generally have higher contents of K and Mg. Isotopically, the brines from the two environments are different. The $^{87}Sr/^{86}Sr$ values of the most saline Shield brines (>100 g $L^{-1}$TDS) reflect extensive water-rock interaction over a protracted, but unknown, period of time, and suggest equilibration with the host rock. Brine values of 0.7080 to 0.7535 are found in host rocks varying from ultramafic to granitic to quartz sandstone. The Michigan Basin brines have a narrow range of $^{87}Sr/^{86}Sr$ values (.7080-.7105) and, with few exceptions, are slightly elevated with respect to Paleozoic seawater values. The host rocks vary from arkosic sandstone to carbonates to evaporite. Water-rock reaction has occurred but equilibration with the host rock has not yet been demonstrated. In both environments, late-forming carbonate and sulphate mineral phases (veins, cement) have isotopic values identical to those in the brines. The consistency of the $^{87}Sr/^{86}Sr$ values in a given host, suggests fluid migration distance up to 10's of km on the Shield and 100's of km in the Michigan Basin. (Authors' abstract)

MADDOX, John, 1987, Amorphous ice still a puzzle: Nature, v. 326, p. 823.

The idea that there is more than one form of amorphous ice has been around for the past three years, but explanation of the true state of affairs is still elusive. (Author's abstract)

MAESTRATI, R., LASNIER, B. and RZEPKA, E., 1987, A Raman spectra catalogue of gems and their inclusions (abst.): Terra Cognita, v. 7, p. 17.

MAGARITZ, Mordeckai, 1987, A new explanation for cyclic deposition in marine evaporite basins: Meteoric water input: Chem. Geol., v. 62, p. 239-250.

MAHER, S.L. and RUGY, H.E., 1987, C and H detection in quenched glasses (abst.): EOS, v. 68, p. 440-441.

MAISONNEUVE, J., MERGOIL-DANIEL, J. and LABERNARDIÈRE, H., 1987, From granites to ore deposits: Mobilization and transport of uranium by hydrothermal $CO_2$-waters (abst.): Int'l. Symp. on Granites and Associated Mineralizations, Salvador, Bahia, Brazil, Jan. 21-31, 1987, Extended Abstracts, p. 217-273.

MALYUK, G.A. and VOZNYAK, D.K., 1987, Mass-spectrometric determination of gas composition of mineralizing-fluid inclusions in quartz on heating under vacuum: Geochem. Int'l., v. 24, no. 1, p. 67-73. English translation of Geokhimiya, no. 6, p. 819-824 (1986); abstract in Fluid Inclusion Research, v. 19, p. 279-280. (H.E.B.)

MANDAL, Nibir and BANERJEE, Sanjib, 1987, Rotation rate versus growth rate of syntectonic porphyroblasts: The controlling parameter of the shape of the inclusion trail: Tectonophysics, v. 136, p. 165-169. Authors at Dept. Geol. Sci., Jadavpur Univ., Calcutta 700 032, India.

The development of curved inclusion trails within syntectonic porphyroblasts has long been explained in the light of the rotation of the porphyroblast with respect to the external foliation. The present paper shows that both the rate of rotation and the growth rate of the porphyroblast play a role in the development of the inclusion pattern. An equation is derived involving the ratio of growth rate and rotation rate that enables computation of the rotation rate from natural porphyroblasts and also offers a measure of the noncoaxiality of a deformation. (Authors' abstract)

MANG, Kuiyuan, 1987, The mineralization of Xiaoyingpan gold deposit in Hebei: Earth Sci., v. 12, no. 2, p. 179-184 (in Chinese; English abstract). Author at Tianjin Inst. Geol. & Min. Resources.

The Na/K ratio of inclusions is 1.43 in the Xiaoyingpan Au deposit. This ratio indicates that a certain amount of sylvite should yet be produced. It is calculated that the KCl is about 8% and NaCl 9.9%, so that the total salinity reaches 17-18%. Using Na/K/Ca geothermometer the author calculates the equilibrium T is 540°C. The total P of the ore-bearing hydrothermal fluid is $4.19 \times 10^7$ Pa. The above mentioned data suggest that this Au deposit may be explained by a circulating model. (Author's abstract)

MANGAS, José, 1987a, Geological and fluid inclusion study in the uranium ore body of "Los Ratones" (Caceres, Spain) (abst).: Program, Symp. "VII Semana de Geoquímica," Aveiro, Portugal, December 1987.

The vein ore body of "Los Ratones" is found to the west of Albala, fitted into a medium to coarse-grain granite. The mineralization consists of quartz veins with massive pitchblende, pyrite, marcasite and melnicovite, as primary minerals, and autunite, phosphuranilite, saleite, torbernite and gummites, as secondary ones.

Microthermometry and crushing tests on quartz from mineralized veins were used to find out the physical-chemical characteristics of uranium mineralization.

The fluid inclusions indicate two stages of fluid circulation. The first consists of $H_2O$-NaCl solutions with salinities <8.5 eq. wt. % NaCl and Th between 140 and 400°C. The second consists of $H_2O$-NaCl-KCl-$CaCl_2$-$MgCl_2$ solutions with salinities from 10 to 26 eq. wt. % NaCl an Th between 120 and 200°C. (Author's abstract)

MANGAS, José, 1987b, Studies of the fluid inclusions in mineral desposits of western Spain associated with Hercynian granites: PhD dissertation, Univ. Salamanca, 646 pp. (in Spanish).

See Mangas and Arribas, 1985, Fluid Inclusion Research, v. 18, p. 263-264. (E.R.)

MANGAS, José, 1987c, Fluid inclusion study in the Spanish Sn deposits associated with the Hercynian granites (abst.): Symp. "VII Semana de Geoquímica," Aveiro, Portugal, Dec. 1987.

See Mangas and Arribas, 1985(a,b,c), Fluid Inclusion Research, v. 18, p. 263, and also following items. (E.R.)

MANGAS, J. and ARRIBAS, A., 1987a Fluid inclusion study in different types of tin deposits associated with the Hercynian granites of western Spain: Chem. Geol., v. 61, no. 1/4, p. 193-208.

Full paper for abstract in Fluid Inclusion Research, v. 18, p. 263-264, 1985. (E.R.)

MANGAS, J. and ARRIBAS, A., 1987b Hydrothermal evolution in relation to Sn mineralization in Feli deposit (western Spain) (abst.): ECRFI, European

Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 75-76. First author at Dept. Geol., Las Palmas Univ., Apdo 550, Spain.

At the Feli orebody, located in the western border of the Salamanca province, a large pegmatite dike with Li-muscovite is associated with a stockwork of quartz and pegmatite dikes cutting Cambrian schists, quartzites and amphibolites. Quartz, microcline, albite, muscovite, lepidolite, beryl, spodumene and small amounts of sulphides accompany the cassiterite. The orebody is associated with intrusions of syn- and late kinematic Hercynian granites.

The study of the fluid inclusions was made by microthermometry, Raman microprobe and crushing test analyses on quartz belonging to different veins and pegmatite dikes. The successive variations of the fluid inclusion chemical composition, density, T and P indicate that the hydrothermal evolution resulted from a discontinuous sequence of specific events, each of them corresponding to opening of fractures, active fluid circulation and mineral deposition. The physical-chemical characteristics of the inclusions indicate three stages of fluid circulation. The first stage, associated to the deposition of the cassiterite, is characterized by complex $CO_2$ aqueous inclusions (<15 wt% NaCl equiv.) trapped between 250° and 400°C and P <800 bars. The second stage is represented by low salinity aqueous inclusions (<8.5 wt% NaCl eq.) trapped between 300° and 100°C. The third stage is characterized by mixed salt aqueous inclusions (<40 wt% NaCl eq.) trapped between 130° to 60°C.

The results obtained by this study indicate that, in general, with descending T, the chemical evolution of the mineralizing fluids is characterized by a progressive decrease of the salinity and $CO_2$ content. However, for the fluids trapped at lower T (130°-60°C) the salinity is much higher, which is presumably due to the increase in $Ca^{++}$, $Mg^{++}$, $Na^+$ and $K^+$ salts content. (Authors' abstract)

MANNING, C.E. and BIRD, D.K., 1987, Contact metamorphism of basalts marginal to the Skaergaard intrusion (abst.): EOS, v. 68, no. 16, p. 467. Authors at Dept. Geol, Stanford Univ., Stanford, CA 94305.

The Early Tertiary Skaergaard magma-hydrothermal system of East Greenland caused extensive circulation of meteoric water and metamorphism of its host rocks. Preserved metamorphic T range from >1000°C at <10 m to 700°C at 200 m from the intrusion (cpx ± opx geothermometry), drop sharply to <425°C at >250 m (prehnite dehydration), and are constant in the range 200-275°C at >1 km (fluid inclusion Th, qtz-epd $^{18}O$ fractionation, and $Fe^{8+}$ ordering in epd). (From the authors' abstract)

MANRIQUE, Jose and CAMPBELL, Andrew, 1987, A fluid inclusion study of the Waldo-Graphic mine, Magdalena district, New Mexico: New Mexico Geol., v. 9, no. 1, p. 1-6, 10. Authors at Dept. Geosci., New Mexico Inst. Mining & Tech., Socorro, NM 87801.

This is the full paper for abstract in Fluid Inclusion Research, v. 19, p. 280-281. (E.R.)

MANRIQUE, J.R., CHAVEZ, W.X., Jr. and NORMAN, D.I., 1987, Preliminary report on fluid inclusions in pyrargyrite: Arcata mining district, southern Peru (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated).

Fluid inclusion studies are being performed on ore minerals from the Marion vein of the Arcata Ag/Au volcanic-hosted epithermal vein deposit. Pyrargyrite, which bears microscopic fluid inclusions visible under ordinary light, occurs sporadically in restricted areas of the vein as massive dull red bands up to 10 cm wide.

Inclusions are of two types: a) two-phase liquid-rich inclusions up to 120 microns in length; and b) single-phase liquid-filled fluid inclusions with lengths up to 15 microns. The first type are generally isolated with both negative crystal and rounded shapes, and also occur as arrays of small fluid inclusions. In this group, a few irregularly shaped inclusions also were observed. The degrees of filling are up to ~75 percent.

In studying these inclusions special problems are faced. The high reflectivity and the strong double refraction of pyrargyrite inhibit the location and identification of the inclusions. These difficulties were resolved by: preparing very thin highly polished slabs, rotating the sample during observation to avoid double refraction, carefully collimating the light of the optical system; and, importantly blocking the light with the hand under the microscope stage to induce movement of the inclusion bubbles due to their response to T difference. On cooling several submicroscopic fluid inclusions were observed to explode (mainly those located near fractures and cleavage planes). As a result, areas under observation sometimes were obscured. The wide dark border of the inclusions also caused difficulty in measuring Tm. This was resolved by warming the inclusion at slow rates (0.1 C/min) and fixing Tm by the last movement of the bubble. Finally on heating, some minute inclusions decrepitated at about 130°C. Further, pyrargyrite shows reversible changes of color and transparency at >200°C and the wide borders of the inclusions inhibit Th measurements. This problem was resolved by doing rapid T decreases after the bubble had disappeared in the dark areas, to obtain the last T at which instantaneous growth of the bubble occurred and hence Th. These measured values are considered to be minimum Th.

Most of (L-V)L inclusions homogenize between 217-264°C; Tm values were in the range of -1.1 to -1.5°C which correspond to 1.9-2.6 wt.% eq. NaCl. The submicroscopic inclusions are interpreted as water-filled inclusions that explode due to volumetric expansion as a result of phase change (Roedder, 1986, personal communication). These results are being compared with data of cogenetic quartz. (Authors' abstract)

MANRIQUE, J.R., CHÁVEZ, W.X., Jr., NORMAN, D.I. and GUERRERO, Tomás, 1987, Arcata, Peru: An excellent example of a low sulfidation state volcanic-hosted silver-gold epithermal deposit (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 759-760. Authors at New Mexico Tech., Socorro, NM 87801.

The Arcata District is located in the Puquio-Caylloma belt of Southern Peru. Fluid inclusion microthermometric measurements performed on pyrargyrite, sphalerite, quartz and fluorite indicate that mineralization was formed from low salinity (less than 1 wt% NaCl eq.) fluids at T of 200-250°C. Paleogeographic considerations suggest emplacement at depths less than 1 km. Although no conclusive evidence of an ore deposition-boiling relationship is inferred from fluid inclusion study to date, a close association of lamellar-calcite with pyrargyrite suggests that at least local, episodic boiling occurred during ore deposition. (From the authors' abstract)

MAO, Dongqing, LU, H.-Z. and FANG, Gengbao, 1987, Melt inclusions in basalts of Ross Island area, Antarctica (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). First author at Inst. Gold Research, Shenyang, PRC.

There are many melt and fluid inclusions (mainly $CO_2$-rich) in olivine and pyroxene minerals in basalts from the Ross Island area. The melt inclusions can be classified as follows: (1) crystalline melt inclusion, (2) fluid-melt inclusion and (3) glass inclusions. The daughter minerals in type (1) melt inclusion include olivine, plagioclase, ilimite, etc. Fluid-melt inclusions are a new type which represent the immiscibility of magma and fluid at a particular stage of evolution. Three types of fluid-melt inclusions were found in this study: a) crystals + liquid + gas, b) coexist with glass inclusions and fluid inclusions, and c) crystal + daughter minerals (dissolved salts) + gas. Both primary and secondary melt inclusions occurred in the samples. The secondary melt inclusions were formed during the healing of fracture in the host minerals when the basalt magma uplift.

The homogenization temperatures (both Leitz 1350 and quench methods used) of melt inclusion in basalts range from 1190 to 1350°C with high pressure (about 7 Kbar), this indicates that the basalt may have come from the upper mantle.

The discoveries of melt-fluid immiscibility in basaltic magma, and that the $CO_2$-rich fluid is the main fluid phase in the upper mantle are significant in understanding the evolution of magma and processes in the deep part of the earth.

The homogenization temperatures of melt and fluid inclusions in granites and metamorphic rocks in this area are from 980-1100°C and 279-350°C respectively(sic). (Authors' abstract)

MARCHENKO, E.Ya., 1987, Willemite from near-fault metasomatites: Mineral. Zh., v. 9, no. 1, p. 86-90 (in Russian).

MARIGNAC, Ch., 1987, P, T evolution of ore veins associated with paleogeothermal activity at Aïn Barbar (NE Constantinois, Algeria): Reconstruction from fluid inclusion data (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 77-78. Author at Ecole des Mines de Nancy, 54042 Nancy Cedex, France.

The polymetallic ore veins at Aïn Barbar (NE Constantinois, Algeria) are the result of fluid circulation along deep fractures within a paleogeothermal system active in Langhian times (Marignac 1983, 1985*). Hydrothermal minerals record a multistage evolution: early chlorite-epidote stage, sphalerite stage, chalcopyrite stage, late stages. Fluid inclusion studies in quartz provide information not only on the ore-forming fluids but also on the conditions prevailing in the paleogeothermal field.

I. The use of fluid inclusion data yields estimates of the confining P. During circulation along the ore veins, sporadic boiling occurred as demonstrated by the presence of vapor bubble trails. Hence the hydrostatic P was close to the internal P in the inclusions at maximum Th. At chalcopyrite stage this is in the order of 100 bars, in good agreement with the reconstructed depth of about 1 km; an important unroofing is however demonstrated at late stages with a calculated rate of about 0.5 mm.year$^{-1}$. There is no generalized boiling in the Aïn Barbar field; P within the ore veins were not therefore purely hydrostatic, because of self-sealing phenomena, and/or overpressure in head of the ascending fluid column. However this excess was not very important: Th are in fact in good agreement with independent estimates of T provided by sulfide paragenesis or chlorite compositions. That means that a minimal correction P must be considered, the value of which cannot exceed a few 10 bars. True boiling is locally recorded in association with early potassic alteration in a microgranite, thus leading to direct P measurement (100 bars) in good agreement with the previous ones.

II. Main lines of thermal evolution may be reconstructed from the beginning of the chalcopyrite stage (there are no fluid inclusions recording the earlier stages). Two fluids are involved in chalcopyrite deposition: a hot (330°-340°C) moderately saline fluid (6% wt. eq. NaCl; but a divalent cation is certainly present) issued from deep parts of the aquifer, where it equilibrated with pyrrhotite; and a cooler (300°-310°C) less saline fluid (1.5-2% wt. eq. NaCl) issued from higher levels, where it equilibrated with pyrite. Their mixing, with progressive dominance of the second one, results in a shift of f($S_2$) towards higher values as recorded by the sulfide paragenesis (transformation of pyrrhotite into pyrite and decreasing of the iron content in sphalerite).

Thereafter, the system seems dominated by the high level fluids with progressive cooling down to 250°-230°C. Then it is reheated up to 290°-300°C, by the influx of low saline fluids (1.0-1.2% wt. eq. NaCl), the system being finally cooled down to 170°-180°C. This recurrent hydrothermal cycle is correlated with resurgent magmatic activity in the area. It is marked by minor sulfide and sulfoarsenide deposition.

III. Detailed studies of fluid inclusion spatial distribution locally show the existence of T fluctuations in the order of a few 10°C. Such fluctuations reflect the dynamics of fluid circulation in the ore veins, characterized by self-sealing and crack-seal phenomena. (Author's abstract)

*References given in original. (E.R.)

MARIGNAC, Christian, CATHELINEAU, Michel, GIANELLI, Giovanni and PUXEDDU, Mariano, 1987, Recent to present day hydrothermal circulations in the geothermal system of Larderello (Italy), from fluid inclusion data (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 79-80. First author at E.M.N. (I.N.P.L.), Parc de Saurupt, 54042 Nancy Cedex, France.

Samples from drill cores in the deepest parts of the Larderello active geothermal field exhibit strong hydrothermal metamorphism with high T minerals such as wollastonite, diopside-rich clinopyroxene, biotite, amphibole, andesine-labradorite plagioclase, and tourmaline. These samples are close to the inferred contact of the intrusive body responsible for the thermal anomaly at Larderello. Fluid inclusions were studied in quartz veins and recrystallized quartz rods from samples of wells VC 11 (Serrazano), Sasso 22 and San Pompeo at depth ranging from 1500 to 4000 m. Two sets of fluids were recognized:

I. Early fluids are characterized by their high Tt (400° to >550°C). They are of two types:

1. A series of aqueous brines and vapors without carbonic component, characterized by their very low Te, close to -70°/-75°C, which is suggestive of the presence of LiCl in the fluids. These brines are of three types: a) highly saline fluid without dms, exhibiting melting of a first ice[sic] between -30° and -40°C, and of a salt hydrate at -21°/-23°C; interpreted in the LiCl-$H_2O$ model system, that means a salinity 20 to 35% wt. LiCl. Th are ~500°C. b) NaCl saturated fluid with Tm ice of ~- 40°C, i.e., 20% wt. eq. LiCl, and Tm NaCl in the range 185°-215°C, i.e., 31% wt. eq. NaCl. Th are very high (>550°C). c) NaCl-KCl saturated fluid with Tm sylvite in the range 220°-260°C and of halite in the range 290°-305°C, corresponding to 33-34% wt. KCl and 24-23% wt. NaCl in the NaCl-KCl-$H_2O$ model system. Salt hydrates exhibiting complex melting relationships in the range +20°/+50°C are observed: the presence of $CaCl_2$ or $FeCl_3$ is therefore suspected. Th are very high (>550°C).

The vapors are of two kinds: d) highly saline (Tm ice in the range -18°/-25°C, i.e., 12-15% wt. eq. LiCl) with very high Th (>550°C). e) Moderately saline (Tm ice in the range -5°/-10°C) with lower Th (430°-530°C). These fluids are interpreted as the result of boiling of type a) brine underneath the site of trapping, at T decreasing from >550°C to 430°C. Type a) brine, with its high K/Na ratio and rather exotic composition, is most probably of magmatic origin.

2. $CO_2$-$CH_4$-bearing aqueous vapors with low to moderate salinities and Te of ~-60°C, suggestive of the presence of Ca or $Fe^{3+}$ component. They differ in composition from present day carbonic fluids in the field (richer in $CH_4$, poorer in $H_2O$). Th are rather low, ~340°-375°C; however, these fluids appear to have been trapped earlier than brines (in sample from well Sasso 22 at 4000 m). Their Tt must therefore have been higher (~550°C), that means a confining P at the time of trapping of about 1.2 kb; this is a lithostatic pressure, in good agreement with the depth of the samples. The origin of these fluids is sought in the devolatilization of C-rich low-grade surrounding rocks.

II. Late fluids are characterized by Th consistent with T observed presently in the drill holes. Two types of fluids are again present:

1. Aqueous liquids with Te ~-30°/-40°C suggestive of the presence of a divalent cation; there are both brines (Tm ice -20°C, i.e., 22% wt. eq. NaCl) and low to moderate saline fluids (2 to 12% wt. eq. NaCl), with a possible dilution trend. Th are in the range 300°-350°C.

2. $CO_2$-bearing aqueous vapors and liquids of very low salinity (2- and 3-phase inclusions). Th are in the range 270°-285°C, lower than the present day T at the same level. To obtain Tt in the order of present day ones, a confining P at the time of trapping must be considered, which is intermediate between the present day hydrostatic P and a lithostatic one. Compositions are close to those of present day aquo-carbonic fluids, which are however much more water diluted.

These late fluids record transition of the system from the early contact metamorphism stage (lithostatic P, high T) towards the present day situation (hydrostatic P, T <350°C). (Authors' abstract)

MARLEY, N.A., ROGERS, P.Z., BENJAMIN, T.M. and JANECKY, D.R., 1987, The study of metal speciation at high temperatures and pressures via laser Raman spectroscopy (abst.): EOS, v. 68, p. 1538.

MARRA, R.K., POETTMANN, F.H. and THOMPSON, R.S., 1987, Density of crude oil saturated with carbon dioxide: Proc. 57 Annual Meeting Soc. Petroleum Engineers, SPE 16350, p. 283-295.

Of pertinence to problems of $CO_2$-HC equilibria in fluid inclusions. (E.R.)

MARSHALL, T.E. and FINFINGER, G.L., 1987, Gas content determinations of salt samples using acoustic responses: U.S. Bur. Mines Rept. Invest. RI 9113, 14 pp.

MARSHALL, W.L., 1987, Electrical conductance of liquid and supercritical water evaluated from 0°C and 0.1 MPa to high temperatures and pressures. Reduced-state relationships: J. Chem. Eng. Data, v. 32, p. 221-226.

MARTI, K. and CRAIG, H., 1987, Cosmic-ray-produced neon and helium in the summit lavas of Maui: Nature, v. 325, no. 6102, p. 335-337.

MARTY, B. and JAMBON, A., 1987, C/$^3$He in volatile fluxes from the solid earth (abst.): Terra Cognita, v. 7, no. 2-3, p. 407.

MARUÉJOL, P., CUNEY, M. and TURPIN, L., 1987, Mineralogical controls on REE, Y, Th, and U mobility in the Xihuashan S-deposit granites (Jiangxi, China): Rev. Brasileira de Geociências, v. 17, no. 4, p. 647-650. First author at CREGU, BP 23, 54501 Vandoeuvre-les-Nancy, France.

The slightly peraluminous leucogranitic apex of the Xihuashan district (southern Jiangxi) presents four intrusions emplaced during Upper Jurassic, that are affected by several alterations: early albitization, chloritization, greisenization, quartz leaching + Na-K metasomatism, and secondary silicification.

Microthermometry and Raman spectrometry shows two groups of fluids in the residual quartz of the K-metasomatites: a) a $H_2O$-$CO_2$ fluid (5 to 10% of the inclusions) with $H_2O$ L > $CO_2$ L + G, high $CO_2$ density (0.78-0.88 g/cm$^3$), 2 to 8 mol% $CH_4$ + $N_2$ and Th >200°C; and b) low-saline $H_2O$ fluids (90-95% of the inclusions) with $H_2O$ L > $H_2O$ G with 7.3 to 6.6% eq. NaCl and Th = 200°C and 1.4% eq. NaCl and Th = 175°C. Carbonic and moderately saline fluids have been also observed in the quartz-wolframite veins of the Xihuashan mine (Giuliani et al., 1983). (Shortened from the authors' extended abstract, by K. Fuzikawa)

MASSARE, Dominique, 1987, High pressure heating stage (P max = 700 MPa) for study of geological inclusions (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, Portugal, May 4-6, 1987, p. 81 (in French).

See next item and Couty, et al. (1987), this volume. (E.R.)

MASSARE, Dominique and CLOCCHIATTI, Roberto, 1987, Pressure effect on homogenization temperatures of fluid and melt inclusions: First data from high pressure microscope stage in the 0.1-400 MPa; 200-850°C range: C.R. Acad. Sci. Paris, v. 305, Ser. II, p. 1207-1210 (in French; English abstract).

A new high P (to 700 MPa), high T (to 1400°C) microscope stage has been used to measure the P effect on Th of fluid and melt inclusions in hydrothermal quartz and volcanic sanidines. In quartz synthetized in a hydrothermal environment, aqueous fluid inclusions show a 9°C/100 MPa (1 kb) P effect in the 200-250°C T range and 0.1-400 MPa measure ranges. Rhyolitic melt inclusions trapped in sanidines show a much greater P effect: Th decrease by up to 70°C/100 MPa in the T range 560-850°C for the same P field as above. (Authors' abstract)

MATHEZ, E.A., 1987, Carbonaceous matter in mantle xenoliths: Composition and relevance to the isotopes: Geochim. Cosmo. Acta, v. 51, p. 2339-2347.

MATHEZ, E.A., BLACIC, J.D., BEERY, J., HOLLANDER, M. and MAGGIORE, C., 1987, Carbon in olivine: Results from nuclear reaction analysis: J. Geophys. Res., v. 92, no. B5, p. 3500-3506. First author at Dept. Min. Sci., Am. Museum of Natural History, New York.

None of the samples studied showed C in concentrations above the detection limit. (E.R.)

MATHEZ, E.A. and HOLLOWAY, J.R., 1987, The evolution of C-O-H-Cl fluids during crystallization [of] mafic magma (abst.): EOS, v. 68, p. 1542. First author at Dept. Min. Sci., American Museum of Natural History, New York, NY 10024.

The nature of C-O-H-Cl fluids evolved during crystallization of mafic magma in the shallow crust has been investigated with a free energy minimization procedure and considering all species in the JANAF tables. HCl is the major Cl species throughout most of the system. In H-poor fluids in equilibrium with graphite, $COCl_2$, $CCl_4$, and $Cl_2$ are present; in those more H-rich than CO-$CO_2$-HCl mixtures, $CH_3Cl$ is a major species. The position of the graphite surface in the C-O-H-Cl tetrahedron extends for HCl to near $CO_2$, $CH_4$ and $CCl_4$ on the binary joins eminating from C, depending on T and P. Graphite stability is not strongly influenced by T and P in Cl-rich fluids.

In relatively oxidized fluids $fO_2$>log (QFM-2) nearly all Cl exists as HCl, and $H_2O$ is present only to the extent that bulk atomic H > Cl. This behavior and the low solubilities of C and Cl compared to H in mafic melts at P imply that the first vapor to exolve from Cl-bearing magma will consist of a mixture of $CO_2$, CO and HCl and contain little $H_2O$, even for a relatively hydrous magma. During cooling, magmatic vapors evolve to more H-rich compositions by exsolution of progressively more $H_2O$ from residual melt and crystallization of graphite. If alkali contents are low, $CH_3Cl$ will form, the effect of which is to strongly depress relative abundances of $H_2O$ and $CH_4$. (Authors' abstract)

MATSUHISA, Yukihiro, 1986, Effect of mixing and boiling of fluids on isotopic compositions of quartz and calcite from epithermal deposits: Mining Geol., v. 36, no. 6, p. 487-493. Author at Geol. Survey Japan, 1-1-3 Yatabe-Higashi, Ibaraki-ken, 305 Japan.

Oxygen and carbon isotope effects due to boiling and mixing of fluids were examined for epithermal vein systems. The magnitude of oxygen isotope change of fluid which could be produced by boiling is not greater than 2‰ at >100°C. In case of carbon isotopes, boiling could produce an increase in $\delta^{13}C$ values of precipitating calcite (up to 2 to 3‰) due to increasing pH of the fluid. Mixing of a deep hydrothermal fluid with a low-T groundwater could provide a wide range of $\delta^{18}O$ values in a relatively small T interval, depending upon variable initial compositions of the deep hydrothermal fluid. The data for quartz and calcite from the Kushikino Au-bearing epithermal veins suggest either boiling or mixing with a low-T groundwater of a slightly $^{18}O$-enriched (by 3 to 4‰) deep hydrothermal fluid. (Author's abstract)

MATTER, Albert, PETERS, Tjerk and RAMSEYER, Karl, 1987, $^{87}Sr/^{86}Sr$ ratios and Sr-contents of deep groundwaters, minerals and rocks of the crystalline basement and the Triassic sediments from northern Switzerland: Eclogae Geol. Helv., v. 80, no. 2, p. 579-592 (in German; English abstract).

MATTEY, D.P., PILLINGER, C.T. and MENZIES, M.A., 1986, Abundances and carbon isotope compositions of trapped fluids in mantle diopsides: Implications for mantle recycling models (abst.): Fourth Int'l. Kimberlite Conf. Extended Absts., Geol. Soc. Australia Abst. Series No. 16, p. 276-278. First author at Dept. Earth Sci., The Open Univ., Walton Hall, Milton Keynes MK7 6AA, UK.

The stable isotopic compositions of both carbon in $CO_2$ ($\delta^{13}C$ = -9 to -15‰ rel. to PDB) and hydrogen in $H_2O$ ($\delta D$ = -32‰ to -46‰ rel. to SMOW) in back arc basin basalts are different from normal mid-ocean ridge basalts ($\delta^{13}C$ = -6.5‰ and $\delta D$ = -80‰, respectively). This observation provides important evidence for recycling of volatile components from subducted lithosphere and suggests that light element isotope ratios potentially act as sensitive tracers of recycled crustal components in mantle processes. The ubiquitous presence of fluid inclusions in mantle minerals offers a direct means of studying the relationship between mantle volatiles and the petrology and geochemistry of host nodules and magmas. We have used stepped heating, vacuum crushing and high sensitivity mass spectrometry to measure the abundance and isotopic composition of $CO_2$ in diopsides separated from exceptionally well preserved mantle nodules.

Stepped heating clearly resolves two isotopically distinct carbon components in all the samples. The first component dominates the release profile and is released by oxidation with a maximum release peak at 400°C. This component has a uniform isotopic composition (-28 ± 2‰) and is believed to be surficial organic contamination. A second isotopically distinct component is released at higher T, usually above 800°C. This form of carbon is indigenous and may be derived from a number of possible sites. These include 1) $CO_2$ (and possibly CO and $CH_4$) released by the decrepitation of fluid inclusions; 2) molecular $CO_2$ (or other gaseous carbon species) contained within the diopside lattice; 3) decomposition of carbonate species, existing within the lattice, as veins or as daughter crystals in fluid inclusions; 4) oxidation of reduced carbon (e.g., graphite).

Combined pyrolysis/combustion heating experiments suggest that elemental carbon or CO are not present in the samples studied and that $CO_2$ is the principle species released. The source of this $CO_2$ is probably from fluid inclusions, or from the lattice. Vacuum crushing experiments confirm that the contents of the PS and S fluid inclusions which characterize some samples are pure $CO_2$. Other samples do not contain visible fluid inclusions, do not produce $CO_2$ on vacuum crushing and yet release significant quantities $CO_2$ at high T (>1000°C). This carbon must exist as molecular $CO_2$ (or $CO_3^-$) within the diopside lattice. In general, the origin of $CO_2$ released at high T is most likely to be lattice $CO_2$, with a variable contribution from fluid inclusions, according to their abundance, size, and dimensions of their host mineral grain. $CO_2$ from fluid inclusions appears to be released over a wide T range, and can [be] partially masked by the low T contamination release (200°C to 600°C). However, carbon released at high T by stepped heating is wholly indigenous, dominantly released from the diopside lattice, and could be closely associated with the crystallization environment of the diopside.

A possible interpretation of the C-He-Nd data is that subcontinental lithosphere preserves relict carbon isotope heterogeneity, possibly primordial, but more probably related to ancient subduction events, which has either overwritten, or has been overwritten by, other fluids with MORB-source characteristics. (Abbreviated from the authors' abstract by E.R.; references deleted.)

MATYASH, I.V., BAGMUT, N.N. and BOYKO, D.V., 1987, The possible participation of ammonium in the geochemical transfer of gold: Geologicheskiy Zhurnal (Kiev, 1968), v. 47, no. 5, p. 133-136 (in Russian; English summary).

MAYER, Erwin and HALLBRUCKER, Andreas, 1987, Cubic ice from liquid water: Nature, v. 325, p. 601-602. Authors at Inst. Anorgan. & Anal. Chem., Univ. Innsbruck, A-6020 Innsbruck, Austria.

Hexagonal ice (ice Ih) is the only form of ice that is known to occur naturally on the Earth. Recently it has been suggested that small droplets of water in the upper atmosphere may often freeze first to cubic ice (ice Ic), which is metastable relative to ice Ih. The evidence is Scheiner's halo, a rare halo that occurs at ~28° from the Sun or the Moon, and the observation that dendritic snowflakes often have their c-axes at about 70° to one another. Here we report the formation of cubic ice from liquid water at <200 K, using a method for vitrifying pure liquid water, namely rapid quenching of aqueous aerosol droplets ~3 μm in diameter on a cryoplate. Cubic ice made from liquid water transforms much more slowly to the stable form than sample prepared by deposition of the vapor. Speculations about naturally occurring ice Ic are supported by our results. (Authors' abstract)

MAYO, A.L. and MULLER, Anthony, 1987, Deep origin of $CO_2$ gas, in a shallow ground water system, from thermal decomposition of carbonate minerals beneath the Ute Pass overthrust fault (abst.): Geol. Soc. Am. Abst. with Programs, v. 19, p. 429-430. First author at Dept. Geol., Brigham Young Univ., UT.

In Manitou Springs, CO, historically a health spa for native Americans and later for wealthy tourists, more than 30 small discharge springs (less than 0.5 l $s^{-1}$) issue near the Ute Pass Thrust Fault of the Rocky Mountain Front Range. Evolving $CO_2$ gas constitutes 1/4 to 1/2 of total discharge volume of springs associated with the Paleozoic sedimentary rocks, whereas the springs associated with the Pikes Peak granite do not evolve $CO_2$. The copious $CO_2$ discharges indicate an external $CO_2$ source.

The $\delta^2H$ and $\delta^{18}O$ data, which cluster near the meteoric water line at about -85 and -12, respectively, suggest both $CO_2$ and non-$CO_2$ evolving waters recharged under similar climatic and elevation conditions. Significantly, none of the discharge waters have been subjected to thermal conditions which would cause an $^{18}O$ shift. The $\delta^{13}C$ contents, about -2 for $CO_2$ springs and -10 for non-$CO_2$ springs, suggest different $CO_2$ sources. $\delta^{13}C$ data from $CO_2$ evolving springs are consistent with carbon from a carbonate source.

The isotopic data suggest that large quantities of $CO_2$ gas evolve at depth by the thermal decomposition of Paleozoic carbonate rocks which lie beneath the Precambrian granites of the Front Range. The $CO_2$ gas then migrates up the Ute Pass overthrust fault, where it encounters a shallow ground water system in the near surface Paleozoic sediments. (Authors' abstract)

MEIER, A.L. and LICHTE, F.E., 1987, Inductively coupled plasma mass spectrometry - Applications of a new technique in the study of mineral formation processes (Extended abst.): U.S. Geol. Survey Circular 995, p. 44-45.

Inductively coupled plasma mass spectrometry (ICP-MS) is a relatively new analytical technique that is extremely useful in studies of mineral formation processes. The high sensitivity and the low limits of detection (0.02-0.1 ng $mL^{-1}$) of this technique are providing previously unobtainable information for the investigation of transport mechanisms and mobility of many elements in hydrothermal systems. (From the authors' abstract)

MEIER, G., JOHANNES, W. and SCHLIESTEDT, M., 1987, The Varberg charnockite in SW Sweden - petrography, geochemistry and fluid inclusions (abst.): Fortschritte der Mineralogie, Bd. 65, Bhf. 1, p. 133 (in German). Authors at Univ. Hannover, FRG.

Charnockitic rocks are the object of extensive petrologic studies. In the newer literature charnockites are considered as products of granulite facies metamorphism under action of possibly mantle $CO_2$-rich fluids, which are necessary for origin of a "dry" mineral paragenesis. In the area of Varberg (SW Sweden) there occur charnockites which, on the basis of contacts with wall rock, are believed to be intrusive. Due to the mineral composition, two types of charnockite can be distinguished: A - plagioclase, orthoclase, quartz, orthopyroxene, clinopyroxene, garnet, hornblende; B - orthoclase, plagioclase, quartz, hornblende, biotite, clinopyroxene, orthopyroxene. The large perthitic orthoclase crystals are typical of B, frequently occurring in schlieren many meters in size. In charnockites there occur pyroxene-free granitic bodies consisting of quartz, microcline >> orthoclase, plagioclase, hornblende and biotite. The granitic rocks sometimes display sharp contacts with charnockite B. (...) There are continuous variations of major and trace elements from type A through type B to granites: increase of Si, Rb and K, decrease of Ti, Mg, Fe, P, Ca, Mn, Sr, Ba, Sc, Y, V, Zn, Nb and Ce. Fluid inclusions in quartz from charnockite are essentially $CO_2$-rich with most common densities 0.95 and 0.6 g/cm$^3$. For granites the $CO_2$ inclusions have density 0.6 g/cm$^3$ and $H_2O$ inclusions - 0.95 g/cm$^3$. The hypothesis of origin of charnockites by fractional crystallization and/or dehydration caused by $CO_2$ inflow is presented. (Authors' abstract, translated by A.K.)

MEINERT, L.D., 1987, Skarn zonation and fluid evolution in the Groundhog mine, Central mining district, New Mexico: Econ. Geol., v. 82, p. 523-545. Author at Geol. Dept., Washington State Univ., Pullman, WA 99164-2812. Continued

The Groundhog mine contains one of the largest and best exposed Zn-Pb-Cu-Ag skarn deposits in the United States. Skarn is formed in Carboniferous limestones spatially associated with a nearly vertical swarm of Early Tertiary granodiorite porphyry dikes. Metal ratios, mineralogy, composition, and fluid inclusion characteristics of the skarn are systematically zoned from northeast to southwest along the >3-km strike length of the system and relative to the original dike-limestone contact.

Fluid inclusion Th are lower than for most zinc skarns. In the Northeast skarn zone the average Th is 337°C and salt dms are present in garnet and pyroxene (inclusions without dms average 8.5 wt % NaCl), whereas salt dms are absent in the Central and Southwest skarn zones and average Th and salinities are 320°C, 7.3 wt % NaCl, and 293°C, 6.2 wt % NaCl, respectively. P estimates from rare clusters of fluid inclusions with evidence for boiling are between 155 and 175 bars.

Skarn thermal gradients calculated from fluid inclusion Th are 35°C from dike to marble front and 50°C from dike to the limit of alteration (carbonate replacement mantos and chimneys). The calculated average thermal gradient along strike ranges from 8°C/km along the dike contact to 23°C/km along the marble front. The calculated thermal gradients and measured pyroxene compositions are in general agreement with published experimental studies of clinopyroxene stability relations.

The variations in skarn metal ratios, mineralogy, composition, and fluid inclusion characteristics have been incorporated into a general model for zinc skarn formation which can be a guide to exploration. (From the author's abstract)

MENZIE, W.D., HUA, Renmin and FOSTER, H.L., 1987, Newly located occurrences of lode gold near Table Mountain, Circle quadrangle, Alaska: USGS Bull. 1682, 13 pp.

The deposits formed from low-saline fluids (10 wt% NaCl eq.) whose sulfur fugacities were within the stability field of pyrrhotite. Based upon fluid-inclusion data, we infer that the occurrences formed at moderate T from fluids that initially boiled, over the range 370 to 320°C, and then gradually cooled. Field relations and estimated depths of formation of contact metamorphic effects and quartz veins indicate that the occurrences formed in an active tectonic environment. (From the authors' abstract)

MERCOLLI, Ivan, SKIPPEN, George and TROMMSDORFF, Volkmar, 1987, The tremolite veins of Campolungo and their genesis: Schweiz. Mineral. Petrogr. Mitt., v. 67, p. 75-84. First author at Min.-Petrogr. Inst., Baltzerstr. 1, CH-3012 Bern, Switzerland.

Metasomatic veins in Triassic dolomite rocks at Costello, Campolungo, Switzerland, formed by the reaction: 5 dolomite + 8 quartz + $H_2O$ = tremolite + 3 calcite + $7CO_2$.

Reaction occurred by infiltration of fluid along the contact between dolomite and preexisting quartz veins. Evidence from fluid and solid inclusions indicates that fluids of very high salinity were involved in the metasomatic process. The composition of the incoming fluid was not in equilibrium with quartz and dolomite and resulted in the formation of tremolite + calcite at the expense of the reactant minerals.

High salt contents may be related to an evaporitic source rock for the fluids as indicated by oxygen isotope measurements on carbonate minerals. Representative oxygen carbon and oxygen isotope data from coexisting calcite and dolomite in the veins are: $\delta^{13}C(PDB)(dolomite) = 0.04$; $\delta^{13}C(PDB)(calcite) = 0.02$; $\delta^{18}O(PDB)(calcite) = -8.1$.

The structural position of the veins at Costello and postkinematic growth of tremolite are consistent with geothermometry and geobarometry which indicate that reaction occurred during uplift and cooling of the rock mass.

The heat necessary to drive the above devolatilization reaction to the right could have been provided by hot fluids entering the vein system or it could have been derived from wall rock adjacent to the veins. The presence of unreacted quartz and dolomite in close proximity suggests that $H_2O$ was in limited supply. A wall rock source for the heat is therefore considered more likely. (Authors' abstract)

MERLIVAT, L., PINEAU, F. and JAVOY, M., 1987, Hydrothermal vent waters at 13°N on the East Pacific Rise: Isotopic composition and gas concentration: Earth & Planet. Sci. Letters, v. 84, p. 100-108. First author at Lab. Géochimie Isotop., L.O.D.Y.C. (UA CNRS 1206), CEA/IRDI/DESICP, Dépt. Physico-Chimie, 91190 Gif sur Yvette, France.

Gas concentrations and isotopic compositions of water have been measured in hydrothermal waters from 13°N on the East Pacific Rise. In the most Mg-depleted samples ($\cong 5 \times 10^{-3}$ moles/kg) the gas concentrations are: $3\text{-}4.5 \times 10^{-5}$ $cm^3$ STP/kg helium*, 0.62-1.24 $cm^3$ STP/kg $CH_4$, $10.80\text{-}16.71 \times 10^{-3}$ moles/kg $CO_2$. The samples contain large quantities (95-126 $cm^3$/kg) of $H_2$ and some carbon monoxide (0.26-0.36 $cm^3$/kg) which result from reaction with the titanium sampling bottles. $\delta^{13}C$ in methane and $CO_2$ (-16.6 to -19.5 and -4.1 to -5.5 respectively) indicate temperatures between 475 and 550°C, whereas $\delta^{13}C(CO)$ is compatible with formation by reduction of $CO_2$ on Ti at 350°C close to the sampling temperature. $^3He/^4He$ are very homogeneous at $(7.5 \pm 0.1)R_A$ ($^3He/^4He = 1.0 \times 10^{-5}$) and very similar to already published data as well as $CH_4/^3He$ ratios between 1.4 and $2.1 \times 10^6$. $^{18}O$ and D in water show enrichments from 0.39 to 0.69%. and from 0.62 to 1.49%. respectively. These values correspond to W/R ratios of 0.4-7. The distinct $^{18}O$ enrichments indicate that the isotopic composition of the oceans is not completely buffered by the hydrothermal circulations. The $^3He$-enthalpy relationship is discussed in terms of both hydrothermal heat flux and $^3He$ mantle flux. (Authors' abstract)

*[A less ambiguous format would give units of "$cm^3$ He(STP)/Kg." (E.R.)]

METRICH, Nicole and GSTALTER, Nicole, 1987, Sodium diffusion between quartz and their melt inclusions (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 83. Authors at Lab. Pierre Süe C.E.N. Saclay, 91191 Gif-sur-Yvette, France.

Melt inclusions of the quartz crystals from a pumice deposit of "Grande Découverte" volcano (Guadeloupe) show a rhyolitic composition with a high volatile content ($H_2O$, Cl). These glass inclusions were considered to represent trapped magmatic liquid. Their $Na_2O$ concentration is 4.0 wt% ($Na_2O/K_2O = 1.9$).

The exchanges which occur between the host mineral and included glasses were investigated at 810°C (Th of the melt inclusions), using an Adamel furnace. Crystals have been air quenched, after few hours (1h30, 6, 12, 24 hours) to few days (7, 8, 30 days). Then, melt inclusions were analyzed with electron microprobe.

When the quartz faces contacted NaCl, during experiments, $Na_2O$ content of the melt inclusions increases (5 to 8 wt%), as [does] $Na_2O/K_2O$ ratio (up to 3.9). Cl concentrations are not modified (3060-3260 ppm).

Diffusion coefficient $D = 4.2\ 10^{-7}\ cm^2.sec^{-1}$, at 810°C (according to Rybach and Laves, 1967; Geoch. Cosmo. Acta, v. 31, p. 539), is consistent with a Na selective diffusion process through the crystal network. During all the experiments of a few days, a sodium enrichment of the glass inclusions occurs. Such $Na_2O$ concentrations (5.5 to 8 wt%) and $Na_2O/K_2O$ ratio measurements have never been obtained from natural glasses (melt inclusions or obsidian) of Grande Découverte volcano. A positive correlation exists between the $Na_2O$ enrichment and the volume of the cavities. The results leads [us] to consider that Na can migrate from the quartz towards melt inclusions. In some cases a contribution of the glassy film enclosing the crystal (representative of the residual glass) cannot be ruled out. (Authors' abstract)

MEUNIER, J.D. and BREIT, G.N., 1987, Fluid inclusion studies in calcite associated with sandstone-hosted uranium-vanadium deposits of the Colorado Plateau: Int'l. Atomic Energy Agency Tech. Committee Meeting on Uranium Resources & Geol. of North America, 31 Aug.-4 Sept., 1987, Saskatoon, Canada, Abstracts, p. 1. First author at CREGU, BP 23, 54501 Vandoeuvre les Nancy Cedex, France.

From all the present authigenic transparent minerals (quartz overgrowth, barite, calcite, dolomite, ...) only calcite contains usable fluid inclusions. Calcite from three deposits has been analyzed: Cottonwood Wash (Morrison Formation, Utah), Slick Rock District (Morrison Formation, Colorado), Grants Mineral Belt (Todilto Limestone, New Mexico).

In Cotonwood Wash and Slick Rock District, calcite replacing logs contains fluid inclusions characterized by low salinities and Th close to 90°C. Similar fluids have been found in coarse grained calcite in the Todilto Limestone.

In the Slick Rock District a 9% wt. NaCl water with Th ≈ 90°C and a dilute water with Th ≈ 70°C have been observed in calcites associated with Cu deposits located in the Laramide fault.

Comparison of these results with petrographic data and the geochemistry of organic matter leads to a better evaluation of the diagenetic history of host rocks. Consequences for U-V ore deposits are discussed. (Authors' abstract)

MEUNIER, J.-D., LANDAIS, Patrick, MONTHIOUX, Marc and PAGEL, Maurice, 1987, Oxidation-reduction processes in the genesis of the uranium-vanadium tabular deposits of the Cottonwood Wash mining area (Utah, USA): Evidence from petrological study and organic matter analysis: Bull. Minéral., v. 110, p. 145-156. First author at CREGU et Groupement Sci. CNRS-CREGU BP 23, 54501 Vandoeuvre-les-Nancy Cedex, France.

The highest T recorded by fluid inclusions and organic matter evolution in these sandstones ranges from 90 to 120°C (E.R.)

MEYER, H.O.A., 1987, Inclusions in diamond, in Mantle Xenoliths, P.H. Nixon, ed.: John Wiley & Sons, p. 501-522. Author at Dept. Geosci., Purdue Univ., W. Lafayette, IN 47907, USA.

A large number of minerals occur as inclusions in diamonds; notable among them are olivine, garnet, pyroxene, spinel, and sulphides. On the basis of chemical compositions they may be subdivided into two major groups - an ultramafic suite and an eclogitic suite, and possibly a new minor calc-silicate suite. These suites reflect differences in the geochemical environment in which the host diamonds formed. The physical nature of the environment is uncertain since evidence can be cited in favor of crystallization from a partial melt (igneous) or from a solid state transformation (metamorphic). Data from various isotopic studies are at present insufficient to provide an answer to this problem, although recent isotopic investigation of inclusions has suggested that these, and the host diamonds by inference, are Archean in age, in spite of the kimberlite from which they were obtained being Mesozoic. The relationship of diamond to kimberlite, and probably lamproite, is one of passenger to transporting medium. In the absence of evidence to the contrary it is possible that some diamonds (say eclogitic) are the result of subduction whereas others (say ultramafic) represent primitive mantle carbon. (Author's abstract)

MEYER, P.S. and SHIBATA, Tsugio, 1987, Complex zoning patterns in plagioclase feldspars from Serocki volcano (abst.): EOS, v. 68, p. 456. First author at Woods Hole Oceanographic Inst., Woods Hole, MA 02543.

Serocki volcano is located at 22°55'N on the axis of the Mid-Atlantic Ridge (MAR). This segment of the MAR is pervasively faulted and fissured (Detrick et al., 1985) and appears volcanically old with sediment-covered lava flows that are characterized by relatively low magnetizations (Schulz et al., 1986). ODP drilling on Legs 106 and 109 at site 648 penetrated 50 m of moderately plagioclase-olivine phyric basalt. The cored basalt is chemically homogeneous and represents one eruptive unit with several cooling units. Plagioclase phenocrysts in site 648 basalts exhibit diverse morphologies and complex zoning patterns. Chemical mapping of these crystals using backscattered electron images and spot analyses on the electron microprobe indicate at least 3 distinct cores; 1) a tabular core ($An_{80-84}$) free of melt inclusions, 2) a resorbed core ($An_{76-78}$) with equant (10-40 μm) melt inclusions, and 3) a skeletal core with elongated (100-500 μm) melt inclusions and patchy zones of $An_{80-82}$ showing sharp boundaries with areas of $An_{76}$ and $An_{72}$. The core compositions are all more calcic than that ($An_{70-72}$) calculated to be in equilibrium with the glasses and whole-rock analyses from this site. Trace element concentrations in the cores measured on the ion probe indicate small variations in K (150-200 ppm) and Sr (150-200 ppm) but large variations in Ti (10-160 ppm) and moderate variations in Mg (1100-1380 ppm) and Fe (3200-3700 ppm). Major and some trace element variations can be explained by polybaric fractionation and mixing of different magmas. In addition, the large variations in Ti require a nonuniform partition coefficient, possibly relfecting disequilibrium partitioning. Combined geophysical and petrological investigations suggest Serocki volcano represents the waning stages of volcanic activity in an area of generally low magma budget. (Authors' abstract)

MICHELS, D.E., 1987, Salinity stabilization for non-convecting brine in a temperature gradient (abst.): EOS, v. 68, p. 439. Author at Don Michels Assoc., P.O. Box 895, Whittier, CA 90608.

An approximately uniform liquid density with depth, in the presence of a thermal gradient has been long recognized in the Salton Sea Geothermal Field. The requirements for getting such a situation established and sustained in the presence of heat flow that appears to require some advection have been only partly explored. The SSSDP fluid composition can be interpreted to have increasing salinity with depth and other nearby wells clearly are so endowed.

Given brine density (D) as a function of temperature (T) and salt content (N) the implicit relationship $dN/dT = (\partial D/\partial T)/(\partial D/\partial N)$ can be evaluated at constant density to provide a limiting condition for non-advection. In combination with observed temperature gradients, the gravitationally stable salinity gradient over depth (Z) is given as $(dN/dZ)_D = (dN/dT)(dT/dZ)$. In the vicinity of 300°C and gradients of .036 C/m, brine gradients exceeding about 30 ppm/meter are non-advective.

However, some redistribution of materials can still take place, for example the fugacity of water would tend to become leveled, yielding steeper salinity gradients than required to stabilize the temperature gradient. (Author's abstract)

MIES, J.W. and GLAZNER, A.F., 1987, Quartz xenocrysts with rhyolite glass inclusions in andesite as evidence of assimilated granite (abst.): EOS,

v. 68, p. 434-435. Authors at Dept. Geol., Univ. North Carolina, Chapel Hill, NC 27514.

Deeply embayed quartz crystals in andesite are generally interpreted to be xenocrysts. Eichelberger (1978) observed that these xenocrysts often contain rhyolite glass inclusions, and reasoned that the xenocrysts must therefore be phenocrysts inherited from rhyolite magma which mixed with basalt magma to form andesite. We observe, however, that quartz grains in partially fused granite also bear rhyolite glass inclusions and are similar in texture to quartz xenocrysts in andesite. Thus, glass-bearing quartz xenocrysts may be derived from assimilated granite.

Cretaceous(?) biotite granite north of Mono Lake, California, is intruded and fused by a Tertiary andesite plug. Resorbed quartz grains in partially fused granite (50 vol% glass) have irregular shape, are deeply embayed, and bear small (~0.3 mm) rhyolite glass inclusions. Plagioclase and K-feldspar crystals in the same rock are rounded and skeletal with narrow glass channels. Brown rhyolite glass separates incompletely digested quartz and feldspar.

A rhyolite melt (preserved as glass) develops in granite at quartz-feldspar grain boundaries. Spherical, colorless inclusions of rhyolite glass within quartz grains are fused inclusions of alkali feldspar. The irregular form of partially fused quartz reflects the concave, intergranular morphology of quartz in the fresh granite. Deep lobate embayments in quartz form when glass inclusions are breached. Diffusive mixing of colorless glass and brown intergranular glass is observed at many embayments.

Based on these observations, the simplest explanation for quartz xenocrysts in andesite with (1) deep embayments, (2) irregular shapes, (3) rhyolite glass inclusions, and (4) brown glass jackets is assimilation of granite. These observations may also apply to the origin of deeply embayed quartz phenocrysts in rhyolites. Such phenocrysts are generally thought to result from either resorption by the melt or from rapid growth, but they may instead be incompletely melted remnants of the material that was fused to form the rhyolite. (Authors' abstract)

MILLER, G.H., ROSSMAN, G.R. and HARLOW, G.E., 1987, The natural occurrence of hydroxide in olivine: Phys. & Chem. Min., v. 14, no. 5, p. 461-472.

MILLS, R., EASTEAL, A.J. and WOOLF, L.A., 1987, Viscosities and intradiffusion coefficients in the Ternary system $NaCl-MgCl_2-H_2O$ at 25°C: J. Solution Chem., v. 16, no. 10, p. 835-840.

MIYATA, Takeshi, HOSAKA, Masahiro and CHIKAYAMA, Akira, 1987, On the inclusions in emeralds from Santa Terezinha de Goias, Brazil: J. Gemm., v. 20, no. 6, p. 377-379. First author at Inst. Gemm. & Jewelery Arts of Yamanashi, Tokojicho, 1955-1, Kofu, 400, Japan.

Electron microprobe study showed the inclusions were pyrite, magnesioferrite, and mica (possibly biotite). (From the authors' abstract)

MOERS, Mia and KREULEN, Rob, 1987, Experimental determination of isochores for 30-wt.% $MgCl_2$ solutions: Chem. Geol., v. 61, p. 55-58. Authors at Inst. Earth Sci., Dept. Geochem., Univ. Utrecht, 3508 TA Utrecht, The Netherlands.

This study reports the investigation of isochores for 30-wt.% $MgCl_2$ solutions at several densities (viz. 75%, 80%, 85% and 90% filling degree) up to 700°C and 5000 bar. Sealed quartz capillaries filled with $MgCl_2$ solution were heated in cold-seal P vessels. The capillaries exploded when the P inside the capillaries exceeded the confining P by 10-20 bar, and the sound of this explosion was recorded. The starting points of the isochores were determined from Th.

To check the reliability of this new method, two isochores for a 20-wt.% NaCl solution were determined and compared with data from the literature. The results are quite satisfactory, yielding isochores that are approximately straight lines. Fitting of the experimental results on a third-degree polynomial (the MRK equation) shows that the isochores form an internally consistent set, and permits extrapolation to lower and higher densities. (Authors' abstract)

MOGAMI, Yoshihiro and BABA, S.A., 1986, Temperature control systems for light microscopes: Natural Sci. Rept., Ochanomizu Univ., v. 37, no. 2, p. 169-172. Authors at Dept. Biology, Ochanomizu Univ., 2-1-1 Otsuka, Tokyo 112, Japan.

Although done for biological use, pertinent to fluid inclusion designs as well. (E.R.)

MOGE, M., 1987, Geochemical study of diagenetic phases of Jurassic sandstones from the Viking graben (North Sea) (abst.): Terra cognita, v.7, p.341. Author at TOTAL Compagnie Francaise des Pétroles, Laboratoires Exploration, Pessac, France.

The study of fluid inclusions, linked with syntaxial overgrowth of quartz grains, has shown that the inclusions contain water or hydrocarbon and that the minimum Tt is ≈ 105°C (true T is ≈ 130°C for P-200 bars).

Stable isotope analysis, cathodoluminescence observations and microprobe analysis of the carbonate cements confirm the petrographic distinction between the different carbonate phases. However, the fluid inclusion study of these cements shows that early or late cements have precipitated or recrystallized at a minimum T of ≈ 110°C (true T is ≈ 140°C for P-200 bars). (From the author's abstract)

MOINE, B., CHOPIN, C., FORTUNE, J.P., MOREAU, Ph. and VIGUIER, F., 1987, Metasomatic talc and chlorite deposits as examples of intense fluid-rock reactions in shear zones (abst.): Terra Cognita, v. 7, no. 2-3, p. 132-133. Authors at Lab. Min., UA 67 CNRS, Univ. Paul Sabatier, Toulouse, France.

High density, high Ca and Mg inclusions and mineralogy are used as evidence for T = 500-550°C, P = 8-9 kb. (E.R.)

MOISEYENKO, V.G. and ZAYKIN, I.D., 1987, Ore-bearing and ore-free fluids (according to gas-liquid inclusions in minerals) (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 85-86. Authors at Amur Integrated Res. Inst., USSR Acad. Sci. Far East Sci. Center, 675000, Blagoveshchensk, USSR.

Investigation of inclusions in accessory and host minerals, e.g., quartz, are [frequently assumed to be applicable] to ore minerals. Such an approach is generally unjustified and brings about misunderstanding of deposit genesis. This conclusion is unambiguously confirmed by results of the study of gas-liquid inclusions in native gold from extensive deposits related to extrusive bodies in areas of terrestrial volcanism and from shallow deposits of the gold-quartz formation related to small intrusions and dikes in regions of completed[sic] folding with postorogenic activation.

The fluids which formed native-gold differ, first of all, from ore-free ones in the ratios of water to salts to gases. Ore-free and low-gold quartz was deposited by hydrothermal highly aqueous fluids (salt content 5-7 mol%) with low gas content (0.5-3 mol%). The gold-forming fluids were concentrated (salt content up to 50 mol%) and gas-saturated (gas content up to 30%). Besides, they are characterized by sharp increase in reducing components among gases ($H_2$, $H_2S$, CO) as compared to quartz-forming hydrothermal fluids, this indicating the difference in redox conditions of the processes.

The sum of $Cl^-$, $F^-$, $Br^-$, $I^-$ in the fluids, enclosed in native gold, is higher or comparable to $CO_3^{2-}$ content, indicating the essential difference between gold-bearing and ore-free quartz-forming fluids. (From the authors' abstract)

Note: This paper was not presented at the meeting. (E.R.)

MÖLLER, Peter, 1987, Correlation of homogenization temperatures of accessory minerals from sphalerite-bearing deposits and Ga/Ge model temperatures, in E.E. Horn and H.-J. Behr, guest eds., Current Research on Fluid Inclusions, ECRFI, Göttingen, April 10-12, 1985: Chem. Geol., v. 61, p. 153-159. Author at A.G. Geochemie, Hahn-Meitner-Inst. fur Kernforschung G.m.b.H., D-1000 Berlin 39, FRG.

The Ga/Ge ratio in sphalerite can be related to the T of the initial fluids from which the sphalerite grew after mixing with various amounts of fluids from different origins. The extent of mixing of the two fluids can be qualitatively derived from the P-corrected Th (which represents the T after mixing of the fluids) and the Ga/Ge T of sphalerite which indicates the T of the hot metal-bearing initial fluids. Different T information strongly indicate that mixing of fluids did occur prior to sulphide formation. (Author's abstract)

MONTENEGRO, R., 1987, Applications of the freezing technique to the microthermometric study of fluid inclusions: Actas del Congreso Geol. Argentino 10, v. 2, p. 245-248 (in Spanish; English summary).

MOROZOV, S.A., KHASANOV, A.Kh. and ZEVAKIN, N.N., 1987, Thermobarogeochemical conditions of the formation of amethyst in Tadzhikistan: Dokl. Akad. Nauk SSSR, v. 296, no. 1, p. 200-203 (in Russian).

MÖLLER, P., 1987, Correlation of homogenization temperatures of accessory minerals from sphalerite-bearing deposits and Ga/Ge model temperatures: Chem. Geol., v. 61, no. 1/4, p. 153-159.

Full paper for abstract in Fluid Inclusion Research, v. 18, p. 279, 1985. (E.R.)

MOLLER, P., LUDERS, V. and HOEFS, J., 1987, Chemical conditions of mixing model of precipitation of the Upper Harz ore and vein minerals (abst.): Fortschritte der Mineralogie, Bd. 65, Bhf. 1, p. 139 (in German). First author at Free Univ. Berlin, FRG.

The banded calcite ores of Upper Harz (IIc) are rich in lanthanoids and have no central Eu anomaly. The redox potential of solution was high enough to cause yield trivalent Eu. Fractional dissolution of calcite bands sometimes resulted in negative Eu anomalies near the sulfide bands and relatively constant content of Ce, Zn and Pb. Calcite contains a very low amount of $H_2S$ (<0.2 ppm), the amount of $SO_4$ ranges from 0.5 to 0.8 ppm, $\delta^{34}S$ of sulfates has a value of 1‰, indicating origin by sulfide oxidation. (...) Th of inclusions in vein minerals coexisting with galena and sphalerite bands reach 290°C; $\delta^{34}S$ of these sulfides indicate T between 200 and 270°C. (...) There were at least two parent solutions of minerals with the following characteristics: solution I: rich in Ca, REE, Pb, Zn, Fe and Mn, bearing $CO_2$, Cl content 4-5 M, free of $H_2S$ and $SO_4$, concentration of Zn 30-120 ppm, T >240°C, oxidizing. Solution II: $H_2S$-bearing, $SO_4$-free, T and salinity distinctly lower than solution I. Periodic mixing of solution II with solution I, from which calcite was precipitating at 250°C due to cooling caused the interruption of calcite precipitation and abundant crystallization of sulfides. Low $H_2S$ content resulted in precipitation of galena, its increase in precipitation of sphalerite. Exhausting of $H_2S$ and T increase due to new inflow of solution I caused partial oxidation of sulfides and coprecipitation of sulfates with calcite in the next band. (Authors' abstract, translated by A.K.)

MOLNÁR, Ferenc, 1987, Comparative fluid inclusions studies of the primary rock-forming quartz and the hydrothermal quartz from Neogene rhyolitic environment (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 149-150. Author at Mineral. Dept. of Eötvös Loránd Univ Budapest, Muzeum krt. 4/a, H-1088, Hungary.

The Tokaj Mountains [expose] andesitic-rhyolitic [volcanics]. We studied the fluid-gas inclusions of hexagonal-dipiramidal magmatic quartz grains from the rhyolite tuff and of the prismatic, hydrothermal quartz crystals from the veinlets with geodes ("apophysa") of silicified zones [related to Au-Ag mineralization?].

Inclusion types in magmatic quartz are either glass and crystallite P solid inclusions, or S inclusions which are contemporaneous with the hydrothermal activity. These fluid-gas inclusions fill the space of the dissolved glass inclusions along healed microfractures of the quartz, or they are in healed fractures. These inclusions sometimes contain solid crystals. Th are between 210°C and 295°C. On the basis of cryoscopic measurements the solution can be characterized as a $CaCl_2$-($MgCl_2$)-NaCl-$H_2O$-$CO_2$ system, with a [salinity] of 4.3-5.9 NaCl eq. wt.%.

Inclusion types in quartz crystals of hydrothermal origin are: crystallites of adularia; P, PS, and S inclusions containing liquid plus gas and rarely solid crystals; and S inclusions containing only liquid.

The T of the P and the PS inclusions are between 295°C and 245°C with a sharp maximum at 270°C. On the basis of the freezing data, the fluids trapped in the inclusions can be related to the $CaCl_2$-NaCl-$H_2O$ system without $CO_2$. The cotectic T points out the fact that these inclusions contain less alkali-earth metals than those in the magmatic quartz, [and a slighly higher salinity]: 5-6.2 NaCl eq. wt.%. In comparison to the S inclusions in the magmatic quartz, the inclusions in the hydrothermal quartz reflect an earlier condition of the system. Microthermometric data of the inclusions in the magmatic quartz point out the cooling of the system, probably caused by a $CO_2$-bearing solution, which was in equilibrium with a more basic rock (andesite)[sic]. (Author's abstract)

MONNIN, Christophe, 1987, Densities and apparent molal volumes of aqueous $CaCl_2$ and $MgCl_2$ solutions: J. Solution Chem., v. 16, no. 12, p. 1035-1048.

MONTENEGRO, T.F. and NICOLLI, H.B., 1986, Microthermometry of fluid inclusions in minerals of granitic rocks of the eastern flank of the Sierra del Cobre, Salta Province, Republic of Argentina: Acad. Nacional de Ciencias, Miscelanea No. 72, 48 pp. (in Spanish; English abstract). First author at Dept. Geoquimica y de Aplicaciones Geol. de la Teleobservacion, Com. Nacional de Invest. Espaciales, Fac. Ciencias Exactas y Naturales, Univ. Buenos Aires, Becaria del Consejo Nacional de Invest. Cientificas y Tecnicas.

A great variety of fluid inclusions are present in pegmatoid quartz from a Cretaceous alkalic granitic intrusive. The most abundant are two-phase (saline solution with a vapor bubble) and those with dominant $CO_2$. Two types of fluids have been identified: very high salinity (23-24 % NaCl eq.) and minimum Tt of 80 to 440°C, and low salinity (2-13 % NaCl eq.) and minimum Tt of 100 to 300°C

The circulation of NaCl-rich fluids under various environmental conditions must have given rise to the incorporation of other components; in addition, in several stages of fracture opening with subsequent healing, the trapping of the great variety of inclusions found (most of them S or PS) must have occurred. The associated low-T hydrothermal process is linked to mineral recrystallization phenomena. (Authors' abstract)

MOON, K.J., 1986, Study on the temperature and the origin of mineralization at the Samkwang Au deposits: J. Korean Inst. Mining Geol., v. 19, no. 1, p. 19-24 (in Korean; English abstract).

The Samkwang mine is one of Au deposits distributed mainly in the southwestern province (Chungnam) of the Korean peninsula. Au occurs in quartz veins aged 223 ± 4 MA according to K-Ar age dating from muscovite in a pegmatitic quartz vein. Quartz veins intrude Precambrian biotite-granite gneiss and mica schist of unknown age.

Fluid inclusions in the quartz show a range of Th from 159 to 274°C. A calculated T from the isotopes of the galena-sphalerite pair is 375°C. Two-phase fluid inclusions homogenizing in either liquid or vapor phase are frequently observed in specimens over 260°C, which may indicate the boiling of the fluids. P of formation of the quartz veins inferred by the Th of liquid-$CO_2$ bearing fluid is 1 kb. Based on these data, it is assumed that the T of the formation of the Samkwang mine may lie in between 350°-230°C.

$\delta^{34}S(\Sigma s)$ values of sulphide minerals show narrow range of +2.1 to +4.6, and show a trend of enrichments of $^{34}S$ in the fluid from deep to the surface. $\delta^{34}S(\Sigma s)$ in the fluid estimated is less than 3 permil, suggesting that the sulphur originated from the magma. (Author's abstract)

MOORE, G.R., 1980, A chemical and isotopic study of fluid inclusions from the Northern Pennine Orefield: PhD thesis, Univ. Durham, UK.

The present study was undertaken to investigate the origin of the mineralizing fluids and mechanisms of ore deposition with particular reference to the fluorite/barite mineral zonation.

Fluid inclusions in fluorite, barite and quartz provided the principal material for analysis. Quantitative measurement of the inclusion gases, including water, was carried out by decrepitation (thermal rupture) under vacuum. The decrepitated material was subsequently leached with deionized water and the leachate analyzed for Na, K, Ca, Sr, Mg, Cu, Zn, Fe and Mn by flame photometry and atomic absorption spectrometry; and Cl, F and Br by pyrohydrolysis and neutron activation analysis. Hydrogen isotope analysis on the inclusion fluids showed a greater depletion in deuterium for barite than for fluorite and quartz. This work was complemented by oxygen and strontium isotope studies.

It is concluded that the mineralizing fluids originated from sediments in the deep basins to the north, south and east of the Alston block. During compaction of the sediments the pore fluids underwent filtration producing two chemically and isotopically distinct fluids. The filtered high level $SO_4$-rich fluid migrated laterally, while the residual fluid at depth mixed with dehydration water released during montmorillonite-illite conversion to produce a Ca-Na-Cl brine rich in metals. This deeper component, similar in chemistry to the fluorite/quartz inclusion fluids, migrated upwards through the cupolas of the Weardale granite in response to tectonic readjustment in the basement and anomalous high heat flow in the region. Deposition of fluorite and quartz was caused by cooling and slight pH changes in the fluids. In contrast barite deposition was controlled by mixing of the two fluids. Chemical analysis and solubility data support the proposed mechanisms of mineral deposition. (Author's abstract)

See also shorter abstract from IMM Transactions in Fluid Inclusion Research, v. 13, p. 167 (1980). Not subsequently published. (E.R.)

MORETTO, Robert, 1987, Sedimentological and geochemical study of Paleogene saliniferous series of the Bourg-en-Bresse basin (France): Memoire 50, Sciences de la Terre, 252 pp. (in French; English abstract).

The magnesium enrichment of the silico-aluminous phase included in the more carbonated layers is explained by an agradation of the finest part due to the brine chemistry. The Br concentrations indicate a marine origin for the Bressan salt with increasingly significant recyclings in the upper 300 m of the series in keeping with dissolution phenomena. These phenomena arise at the top of the series by the formation of a breccia with collapse structures. The adjustment of a suitable methodology has permitted proposing an estimation of the percentage of the fluid inclusions in the halite and their composition and establishing a warning as to the use of the results obtained on the trace elements as indicators of paleosalinities. (From the author's abstract)

MORGAN, G.B., VI and LONDON, David, 1987, Alteration of amphibolitic wallrocks around the Tanco rare-element pegmatite, Bernic Lake, Manitoba: Am. Mineral., v. 72, p. 1097-1121. Authors at Sch. Geol. & Geophys., Univ. Oklahoma, Norman, OK 73019, USA.

Amphibolitic wallrocks around the Tanco rare-element pegmatite record three episodes of metasomatic alteration by pegmatite-derived fluids. The apparent sequence of alteration was (1) B(±Li) metasomatism (tourmalinization), (2) K-Rb-Cs-F (±Li) metasomatism (formation of metasomatic biotite), and (3) propylitic alteration (Hbl + Pl + Ep + Chl + Ttn + Cal + clay) with concomitant influx of Li and $CO_2$. Holmquistite is present in all three metasomatic assemblages and served as the primary sink for Li. Wallrock metasomatism was preceded by an episode of textural recrystallization at lower-amphibolite-facies conditions. Recrystallization may have been caused by heat loss from the pegmatite, but is more probably an artifact of pre-emplacement metamorphism. All metasomatic alteration that is clearly pegmatite-related took place at greenschist-facies conditions ($T < 500$-550°C, $P < 300$ MPa). The B-rich fluid that caused tourmalinization of wallrocks was generated by the crystallization of albitites within the pegmatite. Fluids responsible for K-Rb-Cs-F (±Li) metasomatism of wallrocks (at T = 450-460°C) were generated by (1) liberation of acidic, F-rich fluid by the late crystallization of albitites and (2) consequent sericitization of pegmatitic microcline and pollucite. Log $(f(HF)/f(H_2O))$ of fluid in equilibrium with exomorphic biotite at the pegmatite contact was -4.9 at T = 400-500°C and approached negative infinity within 4 m from the pegmatite. Internal pegmatite fluids equilibrated with primary amblygonite-montebrasite (X(amb) = 0.40) at 600°C record log $(f(HF)/f(H_2O)) = -4.8$. Propylitic alteration, the most pervasive type of alteration around Tanco, occurred throughout the entire episode of wallrock metasomatism, but became dominant when solute-depleted pegmatite fluids cooled to $T < 420$°C.

Through the documentation of the modal abundance and crystal chemistry of metasomatic and retrograde phases, the total masses of B, F, and alkalies lost from the pegmatite have been estimated. The calculated masses represent significant proportions of these components in the original pegmatite magma. (Authors' abstract)

MORGAN, J.W., 1987, Origin of platinum-group metals, gold, and rhenium in the Earth's mantle and the role of sulfide in mantle-crust partitioning (Extended abst.): U.S. Geol. Survey Circular 995, p. 47-48.

MORRISON, G.W., TEALE, G.S. and HODKINSON, I., 1987, Geology and gold mineralization at Mount Leyshon, North Queensland: Pacific Rim Congress 87, 26-29 August, 1987, Australasian Inst. Mining & Metallurgy, Victoria, Australia, p. 777-780. First author at Gold Res. Group, James Cook Univ. of North Queensland, Townsville, Queensland, 4811.

Sulphide mineral compositions and associations, and fluid inclusion Th data suggest Stage I mineralization T of 500-450°C and Stage II and III mineralization T of 400-300°C. The association of porphyritic intrusives, stockwork Cu-Mo veinlets, potassic-sericitic alteration, Cu-Zn-Pb-Bi-Mo-Ag-Au element assemblages, high T mineralization and high to moderate fluid salinities suggest the mineralization is related to a dominantly magmatic hydrothermal system generated by the porphyry intrusions. (From the authors' text)

MRUMA, A.H. and BASU, N.K., 1987, Petrology of the talc-kyanite-yoderite-quartz schist and associated rocks of Mautia Hill, Mpwapwa district, Tanzania: J. African Earth Sci., v. 6, p. 301-311. Authors at Univ. Dar es Salaam, P.O. Box 35052, Dar es Salaam, Tanzania, Africa.

Fluid inclusion studies on the selected rock types indicate the presence of usually two-phased $H_2O$-rich and $CO_2$-rich fluids with a range of filling from 0.6 to 0.95. Some $CO_2$-rich fluid may be one-phased (liquid) at room T with their degree of filling ranging from 0.4 to 1.0. Most of the $CO_2$-rich inclusions show negative crystal shapes. Fluid inclusions trapped in kyanite in the talc-kyanite-yoderite-quartz schist with isolated negative crystal shapes are considered P. The presence of $CO_2$-rich fluids indicates low water fugacity during the formation of the talc-kyanite assemblage, and so P was probably lower. P fluid inclusions could be trapped at P between 5.2 and 5.6 kb and T ranging from 540 to 570°C; this gives the possible P-T range of the peak of the first phase of progressive metamorphism. (From the authors' abstract)

MULLIS, Josef, 1987a Fluid inclusion studies during very low-grade metamorphism, _in_ M. Frey, ed., Low Temperature Metamorphism, p 162-199.

Presents an extensive review of fluid inclusions from very low-grade metamorphic rocks. (H.E.B.)

MULLIS, Josef, 1987b Rapid burial and uplift in the Northern Apennines deduced from fluid inclusion studies (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 87. Author at Mineral.-Petrogr. Inst. der Univ. Basel, Bernoullistr. 30, CH-4056 Basel.

Detailed studies on quartz morphology, fluid inclusions and illite "crystallinity" (I.C.) from Porretta in the Northern Apennines (Italy) have been used to supplement vitrinite reflectance (V.R.) studies of carbonaceous matter by Reutter et al. (1983; Geol. Rund; v. 72, p. 861).

Inclusions in the earliest generation of window-shaped fissure quartz contain methane-rich and water-rich fluids with Th values into the liquid phase of 114 ± 4 and 223 ± 4°C respectively. Fluid P is calculated as 2.1 to 2.3 kbar for a T of 223°C. If the fluid P is assumed to be equal to the lithostatic P and the average rock density is 2.5 g/cm$^3$, then the resulting rock pile thickness during quartz growth was 8.4 to 9.2 km. These data are not in accordance with the V.R. values of 0.97 to 1.10% Rm and the I.C. values of 0.47 to 0.61° $\Delta 2\vartheta$ which reflect diagenetic oil-window conditions.

The inconsistencies between fluid inclusion, V.R. and I.C. data can be reconciliated by assuming a tectonic evolution involving rapid but deep burial with a short duration of heating. As demonstrated by Reutter et al. (1983), the rocks of the Porretta region and south of them (Modina Cervarola Unit) were indeed subjected to rapid loading as a result of northeastwards thrusting of the Ligurian nappes which took place mainly during mid-Miocene time. Subsequent uplift must have been important during late Miocene time. This interpretation suggests that the "crystallinity" of illite is not only dependent upon T but also upon duration of heating. (Author's abstract)

MULLIS, J., 1987c The behavior of fluids during the Alpine orogeny (abst.): Terra Cognita, v. 7, no. 2-3, p. 135. Author at Min.-Petrog. Inst. Univ. Basel, Basel, Switzerland.

A review. (E.R.)

MULLIS, Josef, 1987d Fluid inclusion investigation in the Nagra boreholes of northern Switzerland: Eclogae Geol. Helv., v. 809, no. 2, p. 553-568 (in German; English abstract). Author at Mineral.-Petrogr. Inst. der Univ., Bernoullistrasse 30, CH-4056 Basel.

See Mullis and Stalder, 1985, Fluid Inclusion Research, v. 18, p. 286 and next item. (E.R.)

MULLIS, J. and STALDER, H.A., 1987a Fluid inclusion investigations in the NAGRA-boreholes of the northern Switzerland (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 89. First author at Mineral.-Petrogr. Inst. der Univ. Basel, Bernoullistr. 30, CH-4056 Basel.

Fluid inclusion studies in quartz and calcite from 6 NAGRA-boreholes and the oil exploration well Pfaffnau in northern Switzerland enable the evolution of fluid composition and trapping conditions to be evaluated. The studied boreholes cover representative sections of the Tertiary, Mesozoic and Permo-Carboniferous sedimentary rocks as well as the underlying crystalline basement.

Two fluid groups were identified, one containing salt-poor NaCl-(KCl) fluids of Pre-Triassic (Pre-Stephanian) age, and a second group containing salt-rich to salt-poor $CaCl_2$-NaCl-($MgCl_2$) fluids trapped between Permian and Tertiary times.

The inclusions of the first group were trapped at relatively high T (~100° to ~350°C, rarely <400°C) and low P (probably <1 kbar). Their widespread occurrence along healed fractures in rock-forming minerals of the crystalline basement and in detrital quartz of the Permo-Carboniferous and Triassic sandstones imply a thermotectonic event on a regional scale.

The second group of inclusions comprises early salt-rich and late salt-poor fluids as well as recent formation waters that are commonly very poor in salt. The inclusions were trapped between ~30° and ~140°C and are detected preferentially in fissure minerals and authigenic cements. The widespread occurrence of these fluids along healed fractures inside the host minerals implicate major tectonic events broadly contemporary with trapping. Meteoric fluids are suggested to have penetrated deeply into the cover rocks and crystalline basement indicating major fluid migration and brine dilution probably driven by seismic pumping.

The two fluid groups are very likely to correlate with the high T low salinity Variscan fluid system and the low T high salinity post-Variscan fluid system of the Black forest and Oberpfalz (Beer et al., 1987). (Authors' abstract)

MULLIS, J. and STALDER, H.A., 1987b Salt-poor and salt-rich fluid inclusions in quartz from two boreholes in northern Switzerland: Chem. Geol., v. 61, no. 1/4, p. 263-272.

Full paper for abstract in Fluid Inclusion Research, v. 18, p. 286, 1985. (E.R.)

MUMPTON, F.A., ed., 1986, Studies in diagenesis: U.S. Geol. Survey Bull. 1578, 368 pp.

Contains 25 papers on various aspects of diagenesis. The most pertinent are abstracted here. (E.R.)

MUNGALL, J.E., FRAPE, S.K., GIGSON, I.L. and DAMINENI, D.C., 1987, Rare-earth abundances in host granitic rocks and fracture-filling gypsum associated with saline groundwaters from a deep borehole, Atikokan, Ontario: Can. Mineral., v. 25, p. 539-543.

MUNOZ, M. and SHEPHERD, T.J., 1987, Fluid inclusion study of the Bournac polymetallic (Sb-As-Pb-Zn-Fe-Cu ...) vein deposit (Montagne Noire, France): Mineral. Deposita, v. 22, p. 11-17. First author at Lab. Min., Associé au C.N.R.S., U.A. 67, Univ. Paul Sabatier, 39, Allées Jules Guesde, 31400 Toulouse, France.

Mineralogical studies demonstrate that the Hercynian polymetallic Sb-rich deposit of Bournac can be described by four stages of ore deposition and one of partial ore remobilization. Fluid inclusion data permit calculation of the composition and T of the fluids associated with each stage of hydrothermal mineralization and concomitant wall-rock alteration. Stages I and II (Fe-As and Zn) are represented by moderate-salinity $H_2O$-$CO_2$-(NaCl) inclusions which correlate closely with early carbonate depositions. Stage III fluids which are responsible for the deposition of Pb-Sb ores are characterized by low-salinity $H_2O$-(NaCl) inclusions. During the final stage of mineralization (IV), corresponding to the main phase of stibnite deposition, abundant aqueous inclusions confirm the continued involvement of low-salinity fluids and the intense development of potassic clays and secondary silica in the wall rocks. Th suggest that the whole cycle of mineralization took place during a gradual decreae in fluid T of 380°-140°C. Stibnite deposition is restricted to the interval of 230°-140°C thus confirming an essentially epithermal environment. Stage V (partial remobilization) is distinguished by the presence of high-salinity $CaCl_2$-rich inclusions which are tentatively related to Triassic barite mineralization in the region and therefore postdate the Bournac antimony ores. Th for this stage range 140°-60°C. (Authors' abstract)

MURALI, A.V., ZOLENSKY, M.E., CARR, R., UNDERWOOD, J.R. and GIEGENGACK, R.F., 1987, Libyan Desert glass: Trace elements and gas inclusions (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 782. First author at Lunar and Planet. Inst., Houston, TX 77058.

Libyan Desert glass (LDG) is the name given to natural non-crystalline high-silica (96.9 to 99.7 wt.% $SiO_2$) fragments found over a 6500 square km elongate area of the Western Desert of Egypt. Although it has been established that LDG has been derived from fusion of the local quartz-rich Nubia Formation, the cause has yet to be determined, although most workers have concluded that it is impact derived. However, there are significant differences between LDG and tektites (and other impact-derived glasses), including (1) higher silica content of LDG, (2) absence of vesicles in some specimens of LDG and (3) absence of nickel-iron microspheres in LDG. While the first of these differences is explained by the silica-rich impact area, the remainder are unexplained. Thus, in an attempt to establish better the origin of LDG we performed trace element and gas inclusion analyses of material collected during expeditions in 1978 and 1979.

The mass spectra of vesicle gas from LDG were collected by crushing specimens, then using a Hewlett Packard mass selected detector. The species $N_2$, $O_2$, Ar, $CO_2$, $H_2O$, and their dissociation products, were detected in atmospheric proportions. In addition, elevated amounts of CO were found, in agreement with earlier results for tektites.

Trace element analyses of LDG, by INAA, are consistent with and extend earlier work (Koeberl, 1985, <u>Meteoritics</u> <u>20</u>, 686). All samples are enriched in the light REE's, by 7 to 12 (La/Lu) times chondritic values. All samples have a negative Eu anomaly, which decreases in magnitude (from 0.6 to 0.4) with increasing REE content. These relations are probably due to mineralogical impurities within the Nubia Formation, however Au and Ir values are presently being determined in an attempt to settle whether there is an expression of the composition of the presumed impactor body among the trace elements. (Authors' abstract)

MURAMATSU, Yoichi, 1987, Distributions, paragenesis and fluid inclusions of hydrothermal minerals in the Kakkonda geothermal field, northeastern Japan: The J. Jap. Assoc. Min., Petrol. & Econ. Geol., v. 82, p. 216-229 (in Japanese; English abstract).

Fluid inclusions in quartz and calcite are generally several microns in size and are liquid inclusions. Th of fluid inclusions in quartz and calcite range 87-296°C and 83-217°C, respectively.

Judging from the distribution of the maximum Th obtained for the samples from geothermal wells (Muramatsu, 1984) and the surface, it is inferred that at least 900 meters of overburden were eroded after the mineralization.

T distribution pattern around the Kakkonda geothermal field suggests that high T fluids ascended mainly from the deeper zone of the western area, and that some meteoric water descended from the central area at Stage I and Stage II (present day). The data on the modes of occurrence, and the distribution pattern and fluid inclusion data of quartz and calcite, indicate that most quartz was deposited from ascending fluids in the convective geothermal system, and that calcite precipitation resulted partly from the boiling of ascending hydrothermal fluids in the vicinity of the surface. (From the author's abstract)

MUROWCHICK, J.B., MUEHLENBACHS, K. and NESBITT, B.E., 1987, Nature of ore fluids in the Coquihalla gold belt, B.C., in Elliott, I.L. and Smee, B.W., eds., Geoexpo/86: Exploration in the North American Cordillera: Assoc. of Explor. Geochem. Pub., p. 160-167. Authors at Dept. Geol., The Univ. Alberta, Edmonton, Alberta T6G 2E3.

More than 120 isotopic analyses of O, C, and H from vein quartz, fluid inclusions, serpentine, carbonates, and whole rock samples from the Coquihalla Au belt indicate that the fluids responsible for mineralization were highly evolved ($^{18}O$-enriched), locally-derived meteoric waters. Fluid inclusion analysis indicate that the fluids had low salinities (ca. 2 wt. % NaCl eq.) and high $CO_2$ content (up to 60 vol. % liquid $CO_2$ in some inclusions). Th (uncorrected for P) average 290 ± 10°C for inclusions related to the mineralizing event. The Tt are about 380°C, leading to a 750-1250 bar trapping P, equivalent to a depth of 3-5 km. As a genetic model, we envisage meteoric waters percolating downward to a decollement at the brittle/ductile transition (ca. 350-400°C at 5-10 km depth), exchanging oxygen and leaching Au from the country rocks. Ascent along fractures adjacent to a transcurrent fault zone focused the fluids and led to Au mineralization via episodic effervescence and/or cooling. (Authors' abstract)

MUSTARD, Harry, 1986, Geology and genesis of the Kidston gold deposit, Australia, in GOLD '86, Proceed. Vol., A.J. Macdonald, ed., p. 404-415. Author at Placer Pacific Ltd., G.P.O. Box 4315, Sydney, N.S.W. 2001, Australia.

Au mineralization at Kidston occurs in a semicontinuous zone around the margin of a large (1300 m by 920 m) breccia pipe. Fluid inclusion studies suggest that the gold bearing mineralizing fluids had a significant meteoric fluid component in contrast to the magmatic fluids associated with the brecciation processes. The fluid responsible was two-phase, highly saline (40 to 53 eq. wt. % NaCl), with T between 250° and 480°C, and co-existed with a moderate T (300°-400°C) gaseous fluid of low salinities (10 eq. wt. % NaCl). The fluids responsible for filling vugs and sheeted veins were of low salinity (<10 eq. wt. % NaCl) and low to moderate T (200° to 400°C). (From the author's abstract and text)

MYERS, Georgianna, 1987, Fluid evolution associated with the underplating of the Kodiak Formation, Kodiak Islands, Alaska (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Author at Univ. California, Santa Cruz, CA 95064.

The latest Cretaceous to earliest Paleocene underplating of the Kodiak Formation resulted in the sequential development of three structurally distinct belts within these slates and greywackes. The deformation of each belt is associated with several generations of quartz veins. Microthermometric analysis of fluid inclusions within these veins reveals compositionally distinct fluids in each structural belt.

Fluid inclusions in veins from the landward belt vary in composition from methane-saturated to methane-undersaturated. Early veins synchronous with stratal disruption resulting from underthrusting are saturated with methane. Microthermometric analysis of these inclusions yield minimum formation conditions of 2600 bars ± 100 bars and 250°C ± 10°C.

The central belt, distinguished by intense noncoaxial deformation, represents a larger shear zone. Fluid inclusions in veins from this structural setting contain carbon dioxide and water in varying proportions. Veins coeval with slatey cleavage suggest minimum emplacement conditions of 2800 bars ± 500 bars and 310°C ± 40°C. Analysis of later veins associated with crenulation cleavage resulting from subhorizontal shortening of the accretionary wedge reveal formation conditions of 2800 bars ± 500 bars and 340°C ± 50°C.

Microthermometric analysis of veins from the seaward belt reveal aqueous inclusion compositions throughout the deformational history. Maximum Th indicate minimum formation conditions of 180°C.

The correlation of regional variations in fluid inclusion compositions and structural belts reflects the intimate relationship between the circulating fluids and the deformation resulting from the accretion of the Kodiak Formation. Microthermometry identifies peak formation conditions during the development of crenulation cleavage. This fluid evolution from methane saturated fluids to carbon dioxide-rich fluids is the product of prograde metamorphism resulting from the underthrusting, and underplating of the Kodiak Formation. (Author's abstract)

MYSEN, B.O., ed., 1987, Magmatic Processes: Physicochemical Priniples: Geochem. Soc. Spec. Publ. No. 1, 463 pp.

Thirty-one papers by various authors. Those that are pertinent are listed by individual author in this volume. (E.R.)

NADEAU, Serge, PINEAU, F., JAVOY, M. and FRANCIS, D., 1987, The isotopic nature of $CO_2$ fluids in the upper mantle beneath the Northwestern Cordillera (abst.): EOS, v. 68, p. 443. Also similar in GAC-MAC Program with Abst., v. 12, p. 76. First author at Dept. Geol. Sci., McGill Univ., Montreal, PQ., H3A-2A7, Canada.

Upper mantle xenoliths from the Canadian Cordillera and Alaska contain several carbon (C) phases which can be extracted at different temperatures by step heating. A low temperature C ($\delta^{13}C$ = -25 to -28‰) is released between 200 and 600°C. Interstitial carbonates break down between 600 and 800°C and give $\delta^{13}C$ values from -10 to -20‰. The concentration of high temperature (>800°C) C is generally lowest in spinel lherzolite, harzburgite and dunite (1-7 ppm C; $\delta^{13}C$ = -25 to -8‰) and increases in pyroxenites (13 to 20 ppm C; $\delta^{13}C$ = -8 to -4.6‰) and xenoliths bearing hydrous minerals (13 to 28 ppm C; $\delta^{13}C$ = -10 to -5.5‰). Variation in high temperature C concentration reflect the abundance of fluid inclusions in the xenoliths. A plot of C concentration versus $\delta^{13}C$ suggests that the high temperature carbon is a mixture dominated by pure $CO_2$ fluid ($\delta^{13}C$ = -4‰) with a small amount of carbon dissolved in mineral phases and/or graphite coating fluid inclusion walls (0.5-10 ppm C; $\delta^{13}C$ = -28‰). The estimated mean $\delta^{13}C$ values for fluid inclusions are similar at all the xenolith localities investigated. Although modally metasomatized xenoliths have higher C contents than cryptically metasomatized xenoliths (13-28 vs 2-6 ppm C) the fluid inclusions have similar isotopic signatures. A mean $\delta^{13}C$ value of -5.0‰ appears to characterize $CO_2$ fluid in isotopic equilibrium with upper mantle mineralogy. (Authors' abstract)

NARSEEV, A.V., 1986, Studies of fluid regime as a method of prospecting and evaluation of the rare-metal ore mineralization: Razvedka i Okhrana Nedr, no. 6, p. 24-28 (in Russian). Author at Prospecting-Geol. Enterprise "Tsentrgeologiya," Moscow, USSR.

The Karaoba rare-metal ore deposit in Central Kazakhstan consists of quartz veins, greisens and stockworks occurring in leucocratic granites of the Akchatau complex, and partly in wall-rock Devonian volcanites. Both granites and volcanites are greisenized and sericitized, etc. Gas components of the mineral-forming fluids from wall-rocks, metasomatites and quartz veins were determined by high-T gas chromatography. Variations of the mean concentrations of volatiles in inclusions given in Table 1.

Table 1

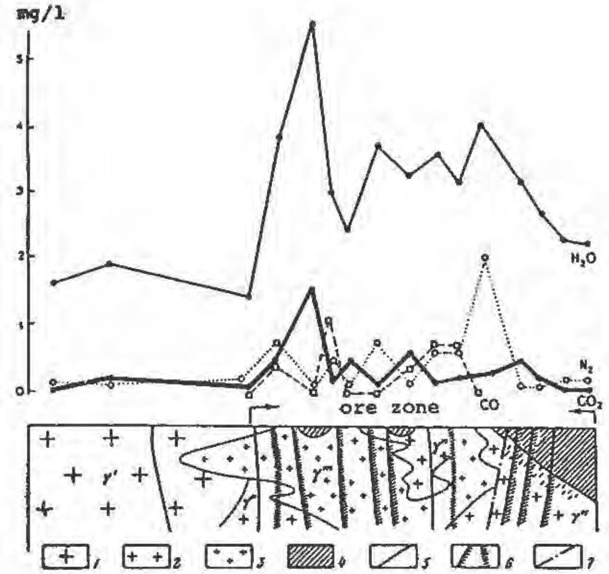
| Rock | $H_2O$ | $CO_2$ | CO | $H_2$ | $N_2$ | Kr |
|---|---|---|---|---|---|---|
| Granites: | | | | | | |
| fresh | 3.20/31 | 0.33/45 | 0.002/130 | 0.031/165 | 0.01/82 | 0.006 |
| weakly altered | 3.83/48 | 0.60/66 | 0.027/120 | 0.077/91 | 0.05/100 | 0.05 |
| greizenized | 4.23/72 | 0.64/93 | 0.048/85 | 0.146/104 | 0.03/120 | 0.03 |
| Greisens | 7.15/65 | 0.54/89 | 0.034/53 | 0.185/83 | 0.03/110 | 0.03 |

Key: mean content of a volatile, ml per g/variation coefficient, %; Kr - reduction coefficient = $CO + H_2/H_2O + CO_2$.

The data indicate that granites and the related rare-metal ores formed under oxidizing conditions; fresh granites have low $CO_2$, $H_2O$ and $N_2$ contents, distributed uniformly. The higher the degree of alteration, the higher the variations of the volatile concentrations. Contents of $H_2$ and CO are low in fresh granites and their variation is high; frequently these two gases were not detected. Altered rocks have higher contents and lower variation of these gases. Similar regularities were found along a profile perpendicular to the extension of the altered and ore zones with the sampling step ca. 50 m.

The following prospecting features were found for the rare-metal ores: 1. Contents of $H_2O$ and $N_2$ higher than background, 2. Presence CO in fluid, 3. Sharp variations of fluid components.

In well-studied vein No. 1 (Fig. 2) the higher values of $H_2O$ occur in the middle and upper parts of the vein and agree with the W-rich zones of the vein. Area of the $H_2O$ haloes exceeds the area of ore bodies by 2-5 times. Distribution of $CO_2$ is uniform within the vein ranges, with some increase in the middle of the vein. The content of CO essentially increases with the



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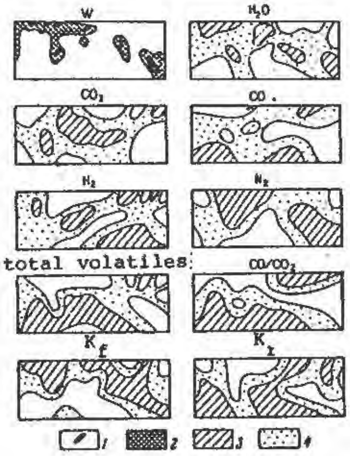

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Fig. 1. Distribution of volatiles across the ore zones in the N part of the Karaoba deposit; granites: 1 - medium-grained porphyric I phase, 2 - medium-grained II phase, 3 - fine-grained III phase, 4 - Devonian volcanic rocks, 5 - quartz veins, 6 - greisenization zones, 7 - faults.

Fig. 2. Distribution of W, volatiles, Kf and Kr in the plane of the vein; 1 - massive ore bodies, 2 - rich disseminated ores, 3 - very high values of the volatile indices, 4 - high ones.

depth. The reverse correlation between CO and ore is very distinct. $H_2$ does not display a correlation with ore mineralization, its content increases with depth. $N_2$ content increases in the upper parts of the vein, moreover it forms haloes around ore bodies exceeding their surface [area] 3-6 times in linear dimensions. Total gas content increases in the lower levels of the vein. Values of the fluid coefficient Kf = 100 $H_2O$/total fluid are distributed in the vein uniformly with positive haloes around the ore bodies. Reduction coefficient Kr and the ratios $H_2/H_2O$ and $CO/CO_2$ have low values, indicating oxidizing conditions of W ore precipitation. Kr and $H_2/H_2O$ have very similar patterns of distribution; their values increase with depth. $CO/CO_2$ forms two fields of the high values. There is distinct reverse correlation of W content and the Kr, $H_2/H_2O$ and $CO/CO_2$ values. The signs of W mineralization are as follows: high contents of $H_2O$ and $N_2$, low values of Kr (<0.02), $H_2/H_2O$ (<0.05) and $CO/CO_2$ (<0.05), high values of Kf (>90). The zoning coefficient $Kz = (H_2O + N_2)/(CO + H_2)$ was calculated and its values increase regularly with the depth (Table 2).(Abstract by A.K.)

Table 2

| Depth of sampling, m | Kz for vein No. 1 | Kz for near-vein greisens |
|---|---|---|
| 0 | 41.4 | -- |
| 60 | 28.8 | 90 |
| 120 | 25.8 | 69.5 |
| 180 | 15.5 | 58.3 |
| 300 | 5.5 | 27.6 |

NAUMOV, G.B., SALAZKIN, A.N., MIRONOVA, O.F. and SAVELYEVA, N.I., 1987, Aureoles of the fluid inclusions and methods of their study in exploration of hydrothermal ores: Geokhimiya, 1987, no. 2, p. 250-259 (in Russian; English abstract).

The methods of revealing and study of aureoles of fluid inclusions are considered in connection with the total complex of geochemical methods of exploration. Aureoles of the fluid inclusions are rather stable characteristics of various types of deposits. They are widely distributed, occurring far beyond the limits of the near-vein alterations and aureoles of the elements-indicators embracing the areas of the tectonic disturbance where the hydrothermal paleoflow was in quasi-equilibrium with the country rocks and did not significantly alter the mineral composition. Examples of practical using of the data obtained for the hydrothermal ores' exploration are given. (Authors' abstract)

NAUMOV, V.B., 1987, Volatile components in magmatic and metamorphic processes: Fluid and melt inclusion data (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 91-92. Author at Vernadsky Inst. Geochem. & Anal. Chem., USSR Acad. Sci., Moscow, USSR.

Our results and other published data from >100 papers involving ~300 rock samples can be summarized as follows:

1. Possible P-T variations in melts and fluids are confined to a broad range up to 1500°C and 20 kbar. The T range of acidic melt crystallization is extensive, from 550°C (ongonitic melts) up to >1250°C. High T of crystallization is characteristic of basic and ultrabasic melts (1000-1500°C). Maximal P of fluids indicative for $N_2$ and $CO_2$ are 11-13 (20) kbar, water P is estimated as 6 kbar.

2. Basic and acidic melts are greatly different in relation to dominant volatiles: $CO_2$ is peculiar to basic melts, $H_2O$ is characteristic of acidic melts. In general the basaltic magmas are considered as "dry" melts. Samples from island arc regions are characterized with markedly high water content. Acidic magmas are enriched with water in the range of content from 0.1 up to 14 wt.%. Highly differentiated acidic magmas are found to contain considerable quantities of F, B and rare elements.

3. The abyssal fluids are represented by $CO_2$, $CH_4$ and $N_2$ at 500-1100°C and 6-13 kbar. There is no water in fluid inclusions corresponding to these conditions. Magmatic melts are not found, only metamorphic rocks are developed. Presumably at depths >20-25 km fluids are practically free of water. Taking in mind that basalts are depleted in water we conclude that fluids related to lower zone of Earth's crust are extremely depleted in water.

4. The volatiles of upper mantle could be characterized in terms of data on fluid and melt inclusions in ultrabasic nodule minerals of alkaline basalts and kimberlites. The dominant component of abyssal xenoliths is $CO_2$ with minor content of CO (up to 12 mol.%) according to Raman spectroscopic data and sulfur-bearing gases. These fluids are practically free of water according to E. Roedder's summary (1965) and succeeding investigations of fluid inclusions in nodule minerals.

5. High $CO_2$ P, up to 1.0-3.5 kbar deduced from the investigation of greisens and mineral assemblages of ore-forming stages of rare-metal deposits, are not in agreement with thermobarometric data on acidic magma crystallization. Such high $CO_2$ P should be related to deep zones of Earth's crust with dominating metamorphic or basic magmatic processes. A number of hydrothermal ore fields are associated with coexisting basic and acidic magmatic complexes. (Author's abstract)

NAUMOV, V.B., AKHMANOVA, M.V., SOBOLEV, A.V. and DHAMELINCOURT, P., 1986, A laser Raman microprobe applied to the gas phase in inclusions in minerals: Geokhimiya, 1986, no. 7, p. 1027-1034 (in Russian; translated in Geochem. Int'l., v. 24, no. 2, p. 116-124, 1987, with first author given as "V.M. Naumov"). First author at Vernadskiy Inst. Geochem. & Anal. Chem., Acad. Sci. USSR, Moscow, USSR.

Translation published in Fluid Inclusion Research, v. 19, p. 512-516, 1986. (E.R.)

NAUMOV, V.B. and KOVALENKO, V.I., 1986, Mineral-inclusion data on the characteristics of the principal volatile components of magmas and metamorphic fluids: Geokhimiya, no. 5, p. 590-600 (in Russian; translated in Geochem. Int'l., v. 23, no. 9, p. 11-22, 1987.

See Naumov and Kovalenko (1985) in Fluid Inclusion Research, v. 18, p. 290-291 and (1986) Fluid Inclusion Research, v. 19, p. 308-309. (E.R.)

NAUMOV, V.B., PROKOF'EV, V.Yu. and LUCHITSKAYA, M.I., 1987, Cryometry of fluid inclusions in the study of hydrothermal ore deposits: Geol. Rudn. Mestorozhd., v. 29, no. 4, p. 69-78 (in Russian).

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 (in Russian).

NAVON, Oded, HUTCHEON, I.D., ROSSMAN, G.R. and WASSERBURG, G.J., 1987, Ultrapotassic sub-micron inclusions in diamonds (abst.): EOS, v. 68, p. 1552. Authors at Div. Geol. & Planet. Sci., California Inst. Tech., Pasadena, CA 91125.

Ion microprobe, SEM and IR spectroscopic analyses of sub-micron inclusions in cubic diamonds and in the inclusion-rich mantles of coated diamonds reveal a composition, completely different from that of the peridotitic or eclogitic suites of "normal" diamond inclusions. The chemical compositions (oxides normalized to 100%) of inclusions in 7 diamonds from Orapa, Botswana, and 3 of unknown locality, show similar compositions: $SiO_2$, 30-50%; $TiO_2$, 2-4%; $Al_2O_3$, 2-10%; FeO, 10-20%; MgO, 2-7%; CaO, 6-18%; $K_2O$, 8-22%; $Na_2O$, 1-8%; and detectable $P_2O_5$, Cl and $Cr_2O_3$. Good correlations exist between $Al_2O_3$, $TiO_2$ and $SiO_2$, as well as between CaO, MgO, $Na_2O$ and $K_2O$. IR spectra indicate the presence of water (3440, 1640 $cm^{-1}$), carbonate (1430, 877 $cm^{-1}$) and phosphate (606, 575 $cm^{-1}$). From available IR absorption coefficients, we estimate the inclusions are composed of 20-50% (wt) water, 10-30% carbonate and 40-70% metal oxides.

These inclusions may represent a trapped fluid or highly evolved melt broadly similar in composition to lamproites but richer in $H_2O$, carbonate and $K_2O$ and lower in Mg. It is distinctly different from the host kimberlites. The high $K_2O$ values and the presence of phosphate suggest that this trapped fluid is enriched in other incompatible elements and may be similar to fluids responsible for widespread metasomatism of the subcontinental mantle. If the inclusions are primary, then the formation process of these diamonds is different from that of diamonds associated with peridotitic or eclogitic inclusions. We infer that zoned diamonds grew in a peridotitic or eclogitic environment and were later overgrown with diamond in a lamproitic-like fluid prior to the kimberlitic eruption. The cubic diamonds may have grown completely in such fluid. The carbon isotopic sources in these two regimes of growth could be distinctive in agreement with observations by Galimov and by Pillinger. (Authors' abstract)

NAVROTSKY, Alexandra, 1987, Calorimetric studies of melts, crystals, and glasses, especially in hydrous systems, in B.O. Mysen, ed., Magmatic Processes: Physicochemical Principles: Geochem. Soc. Spec. Pub. 1, p. 411-422.

NEAL, C.R. and TAYLOR, L.A., 1987, The petrogenesis of lunar granite from a basaltic magma: Extreme fractional crystallization with subordinate silicate liquid immiscibility (abst.): Meteoritics, v. 22, p. 470-471. Authors at Dept. Geol. Sci., Univ. Tennessee, Knoxville, TN 37996.

We conclude that crystal fractionation of a primitive basaltic magma is the dominant process in lunar granite petrogenesis. Subordinate silicate liquid immiscibility occurs with <10% liquid remaining to produce observed lunar granite compositions. (From the authors' abstract)

NEALL, F.B. and PHILLIPS, Neil, 1987, Fluid-wall rock interaction in an Archean hydrothermal gold deposit: A thermodynamic model for the Hunt mine, Kambalda: Econ. Geol., v. 82, p. 1679-1694. First author at Dept. Geol., Univ. Western Australia, Nedlands, Western Australia 6009, Australia.

Equilibrium equations involving fluid components and alteration minerals are used to determine conditions during the alteration event, and in particular, activity gradients of components. Profiles across the schist zone show increasing $fH_2S$ around auriferous quartz veins ($\log fH_2S$ = <-0.75 to >-0.6) but constant $fO_2$ ($\log fO_2 = -29.7$). These results are near the magnetite-pyrrhotite-pyrite triple point for the inferred T of 350°C and explain the pyrite-pyrrhotite-magnetite zonation sequence outward from veins. The profile of $X(CO_2)$ is very close to the value of 0.25 determined independently from fluid inclusions. The $K^+/H^+$ profile shows increases adjacent to auriferous veins corresponding to the zone of biotite stability. Using a value for fluid salinity of 2 eq wt % NaCl, pH was calculated to be around 6.9.

The solubility of Au in solution was estimated for the calculated conditions: for the complex $Au(HS)_2^-$ the maximum solubility is around 0.5 mg $kg^{-1}$ (i.e., 0.5 ppm), for $Au(Cl)_2^-$ it is close to $10^{-6}$ mg $kg^{-1}$, indicating the efficacy of sulfide transport of Au, compared to chloride transport, under these conditions. The calculated decrease in $fH_2S$ away from the auriferous quartz veins results in an 80% (or greater) decrease in Au solubility, suggesting that the sulfidation of Fe-rich wall rocks is geologically reasonable and very efficient mechanism for precipitating Au from solution at elevated T. (From the authors' abstract)

NECHAEV, S.V., KOZAK, S.A. and BONDARENKO, S.N., 1987, Native indium and iron in tin-bearing greisens of the Ukrainian Shield: Mineral. Zh., v. 9, no. 1, p. 74-78 (in Russian).

NEHLIG, P. and HAYMON, R.M., 1987, Microthermometric study of fluid inclusions in a fossil, ridge crest, hydrothermal discharge zone in the Bayda area (North Oman ophiolite) (abst.): EOS, v. 68, p. 1545. First author at GIS Oceanol. & Geodyn., Univ. Bretagne Occidentale, 29287 BREST Cedex, France.

A microthermometric study of fluid inclusions has been conducted in a complete section of upper oceanic crust at the vertical of the Bayda massive sulfide deposit in the volcanic section of the North Oman ophiolite.

The deposit with a maximum thickness of 80 m. formed from hydrothermal activity, 95 m.y.a., on the Tethyan seafloor. It is underlain by a discharge zone up to 500 m. wide, parallel to the spreading axis and extending down in the sheeted dike complex.

Primary fluid inclusions in quartz, epidote and sphalerite from the sheeted dike complex, volcanic stockwork and massive sulfide deposit homogenize always in a liquid phase and have salinities ranging from 3.2 to 10.1 wt % NaCl eq. (x 0.9 to 2.9 seawater) with a modal composition of 5 wt. % NaCl eq. (x 1.4 seawater). These high salinities can be explained either by the dissolution of a previously precipitated, chlorine-rich phase, or by a boiling and phase separation process occurring at deeper levels in the crust.

The samples from the sheeted dike complex show Th ranging from 270° to 380°C, with a mode at 315°C, while fluid inclusions in the overlying stockwork have Th between 140° and 350°C (mode at 315°C). The low T measured in this level are interpreted to reflect high level mixing with cold seawater immediately below the original seafloor.

Fluid inclusions in sphalerite from the massive ore body have Th ~285°C while late pores infilling quartz exhibit T as low as 120°C suggesting that low T circulations were active after the mineralization event.

We conclude that the Bayda deposit formed from fluids issuing from the sheeted dike complex at an average T of 345°C (hydrostatic P), rising to the seafloor with no thermal exchange with the wall rock and submit[sic] to small mixing pulses with cold seawater.

The fluid T in the Bayda hydrothermal discharge zone are much lower than those measured in the nearby Lasail ore body, where boiling has been observed (Spooner and Bray, 1985), suggesting a different heat source and hydrothermal system for the two deposits. (Authors' abstract)

NEHLIG, Pierre and JUTEAU, Thierry, 1987, Geometrical, mineralogical and microthermometric study of the hydrothermal veins in the crustal sequence of the Haylayn Block (Semail ophiolite, Oman) (abst.): Symp. TROODOS 87, Ophiloites and Oceanic Lithosphere, Nicosia, Cyprus, 4-10 Oct., 1987, Abstracts of Papers, p. 151. Similar items in Terra Cognita, v. 7, p. 192, and Soc. Géol. de France Spec. Session Geol. of Oman, Abstracts, p. 20 (in French). Authors at GIS "Océanol. & Géodyn.," Lab. Pétrol., 6, Av. Le Gorgeu, 29287 BREST Cédex, France.

An intense hydrothermal metamorphism affected the crustal sequence of the Semail ophiolite in Oman. A detailed study of the Haylayn Block and a comparison with other ophiolitic massifs of the Semail nappe reveal the existence of a dense net of hydrothermal veins penetrating the crust down to the petrological Moho.

Three main episodes of hydrothermal penetration can be distinguished: 1) hydrothermal circulation at the top of the magma chambers during the main accretion stage; 2) penetration of seawater at the top of the magma chamber during the latest stages of crystallization; and 3) "off axis" penetration of seawater down to the petrologic Moho, after crystallization of the magma chambers, in late open fractures now filled with zeolites, prehnite, calcite and quartz (upper crust) or with amphibole, epidote and zoisite (lower crust).

Fluid inclusion studies on P and/or S inclusions in P plagioclase and S quartz, calcite and amphibole crystals revealed the presence of a two phase aqueous fluid which homogenizes always into liquid at 100°C to 500°C (without P correction) with a 0 to 9.6% NaCl eq. content; the average salinity is that of seawater (3.2%). No trace of boiling or unmixing has been found. (From the authors' abstract)

NEKVASIL, Hanna and BURNHAM, C.W., 1987, The calculated individual effects of pressure and water content on phase equilibria in the granite system, *in* B.O. Mysen, ed., Magmatic Processes: Physicochemical Principles: Geochem. Soc. Spec. Pub. 1, p. 433-445.

NELSON, A., NIEMANN, J.R. and READ, J.F., 1987, Regional Mississippian cementation, Appalachians (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 786. Authors at Dept. Geol. Sci., Virginia Polytech. Inst. & State Univ., Blacksburg, VA 24061.

The Mississippian Newman Limestone (0-30 m thick) in Kentucky contains abundant early phreatic, meteoric cement. Purple- and blue-staining cements are syn- and post-compaction and of burial origin. Most post-date oil migration into the reservoirs. Burial histories suggest Pennsylvanian to Triassic ages for these cements. Burial cementation commonly is preceded in basinal sections by burial leaching of carbonate grains that still were metastable as they entered the burial environment. Purple cements have 1000 to 3000 ppm Fe whereas blue-stained cements have greater than 3000 ppm Fe; Mn compositions are variable. Fe compositions of the cements suggest that the fluids became more reducing with depth. Fluid inclusions suggest Na-Ca-Cl waters with salinities of 5 to 17 wt. % salt. Likely T were 40° to 60°C in Kentucky, increasing to 125°C or more in the deeply buried fold-thrust belt. The $\delta^{13}$C values of these cements show similar trends to meteoric calcites, in that they are lightest in the recharge area, becoming heavier downdip. This suggests that deltaic waters penetrated deep into the aquifers as they were buried. The $\delta^{18}$O values of the calcites in the recharge area become heavier in extreme basinal sections due to intense rock-water interaction. These waters appear to have had a strong meteoric component in updip areas, but were relatively heavy downdip and similar to many deeper basinal brines, possibly generated from dewatering of shales. (From the authors' abstract)

NESBITT, B.E., DRUMMOND, S.E. and BLENCOE, J.G., 1987, Development and testing of a vibrating tube densimeter for the determination of fluid densities at high temperatures and pressures (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 786-787.

NESBITT, B.E., MUEHLENBACHS, K. and MUROWCHICK, J.B., 1987a Comment and reply on "Dual origins of lode gold deposits in the Canadian Cordillera:" Geology, v. 15, p. 472-473. Authors at Dept. Geol., Univ. Alberta, Edmonton, Alberta T6G 2E3, Canada.

A reply to comments by Pickthorn et al. (this volume) on an earlier paper (Fluid Inclusion Research, v. 19, p. 31). (E.R.)

NESBITT, B.E., MUEHLENBACHS, K. and MUROWCHICK, J.B., 1987b Genesis of Au, Sb, and Hg deposits in accreted terranes of the Canadian Cordillera (abst.): GAC-MAC, AGC-AMC Joint Ann. Mtg., Program with Absts., v. 12, p. 76. Authors at Dept. Geol., Univ. Alberta, Edmonton, Alberta T6G-2E3.

Examination of the distribution of Hg, Sb and mesothermal Au deposits of the Canadian Cordillera reveals a pronounced association of these deposits with transcurrent faults. Some of the best examples of this association are Au deposits of the Coquihalla and Juneau districts, as well as Hg and Sb deposits associated with the Pinchi and Yalakom fault zones. Stable isotope studies indicate average $\delta^{18}$O values of qtz of 17.5 ± 1.0‰ (Au-qtz veins), 21.0 ± 1.0‰ (Sb-qtz veins) and 29.0 ± 2.0‰ (Hg deposits). Using temperatures derived from fluid inclusion and stable isotope studies, the $\delta^{18}$O of the ore-forming fluids were calculated to be 9.5 ± 1.5‰ (Au deposits), 10.0 ± 1.0‰ (Sb deposits) and 8.0 ± 2.0‰ (Hg deposits). H/D studies indicate that at all sites studied, the ore-forming fluid was composed of meteoric water which had undergone substantial $^{18}$O enrichment. The results of the isotopic settings, strongly suggest that a genetic link exists between the three styles of mineralization and furthermore, a zoning sequence exists ranging from high T and high P (~1 kbar) Au deposits to intermediate T, Sb deposits to low T, near surface Hg deposits. The deposits are believed to have originated via the deep circulation of meteoric water during transcurrent faulting. During the infiltration of fluid, the fluids evolved isotopically and chemically. Upflow of fluid occurred in zones adjoining the transcurrent faults. Deposition of Au-qtz veins occurred at depths >4 km and was the result of the combined effects of cooling, $CO_2$ effervescence, and the removal of sulfur from the system. At shallow levels Sb-qtz ± Au veins were precipitated from the fluid and, as the fluid neared the surface, Hg ± Sb was deposited in preexisting open spaces in fault breccias. (Authors' abstract)

NESBITT, H.W., 1987, Oxygen and hydrogen isotopes of waters in sedimentary basins with emphasis on the Illinois Basin waters (abst.): Applied Geochem., v. 2, p. 134-135.

NEWBERRY, R.J. and BREW, D.A., 1987, Geology and geochemistry of the Alaska-Juneau (AJ) mine area, Juneau, Alaska (abst.): Program with Abstracts, Symp.: Bulk Mineable Precious Metal Deposits of the Western United States, April 6-8, 1987, Geol. Soc. Nevada, p. 57. First author at Dept. Geol., Univ. Alaska.

The AJ mine consists of an aggregate of nearly-vertical, closely-spaced, anastomozing quartz ± ankerite-pyrrhotite-pyrite-sphalerite-galena-arsenopyrite-gold veins. Gold 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. (From the authors' abstract)

NEWTON, R.C., 1987, Late Archaean/Early Proterozoic $CO_2$ streaming through the lower crust and geochemical segregation: Geophys. Res. Lettrs., v. 14, no. 3, p. 287-290. Author at Dept. Geophys. Sci., Univ. Chicago, Chicago, IL 60637, USA.

Considerable evidence exists for large-scale migration of $CO_2$-rich fluids through the lower continental crust in the Late Archaean and Early Proterozoic, with transfer of heat producing elements and $H_2O$ to higher levels. The evidence manifest in the large charnockitic terrains of this age includes deformation-related charnockitic alteration of gneisses, nearly ubiquitous $CO_2$-rich fluid inclusions in minerals, depletion of large-ion-lithophile elements (LILE), particularly Rb, relative to typical upper crustal rocks, similar depletion of $^{18}O$ in paragneisses and petrographic and geochemical evidence of open-system replacement of amphibole gneiss by charnockite. A conveyor-belt upper mantle source appears to have been necessary for prolonged $CO_2$ supply in high-grade crustal metamorphism, most plausibly by deep subduction of marine carbonate under continental interiors. This plate tectonic mode seems consonant with crustal thickening and orogenic patterns inferred for most charnockitic terrains and with $CO_2$ transport mechanisms constrained by experimental petrology. (Author's abstract)

NGOYANADJI, N. and ARNOLD, M., 1987, Genesis of Largentiere Pb-Zn ore deposit (France): Contribution of fluid inclusions and sulfur isotopes ($\delta^{34}S‰$) studies (abst.): Terra Cognita, v. 7, no. 2-3, p. 228. Authors at CRPG, Vandoeuvre-lès-Nancy, France.

Fluid inclusion studies in quartz, sphalerite and barite reveal more mono- than biphase inclusions (origin of monophase inclusions uncertain). Th range for quartz and sphalerite 50-170°C; for barite 80-260°C. Salinities 4-18 wt%, with Ca and Mg present. (E.R.)

NIELSON, D.L. and HULEN, J.B., 1987, Hydrothermal brecciation in active geothermal systems: Results from VC-1 (abst.): EOS, v. 68, p. 469. Authors at Univ. Utah Res. Inst., Salt Lake City, UT 84108.

Breccias formed through hydrothermal processes have often been described from both active and fossil geothermal systems. Examples of these breccias have been cored between depths of 826 and 856 m in Continental Scientific Drilling Program corehole VC-1 which was drilled immediately south of the structural margin of the Valles caldera, New Mexico. The hydrothermal alteration mineralogy and geothermometry of secondary fluid inclusions from these cored samples demonstrates that brecciation took place at temperatures up to 300°C. The common coexistence of vapor-rich and liquid-rich inclusions shows that breccia formation took place along a reference boiling point curve. The pressures which define this boiling point curve are determined by the least principal stress. These results are consistent with independent estimates of the least principal stress. This analysis provides a quantitative model for the formation of hydrothermal breccias resulting from boiling. The likely triggering mechanism for boiling is pressure reduction due to faulting. (Authors' abstract)

NIELSON-PIKE, J.E., BUDAHN, J.R. and WILSHIRE, H.G., 1987, Fluid-wallrock interactions in the mantle; evidence from composite lherzolite-hornblendite xenoliths: U.S. Geol. Survey Circ. C 0956, p. 86-88.

NIKOLIĆ, D. and GATTER, I., 1986, Genetic interpretation of the results of microthermometric studies on the liquid/gas inclusions of fluorites from Ravnaja (Yugoslavia): Annales Univ. Sci. Budapestinensis de Roland Eötvös Nominatae, Sect. Geol., v. 26, p. 1-12. First author at Univ. Belgrade, Fac. Mining & Geol., Inst. Min., Petr. & Geochem., Belgrade, Yugoslavia.

The fluorite is from the hydrothermal fluorite, Pb, Fe, Zn deposits of Ravnaja in West Serbia. Zn is to be found in these deposits. The formation of several differently colored generations of fluorites took place in two distinctly separate phases at 270 to 245°C and at 205 to 160°C (modified with P correction) under conditions of gradually decreasing T. Cryoscopic data (eutectic points) suggest that the fluid component of the inclusions is of the alkali-chloride type composition with some bicarbonate-sulphate contaminants added. Freezing tests proved the presence of small amounts of $CO_2$ in the inclusions. The concentration of the solutions involved is about 3 to 11 NaCl eq. wt.% - characteristic of the volcanic/subvolcanic environment. The density of the fluids was calculated as 0.98 to 0.80 g/cm$^3$ with a vapor P of <5-50< bars at the time of entrapping. There is no strict correlation between the color of the specimens and the phase transition T observed during the homogenization and cryoscopic tests. (Authors' abstract)

NIXON, G.T. and PEARCE, T.H., 1987, Laser-interferometry study of oscillatory zoning in plagioclase: The record of magma mixing and phenocryst recycling in calc-alkaline magma chambers, Iztaccíhuatl volcano, Mexico: Am. Mineral., v. 72, p. 1144-1162. First author at Geol. Survey Br., Ministry of Mines, Energy, & Petrol. Res., Parliament Bldgs., Victoria, British Columbia V8V 1X4, Canada.

The laser technique is of considerable value in understanding the origin of melt inclusions in these phenocrysts (e.g., p. 1151). See also Pearce et al., this volume. (E.R.)

NIXON, P.H., ed., 1987, Mantle Xenoliths, Wiley Interscience, New York, 844 pp.

A very thorough and comprehensive review of all aspects of mantle xenoliths, including particularly a number of pages dealing with the importance of volatile-rich phases (E.R.)

NOLLER, J.S., 1987, Solid and fluid inclusions in mantle xenoliths; their origins and implications for the properties of the mantle: U.S. Geol. Survey Circ. C 0956, p. 83-85.

NORDSTROM, D.K. and OLSSON, Tommy, 1987, Fluid inclusions as a source of dissolved salts in deep granitic groundwaters, _in_ Saline water and gases in crystalline rocks, eds., Fritz, P. and Frape, S.K.: Geol. Assoc.

Canada Special Paper 33, 1987, p. 111-119. First author at U.S. Geol. Survey, 345 Middlefield Rd., Menlo Park, CA 94025, USA.

The feasibility of fluid inclusions leaking into local groundwater systems from granitic rocks is examined from several points of view: (1) Is there enough salt present? (2) Does this salt contain a chemical signature that can help to distinguish it from other sources? (3) How much of this salt is water soluble? (4) What is the maximum amount of chloride that might be contributed from this source under optimal conditions? and (5) What mechanisms might exist for fluid inclusion leakage? The answers to (1) and (2) are affirmative, with approximately 50% of the total chloride being water-soluble (on the average). A maximum possible chloride concentration of 20,000 mg/L can be attained in a groundwater associated with minimum porosities, maximum soluble rock chloride and static groundwater conditions. Leakage can probably occur through microfracturing of any mineral in the rock under sufficient stress, but microfracturing of calcite, zeolites and other easily broken minerals in fracture-fillings or veins may be highly significant. Stress changes leading to fluid-inclusion leakage could occur in deep mines and radioactive waste repositories as a result of blasting, drilling and dewatering large volumes of rock. (Authors' abstract)

NORMAN, A. and BARANOV, E.N., 1984, Conditions of formation of pyritic-polymetallic stratiform deposits of western Cuba (abst.): 27th Internat. Geol. Congress, v. 6, p. 229 (in Spanish).

The pyritic-polymetallic deposits of Santa Lucia and Castellanos are in Upper Jurassic carbonaceous arenaceous argillite formation with volcanics.

Two types of ore are distinguished in the deposits: banded pyritic-polymetallic, and veinlet-disseminated polymetallic and barite-polymetallic ores. The first type are sedimentary-hydrothermal syngenetic. T of formation is <50°C, with isotopically light S isotopes of 20% [trans. note: likely means 32S/34S ratio and not percent, 32S/34S of CDT = 22.21].

The second type ores are hydrothermal-metasomatic, and are superimposed upon the banded ores, producing a major redistribution of metals. Th fluctuated between 350-130°C. The S isotope composition of sulfides is much heavier, 17.6% [trans. note: likely means 32S/34S ratio and not percent. However, this leads to an impossible $\delta^{34}S$ value of 262 permil. Strictly, a 17.6 percent or 176 permil is also impossible.]. (From the authors' abstract, translated by G. Landis)

NORMAN, D.I., 1987a Why some geothermal systems deposit Au-Ag ores (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 790. Author at Geosci. Dept., New Mexico Inst. Mining & Tech., Socorro, NM 87801.

Volatiles in fluid inclusions from 26 epithermal deposits in the western US and Mexico have been analyzed by mass spectrometer and GCMS in order to determine the distinctive chemical characteristics of geothermal systems that form Au-Ag ore deposits. In contrast to most presently active geothermal systems, and to inclusions from veins with little Au or Ag, inclusions from Au-Ag ore deposits have $H_2S$ concentrations > 0.01 mol.% and generally higher levels of $N_2$ and organic compounds. Inclusions from Ag ores have $H_2S$ concentrations of approximately 0.01 mol.%, whereas those from Au deposits generally have $H_2S$ > 0.1 mol.%

Organic compounds are principally alkenes. The most common species are propene and butene, however the distribution of organic species is quite variable from deposit to deposit. High $N_2$ concentrations in inclusions is associated with high levels of organic compounds. Organic species have not been detected in inclusions from all Au-Ag deposits suggesting their presence is not a prerequisite for Au-Ag ore solutions.

The calculated solublity of Au in the fluids that deposited Au ores based on fluid inclusion analytical data indicates it typically was 1 to 10 ppm. This indicates these solutions were highly effective agents for leaching and transporting Au. Only a small percentage of geothermal systems form Au-Ag ores. This data suggests one distinguishing characteristic of Au-Ag depositing geothermal systems is high levels of $H_2S$. (Author's abstract)

NORMAN, D.I., 1987b Analysis of Rb-Sr and Sm-Nd in fluid inclusion waters (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Author at New Mexico Inst. Mining & Tech., Socorro, NM 87801.

Measured concentrations of Sm, Nd, Rb, and Sr in fluid inclusion waters are typically 10 to 100 ppm. Hence, inclusion fluid extracted from 10 grams of mineral have approximately 100 pg of these elements. As long as blank levels are >1* pg and >0.1* pg respectively for Rb-Sr and Sm-Nd, precise analyses of isotopic raitos and elemental concentrations can be made.

Inclusions are opened by thermal decrepitation and leached with a weak $HNO_3$ solution. The leachate is split 1:2 for isotope dilution (ID) and isotopic composition (IC) analysis, spike added to the ID aliquot, leachates dried, 1 ml 3N HCl added, and then the solutions are dried again. The sample is then treated in a similar manner to digested rock samples for the separation of elements by ion chromatography.

Rb-Sr isotopic data from inclusions rarely lie on an isochron. This is a result of the isotopic heterogeneity of hydrothermal fluids, which is demonstrated by large spreads in $^{87}Sr/^{86}Sr$ measured in co-deposited Sr-rich minerals such as fluorite. However, the time of mineralization can generally be constrained by construction of Sr isotope evolution diagrams. For the Snowbird Mines, MT, $^{87}Sr/^{86}Sr$ for four fluorites ranged from 0.7759 to 0.8789 and there is appreciable scatter in Rb-Sr isotopic data for inclusion from quartz. However, a Sr isotope evolution diagram constrains the age of mineralization between 64 and 77 Ma, which agrees well with a U-Pb date for the deposit of 74 ± 1 Ma.

Isotopic data can indicate the source of fluids. Rb-Sr isotopic data for Sn-quartz veins in the Mayo Darle granite lie far above the isochron for the granite. This indicates the ore solutions were not magmatic fluids derived from the host granite. The radiogenic Sr is either from the crust or leached from biotite several million years after the granite crystallized. Rb-Sr isotopic data from inclusions in the Drammen granite, Norway, constrain the mineralizing event to 10 to 15 Ma after crystallization. Sm-Nd isotopes in inclusion water confirm that crustal material was introduced into the granite during this event.

In conclusion, Rb-Sr and Sm-Nd isotopes in inclusion fluids may be used to constrain the age of mineralization and determine the source of the solute. Sm-Nd isotope systematics are such that these isotopes are best to use as a tracer for solutes. (Author's abstract) [*sic, these should be <, personal comm., D.I. Norman.]

NORMAN, D.I., APODACA, L.E., BAZRAFSHAN, Khosrow and BEHR, Christina, 1987, The use of fluid inclusions for the exploration of epithermal Au-Ag fluids (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 93-94. Authors at New Mexico Inst. Mining & Tech., Socorro, NM 87801, USA.

Only a small percentage of geothermal systems deposit Au-Ag ores. Inclusions were studied to determine if the fluids that form ores are in any way unique. Mineral deposition was modeled based on data obtained from fluid inclusion microanalyses to see if grade and dimensions of ore deposits can be predicted. The use of fluid inclusion microthermometry data to determine paleo-flow of ore solutions was studied both on the scales of a district and on an individual vein. The object is to direct exploration drilling to centers of mineralization. Samples from 21 epithermal deposits have been studied, and three districts were studied in detail.

Epithermal Au-Ag deposits generally have Th values >200°C and salinities <3 eq. wt.% NaCl, but these temperatures and salinities are common in geothermal systems. The gas chemistry of inclusions from ore deposits is distinctively different. They have orders of magnitude more $H_2S$, $H_2$, $N_2$, and organic compounds than reported in geothermal systems or found in non-ore-vein minerals. The high levels of $H_2S$ are understandable because Au is considered to be transported as a bisulfide complex. Measured $CO_2/H_2S$ from Au-Ag deposits are 1.3 to 0.1 and the highest values measured are from Au ores of exceptionally high grade from El Indio, Chile.

Over 7000 inclusions from 117 prospects and deposits in the Hermosa district, NM, were measured by microthermometry. Computer processing the data clearly shows the centers of mineralization. Au mineralization occurs at or near these centers with base metals and Ag zoned outwards. At the Cochiti deposit, NM, Th and salinity measurements on vein quartz indicate that T and salinity decrease laterally and vertically around ore shoots. When the data are contoured they outline upwelling centers of the ore solutions. Further, Au grades appear to correlate with closely spaced T contours.

Modeling Au, Ag and base metal deposition using the amounts of $H_2S$, $CO_2$, $H_2$ from microanalysis and salinity from microthermometry measurements has been done on several ore deposits. The vertical extent of mineralization, range in T over which mineralization occurred, and grades are close to those in the deposits studied.

Our data indicate that Au-Ag depositing fluids are chemically distinct from fluids that do not deposit ores and that a simple scoring method can be used to determine if a paleo-geothermal system had the proper fluids to deposit Au-Ag ores (e.g., a score of 1 is given for each condition such as $H_2S/CO_2$ is common with Au-Ag deposits, and -1 for each condition lacking). The data indicate that Th measurements can be used to find centers of mineralization where Au is most likely to occur and that modeling ore deposition from information gained from fluid inclusions can be used to predict the grade and extent of ore deposits.

We conclude that fluid inclusions are most useful and should be included along with the many other tools used for the exploration of epithermal Au-Ag deposits. (Authors' abstract)

NORMAN, D.I., CONDIE, K.C., SMITH, R.W. and THOMANN, W.F., 1987, Geochemical and Sr and Nd isotopic constraints on the origin of late Proterozoic volcanics and associated tin-bearing granite from the Franklin Mountains, west Texas: Can. J. Earth Sci., v. 24, p. 830-839. First author at Dept. Geosci., New Mexico Inst. Mining & Tech., Socorro, NM 87801, USA.

Includes some discussion of published inclusion analyses. (E.R.)

NORMAN, D., KYLE, P., SEGALSTAD, T. and WALDER, I., 1987, Mobility of trace elements in thermal waters in granite terranes (abst.): Abstracts, NATO Advanced Research Workshop, Fluid movements, element transport, and the composition of the deep crust, Lindås, Norway, 18-24 May, 1987 (unpaginated). Similar abstract, with added author J. Wan, in Amer. Current Research on Fluid Inclusions, Jan 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). First author at Dept. Geosci., New Mexico Inst. Mining & Tech., Socorro, NM 87801, USA. **Continued next page.**

Thirty-eight major and trace elements in fluid inclusions from the Drammen Granite, Norway, and Mayo Darle Granite, Cameroon, were analyzed. Drammen granite quartz is from several intrusive phases of the granite and from miarolitic cavities. Mayo Darle quartz is rock-forming quartz and from cassiterite-quartz veins. Quartz was scrupulously cleaned in HF, $HNO_3$, and electrolytic cells. The samples were split and one aliquot was decrepitated in air and leached with a 0.1% $HNO_3$ solution. The leachate was then dried in pure silica vials and analyzed by INAA. The decrepitated quartz was also analyzed by INAA. The volatiles, and Na, Ca, Ma[sic; Mg?], Cl and $SO_4$ were measured in the remaining sample by thermal decrepitation in a vacuum line coupled to a mass spectrometer, then leaching the decrepitated sample and analyzing the leachate by ion chromatography and ICP methods.

There is little correlation between the concentrations of elements in decrepitated quartz and that in the leachate. We conclude that elements in the leachate are primarily from inclusion liquids.

In order to illustrate the relative mobility of the elements, the analyses were normalized to Na, and to average crust. Differences in relative mobility of the elements measured is greater than 6 orders of magnitude. The elements mobile in all fluids measured are Cs, As, and Zn; those least mobile are Sc, Cr, Co, and Hf. The rare earth elements exhibit a range in relative mobility of 4 orders of magnitude; for example, measured levels of Nd in inclusion fluids range from 5000 to 0.3 ppm.

REE patterns are flat with an Eu anomaly and mimic those in the host granites. Inclusions in miarolitic quartz from the Drammen granite, which have Tt of 650 to 800°C and are inferred to be magmatic fluids, show high levels of chalophile elements and generally low levels of lithophile elements. Rock-forming quartz from the Drammen granite has S inclusions with Th values of 250 to 350°C that are inferred to be crustal fluids. These have relatively high levels of W and As. Mayo Darle rock-forming quartz has inclusions with Tt to 600°C and they have high levels of REE and other lithophile elements. Quartz from the Sn veins at Mayo Darle has inclusions with similar Th values as the granite but with a distinctively different chemistry lower in REE. These differences can be explained by different concentrations of the complexing agents $Cl^-$, $HS^-$ and $F^-$, and the T, pH, and $f(O_2)$ of the solutions.

We conclude that different geologic-hydrothermal systems mobilize different assemblages of elements and that at least minor amounts of all elements are transported in aqueous fluids. Trace elements that can be more mobile than Na are: Mo, W, Ir, Au, Zn, C, S, As, Sb, Rb, Cs, Ba, Ce, La-Lu, Ta, Th, and U. Even though a solution rich in these elements fluxed through a granite without appreciable leaching or deposition, isotopic ratios of these elements in the granite could be altered by exchange processes. (Authors' abstract)

NORMAN, D.I. and SAWKINS, F.J., 1987, Analysis of volatiles in fluid inclusions by mass spectrometry: Chem. Geol., v. 61, p. 1-10. First author at Dept. Geosci., New Mexico Inst. Mining & Tech., Socorro, NM 87801, USA.

Means of extracting and quantitatively analyzing volatiles in fluid inclusions have been studied and details of the methods developed are presented. Thermal decrepitation is the preferred method to open inclusions because experiments indicate that this method yields more accurate measurements of the sulphur-species gases and water.

Two assemblages of inclusion species have repeatedly been detected in inclusions from mineral deposits. A $CO_2$-dominated assemblage typically has been measured in inclusions from porphyry-type deposits. A $CO_2$-$N_2$-$C_nH_n$ assemblage is typical of inclusion volatiles from sediment-hosted and epithermal deposits. The probable source of $N_2$ and organic compounds is biologic material which is consistent with a crustal source for the ore solutions.

Inclusion volatiles from most ore deposits have 1-3 mole% gaseous species. However, levels of 5-15% have been measured in assemblages of vapor-dominant and liquid-dominant inclusions from epithermal deposits. The interpretation is that vapor-dominant inclusions are rich in gaseous species. This implies that the indicated "boiling" of the ore solutions are not strictly aqueous boiling but more an unmixing of the gaseous components.

Analytical data on volatiles in fluid inclusions have been used to calculate $fO_2$, $fS_2$, $fCO_2$ and pH of ore fluids, and these values agree with values calculated from other data. Data on gases in fluid inclusions have also been used to estimate trapping P and study paragenesis. (Authors' abstract)

NORONHA, F., DORIA, A. and KOSZTOLANYI, C., 1987, Fluid inclusion studies of the sterile quartz veins of the Sn-W deposit of Panasqueira, central Portugal (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 95-96. First author at Centro de Geol. da Univ. do Porto, Portugal.

In addition to the mineralized, subhorizontal veins, the Panasqueira mine contains other (barren) quartz veins, namely: veins subconcordant with the main cleavage, composed of synmetamorphic milky quartz ("Seixo bravo" - Quartz I); and subhorizontal saccharoid quartz veinlets (Quartz II) developed parallel to the mineralized veins.

Fluid inclusion studies on the Panasqueira mineralized veins have been previously reported; here we present some new data on these, together with a first report of fluid inclusion studies on barren veins (microthermometry and Raman spectrometry).

The "Seixo bravo" is crosscut by mineralized veins. The quartz from the spotted schist zone exhibits clear intracrystalline deformation under ductile conditions. It is very rich in fluid inclusions, dominantly two phase (type L) inclusions. We avoided the deformed inclusions so we presume that the fluids studied are contemporaneous with the earliest regional metamorphic episode. The aqueous phase has a salinity of 10 wt% eq. NaCl. The nonaqueous part (Flw = 0.7) is dominantly composed of $CH_4$ (67 mole% $CH_4$; 17 mole% $CO_2$; 16 mole% $N_2$) and its P is high enough to form clathrates (TmC = +5°C). The fluid has d = 0.775. The only likely source for the methane lies in the host metasedimentary rocks.

Quartz II exhibits a mosaic of recrystallized quartz with scarce relics of the prior deformed quartz. This quartz has few, small inclusions, because the bulk of the P fluid inclusions were concentrated in the intercrystalline boundaries. The study of fluid inclusions in the interior of the crystals indicates a highly aqueous fluid (11.5 wt% eq. NaCl), less dense than in "Seixo bravo" (d = 0.680). The composition of the gas phase is also quite different. $CO_2$ is absent and $N_2$ is dominant (87 mole% $N_2$; 13 mole% $CH_4$). We assume that Quartz II fluids are related with the recrystallization due to the thermal metamorphism ($T \simeq 470°C$, $P \simeq 1000$ bar). The $N_2$ content could indicate that all $NH_4$ present in silicates had been released during this thermal metamorphic event.

The fluids related to mineralization are quite different. There is an increase of low density $CO_2$ (63 mole% $CO_2$; 6 mole% $CH_4$; 23 mole% $N_2$). The aqueous phase shows a drop of salinity (8 wt% eq. NaCl). The overall composition is 90-93 mole% $H_2O$; 2-3 mole% NaCl; 3-4 mole% $CO_2$; 0-1 mole% $CH_4$ and $N_2$. $T \simeq 350°C$ ind $P \simeq 600$ bar for W deposition agree with the results of Kelly and Rye (1979).

The existence of flat joints filled with Quartz II implies that these joints predate the thermal metamorphic event. As Quartz II was deformed and locally the veinlets are folded, the flat joints are contemporaneous with the regional deformation as proposed by Ribeiro an Pereira (1982): these authors suggest that the flat joints are the result of a stretching contemporaneous with the folding responsible for the regional subvertical cleavage (N 120°E).

The opening of the pre-ore joints is related to an effective vertical tension $\sigma 1$ ($\sigma 2 \approx \sigma 3$ horizontal) caused by shrinkage of the granitic batholith and associated with hydraulic pressure related to mineralizng fluids. (Authors' abstract)

NORONHA, F. and MANGAS, J., 1987, Hydrothermal evolution of the Sn-W deposits associated with the Hercynian granites of the central Iberian zone: A review (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 151-152. First author at Centro de Geol. da Univ. Porto, 4000 Porto, Portugal.

The Sn-W metallogenic province of Iberian Peninsula is one of the most important of Europe. It contains many deposits of several types. The W deposits of Portugal and Spain are the leading sources of W from Europe. The most important deposits are related to the syn to late tectonic Hercynian granites. The latter include the following types: I - pegmatitic ore deposits (Sn); II - quartz veins (Sn; Sn-W-Mo; W); III - disseminated mineralization in granites.

In spite of the importance of the Iberian Sn-W deposits there [have been] very few fluid inclusion studies, [but these] throw some [light on] the metallogeny.

We observed the systematic presence of fluids with complex composition ($H_2O$-$CO_2$-NaCl-$CH_4$-$N_2$) and low density, or predominantly aqueous fluid ($H_2O$-$CO_2$-NaCl) with high densities. The most complex fluids are generally associated with pegmatitic, disseminated, intragranitic and deep exogranitic quartz vein mineralizations and in these cases $300°C < T < 500°C$ and $P < 2000$ bar. Although late fluids, in all these cases, were systematically aqueous, in high level exogranitic quartz veins this type of fluid is the only one present.

Sn-W deposition is generally related with a drop in $CO_2$ contents and therefore a drop in P. We realize that, in the examples studied, there exist two principal types of mineralizing fluids: (1) $CO_2$-poor, $H_2O$-NaCl-dominated fluids, and (2) $CO_2$-richer, generally associated with $N_2$ and $CH_4$. The presence of $N_2$ and $CH_4$ suggest a role for organic matter on Sn-W metallogeny. (From the authors' abstract)

NORTH, R.M. and TUFF, M.A., 1986, Fluid-inclusion and trace-element analyses of some barite-fluorite deposits in south-central New Mexico: New Mexico Geol. Soc. Guidebook, 37th Field Conf., Truth or Consequences, p. 301-306. Authors at New Mexico Bureau of Mines & Resources, Socorro, NM 87801.

Fluid inclusions in fluorite collected from barite-fluorite (± galena) deposits in south-central New Mexico show they formed from fluids of similar temperatures and variable salinities. Deposits spatially associated with igneous rocks show salinities of less than 1.5 eq. wt% NaCl, while those not obviously associated with igneous activity range from almost fresh water (0.1%) to 8%. Th on all types ranged from 120 to 218°C, with most measurements falling between 140 and 180°C.

Trace element analysis of barite showed considerable variation in samples from the same localities and no pattern was detected. The Y-Sr ratio in fluorite appears to separate igneous-associated deposits (e.g., Chise district) from sedimentary-hydrothermal deposits (e.g., Hansonburg district). The ratio is less than 1.5 in igneous-associated deposits and greater than 3 in known sedimentary-hydrothermal deposits. (Authors' abstract)

NOVICK, J.S., LABOTKA, T.C. and NABELEK, P.I., 1987, Metamorphic fluids in the Weeks Formation, Notch Peak, Utah: Evidence from fluid inclusions (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 791. First author at Dept. Geol. Sci., Univ. Tennessee, Knoxville, TN 37996-1410.

Upper Cambrian argillaceous limestones of the Weeks Formation were intruded by the Notch Peak quartz monzonite stock during the Jurassic. The assemblage wollastonite + vesuvianite + diopside + K-feldspar in the contact metamorphosed Weeks Formation indicate extremely low values of $X(CO_2)$, despite the loss of ~23% $CO_2$ by decarbonation reactions. Fluid inclusions were examined to determine whether fluid compositions were consistent with mineral equilibria. Three rock types were examined: 1) the Notch Peak granite, 2) skarns adjacent to the granite, and 3) high grade rocks from the Weeks Formation. Inclusions are secondary and consist of an $H_2O$-rich liquid and a vapor phase at room T. Fluid inclusion Tm of -12 ± 12°C give salinity values of 5-27 eq. wt. % NaCl. Th of 170 ± 40°C give filling T of 300 ± 100°C at 2 kb. These filling T indicate that fluid inclusions do not contain fluids from the presumed peak of metamorphism (500°-600°C). Moderate salinities are consistent with the widespread occurrence of scapolite. The presence of salinities higher than that of the $H_2O$-NaCl eutectic and the absence of daughter crystals in inclusions imply that the fluids that passed through these rocks must have contained salts other than NaCl. Even though fluid inclusions contain late metamorphic fluids, their composition is consistent with fluid compositions indicated by mineral assemblages. The presence of $H_2O$-rich fluids does not appear to be a result of fluid-phase separation of a low density $CO_2$ phase, because evidence for "boiling" was not observed. Unless the $CO_2$-rich phase failed to be trapped, the $H_2O$-rich fluid composition could have only been attained by massive infiltration of a water-rich brine. (Authors' abstract)

NOVIKOVA, L.N. and NOVIKOV, Yu.A., 1987, Parameters of hydrothermal solutions of geochemical haloes in the Rubtsovsk polymetallic ore deposit (USSR): Izv. Vyssh. Uchebn. Zaved., Geol. Razved., 1987, no. 8, p. 54-60 (in Russian).

NOWAK, E.J. and McTIGUE, D.F., Interim results of brine transport studies in the Waste Isolation Pilot Plant (WIPP): Sandia Nat'l. Labs. Rpt. SAND87-0880, 78 pp.

NOWLAN, G.S. and BARNES, C.R., 1987a Application of conodont color alteration indices to regional and economic geology, in Conodonts: Investigative Techniques and Applications, R.L. Austin, ed.: E. Horwood, Ltd., p. 188-202. First author at Geol. Survey of Canada, 601 Booth St., Ottawa, Ontario, K1A 0E8, Canada.

Compares the conodont color alteration index with fluid inclusion temperature data. Preliminary work suggests that perhaps ore-forming events (low temperature) may not be of sufficient duration to affect the conodont index. (H.E.B.) See also next item. (E.R.)

NOWLAN, G.S. and BARNES, C.R., 1987b, Thermal maturation of Paleozoic strata in eastern Canada from conodont color alteration index (CAI) data with implications for burial history, tectonic evolution, hotspot tracks and mineral and hydrocarbon exploration: Geol. Survey. Canada Bull. 367, 47 pp. (Continued)

Compares conodont "temperatures" with literature data on fluid inclusions from Mississippi Valley-type deposits. (E.R.) See previous item.

NUTMAN, A.P. and GARDE, A.A., 1987, The role of fluid in the accretion of Archaean sial (abst.): Abstracts, NATO Advanced Research Workshop, Fluid movements, element transport, and the composition of the deep crust, Lindås, Norway, 18-24 May, 1987 (unpaginated).

NUTMAN, A.P., RIVERS, T., LONSTAFFE, F. and PARK, F.J.W., 1987, Mid-Proterozoic retrograde metamorphism of early Archaean tonalites of the Isukasia area, southern West Greenland: Reactions, fluid compositions and implications for regional studies (abst.): Abstracts, NATO Advanced Research Workshop, Fluid movements, element transport, and the composition of the deep crust, Lindås, Norway, 18-24 May, 1987 (unpaginated).

OAKES, C.S., BODNAR, R.J., COLE, D. and WESOLOWSKI, D., 1987, Methane-bearing fluid inclusions from the Tallulah Falls Dome, NE Georgia: Implications for an unconventional methane resource in the southern Appalachians (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 791. First author at Dept. Geol. Sci., Virginia Polytech. Inst. & State Univ., Blacksburg, VA 24061.

Organic-rich sediments underlying crystalline thrust sheets in stack duplex structures are potential unconventional sources of hydrocarbons in the southern Appalachians. Hydrocarbons produced in these environments during and after thrust sheet emplacement may remain trapped beneath the crystalline sheets and thus be available for later economic exploitation. The Tallulah Falls Dome in the Blue Ridge province of northeastern Georgia is such a structure and is being considered as a scientific drilling site in which to test geologic hypotheses concerning crustal processes and the potential for unconventional methane resources (COSPLUM Project).

Fluid inclusion studies of samples from the Tallulah Falls Dome suggest that hydrocarbons generated in the underlying sediments may have leaked into the overlying crystalline rocks during or following emplacement of the thrust sheet. High-density (0.4 g/cc), secondary liquid methane inclusions in the Tallulah Falls quartzite are thought to represent these fluids and provide strong evidence for the possible accumulation of methane beneath the Tallulah Falls quartzite, which acts as a seal. Tar(?)-bearing inclusions surrounded by decrepitation haloes and the absence of $CO_2$ in methane inclusions suggest that methane may have been generated by thermal degradation of petroleum under highly reducing conditions. These inclusions combined with estimated trapping P and T of 250°-475°C and 3.7-5.5 kbars would preclude the existence of liquid hydrocarbons (petroleum) at depth and indicate that methane was produced either during or after emplacement of the crystalline thrust sheet. (Authors' abstract)

OAKES, C.S. and WILLIAMS, A.E., 1987, Fluid inclusion, stable isotope, and chemical evidence for fluid mixing in the Salton Sea geothermal field, California (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). First author at Dept. Geol. Sci., Virginia Polytech. Inst. & State Univ., Blacksburg, VA 24061.

Fluid inclusion, stable isotope, and chemical analyses of samples from the closely spaced Fee #1, Fee #5, and Britz #3 geothermal wells on the northeastern flank of the Salton Sea Geothermal Field (SSGF) indicate that complex mixing of chemically distinct fluids is occurring in the geothermal reservoir. These data provide valuable information for modeling of fluid flow and mixing in sediment hosted hydrothermal systems.

Production spinner logging of the Britz #3 geothermal well indicates that brine enters the wellbore at three discrete horizons: 73% at 2,375 m, 10% at 2,710 m, and 17% at 2,865 m. Ca, K, Mn, Fe, and Zn concentrations in this brine are depleted by 60% relative to the Fee #1 brine. It is therefore likely that the lower two entries contribute a brine of 25 wt % TDS and composition similar to the Fee #1 brine. The calculated chemistry of the corresponding 7 wt % TDS brine produced at 2,375 m bears a striking resemblance to dilute deep basin brines produced from oil exploration and geothermal wells elsewhere in the Salton Trough.

Fluid inclusions in a single vein calcite sample from the 2,375 m entry of the Britz #3 well contain between 1 and 18 wt % NaCl equiv. Th are nearly constant at 250°C. The implication that saline brines have been replaced by dilute brines of lower density in the Britz #3 reservoir is contrary to the expected replacement of dilute brines by denser, saline brines. Fluid inclusions in vein quartz and calcite from the Fee wells show 'normal' replacement of 1 to 12 wt % NaCl equiv. brines by brine containing up to 28 wt % NaCl equiv. Replacement of high density, saline brine by low density, dilute brine requires severe impedance in the vertical flow of the dilute brine. Calcite $\delta^{18}O$ compositions (SMOW) imply that horizontal flow persists in a distinctive sandstone unit over lateral distances of at least 1 km. The Fee #1 and Fee #5 wells have been cased below this aquifer and thus the production brines from these wells do not contain significant quantities of dilute brine.

The -6‰ $\delta^{18}O$ compositions of shallow, dilute (1 wt % TDS) groundwaters in the vicinity of the Fee and Britz wells agree with minimum brine $\delta^{18}O$ compositions calculated from vein calcites. Thus, the dilute surface waters are probably modern, low T analogs of the impled low $\delta^{18}O$ geothermal fluids. The heaviest, +6‰, brines indicated by calcite veins are substantially more enriched than the heaviest brines yet measured in the SSGF (+3.5‰). The trend of measured $Cl^-$ and $\delta^{18}O$ compositions of most SSGF geothermal brines, however, is best fit by a mixing line between the compositions 4,000 ppm $Cl^-$, -6‰ $\delta^{18}O$ and 180,000 ppm $Cl^-$, +6‰, $\delta^{18}O$. Though the later brines have never been directly observed in the SSGF, the high density of this brine may restrict it to the deeper, undrilled portions of the geothermal system. The high isotopic composition is probably due to extreme water-rock interaction and limited circulation. Ephemeral incursions of isotopically heavy, hypersaline brine into the upper (drilled) levels of the geothermal system may be caused by local dike injections or fracturing of deep over-pressured zones. (Authors' abstract)

OGEDENGBE, O., 1984, A study of the geochemisry, mineralogy, and ore genesis in the mineralized plutonic rocks of the Ririwai Complex: Kano State, Nigeria: MS thesis, Univ. Manchester.

Includes some fluid inclusion studies (pp. 162-168). Inclusions in quartz from various stages of alteration were studied. The earliest greisen stage (I) had P inclusions with Th 353-373°C and Tm -9.1 to -10.8°C. Late kaolinization was at 197°C and Tm -2.8. (E.R.)

OGEDENGBE, O., 1987, Greisen types and the processes of greisenization in the Ririwai tin lode, Kano state of Nigeria: Records of the Geol. Survey of Nigeria, v. 10, p. 45-61.

The chemical alterations usually associated with greisenization occur along the whole length of the Sn-Zn lode located at the center of the Ririwai ring complex. The greisen has been classified into three types based on spatial distribution, silicate and ore mineralogy. Chemical and mineralogical studies reveal differences and causes of differences in major and trace element composition between different types.

The following conclusions have been drawn regarding the genesis of the greisen types (Tf in °C and wt% NaCl eq. in %):

(i) Type I greisen was generated at a higher T (360-380; 14-15) than other greisen types. It was insulated from further interaction with incoming low T hydrothermal solution after the initial cassiterite mineralization.

(ii) Types II (314-320 and 11-12; 220-270 and 10-11) and III (250-280; 10-11) greisen were generated and mineralized in at least two phases viz: An early high T phase associated with zinnwaldization and cassiterite mineralization and a late lower T phase associated with chloritization of earlier formed zinnwaldite and contemporaneous sulphide mineralization. The degree of alteration of type II to type III is controlled by proximity to the pathway through which hydrothermal solutions ascended. (Author's abstract and summary)

OGUNDIPE, I.E., 1987, Mineralogical, fluid inclusion and stable isotope studies of the Benue valley lead-zinc-barite-fluorite deposits, Nigeria: PhD disser., Univ. Ibadan [Nigeria].

The epigenetic Pb-Zn-Ba-$CaF_2$ deposits of the lower, middle, and upper Benue valley are localized in fractures in Cretaceous sediments.

Fluid inclusion studies of the ore and gangue minerals indicate that T of deposition varied from district to district: values of Th are about 140°C in lower Benue (Pb-Zn), 130°C in middle Benue (Ba-F) and ~220°C in upper Benue (Pb-Zn). Variations of ~50°C occur within and between early and late minerals. The most saline fluids (~20 wt % eq. NaCl) occur in lower Benue sulfides but decreases gradually from the middle (15 wt % eq. NaCl) to upper (12 wt % eq. NaCl) Benue. Chemical analyses indicate Na-Ca-Cl brines.

The variations in $\delta^{34}S$ (-13 to +10 per mil) [presumably] reflect differences in the nature of the diagenetic sulfate reduction processes. The Pb is low radiogenic, with variations suggesting multiple sources. H and O isotopic data for the fluids associated with sulfides and quartz are consistent with a formation water origin. Carbon isotopes suggest carbon dominantly derived from dissolution of marine carbonates. No systematic evidence for mixing with less saline and cooler surface waters or boiling, except probably for $CO_2$, has been observed. (From the author's abstract)

OKUYAMA-KUSUNOSE, Yasuko and ITAYA, Tetsumaru, 1987, Metamorphism of carbonaceous material in the Tono contact aureole, Kitakami Mountains, Japan: J. Metamorphic Geol., v. 5, p. 121-139.

OLLILA, J.T., 1987, Genetic aspects of Sn, Li, Be, Nb-Ta pegmatites and Sn-W vein deposits of the Damaran orogeny, Namibia: Bull. Geol. Soc. Finland 59, Part 1, p. 21-34.

The pegmatites of the Northern, Central and Southern tin belts of the Damaran orogeny, which contain Sn, Li, Be, and Nb-Ta mineralizations, belong to the Abukuma low P metamorphic facies series, or to the intermediate-level rare-element pegmatite formations.

According to the present field and fluid inclusion study, the fluid P at the time of crystallization of the pegmatites did not exceed 2 kb in the Northern, Central and Southern Sn belts, considering the phase relations of the Li minerals (spodumene absent) and the barometry of the fluid inclusions. The depositional P increase northwards, however, being about 1 kb at Strathmore (Northern Sn belt), about 1.5 kb at Brandberg West and 2.4 kb at Awarab (Goantagab Sn belt).

The interaction of metamorphic connate water with hydrothermal fluid of magmatic origin is proposed as the deposition mechanism for vein type cassiterite-wolframite occurrences. The pegmatites may have derived from the residual fraction of volatile-rich Salem granite melts during the waning phases of the Damaran orogeny and crystallized in high water activity zones around their feeder intrusions. The importance of large-scale lineaments in relationship to pegmatites is also indicated. (From the author's abstract)

OLSEN, S.N., 1987, The composition and role of the fluid in migmatites: A fluid inclusion study of the Front Range rocks: Contrib. Mineral. Petrol., v. 96, p. 104-120. Author at Earth & Planet. Sci., The Johns Hopkins Univ., Baltimore, MD 21218, USA.

Monophase $CO_2$ inclusions occur in the leucosome quartz. They are, however, quite rare in the mafic selvage and paleosome (host rock) quartz. The mode of occurrence suggests that these are the earliest inclusions to form. In addition to the difference in abundance, there is a difference in $CO_2$-density distribution on a scale of a few centimeters between migmatic zones. Th for the leucosome inclusions range from -67°C to +20°C with two maxima (at ~ -21°C) while those for the paleosome and selvage inclusions are -37°C to +20°C with a single maximum at ~ +5°C. The densities corresponding to the Th maxima are appropriate for the P-T conditions for migmatization; these inclusions contain nearly pure $CO_2$, (Tm $CO_2$ = -56.5° to -57.2°C), as was confirmed by Raman.

It has been proposed by other workers that $CO_2$ fluid in the inclusions could form from an $H_2O$-$CO_2$ fluid when $H_2O$ is partitioned into the silicate melt. Such partitioning should result in some early $H_2O$-rich inclusions: $H_2O$ must be released as the melt crystallizes. As found in migmatites from other areas, most aqueous inclusions in the Front Range rocks are obviously much younger than the early $CO_2$ ones. However, early $H_2O$-rich fluid may still be preserved, at least in three ways: (A) in rare, isolated or clustered inclusions within quartz inclusions in feldspar; (B) as inclusions in microcline porphyroblasts; (C) in hydrous alteration products of feldspar. (A) contain dilute fluids, 1 to 6 wt% NaCl eq. The densities of (A) as well as those of the early $CO_2$ inclusions found in the quartz inclusions in feldspar are appropriate for the range P-T conditions estimated for migmatization. These early inclusions must have been preserved because of "protected" environment. Inclusions (B), found to contain $H_2O$ (and possibly $CO_2$) by infrared analyses, must be early because they are absent from recrystallized grains. (B) and (C) are much more common in the leucosome than in the other zones suggesting that they are related to migmatization process. The concentration of early $CO_2$ inclusions in the leucosome is consistent with the model of migmatization in which fluid concentration in the leucosome was a cause of melting. (From the author's abstract)

OLSEN, S.N., 1987, Problem of high density $CO_2$ inclusions (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 794. Author at Dept. Earth & Planet. Sci., Johns Hopkins Univ., Baltimore, MD 21218.

A fluid density in an inclusion too low for the P-T estimates for postulated time of trapping is commonly observed, and is generally attributed to fluid loss during the uplift process. A density too high is more difficult to explain. In the 1800 m.y. Front Range migmatites, high density $CO_2$ inclusions in leucosome quartz with Th <-30°C are associated with heavily altered plagioclase indicating concentrated fluid activities. They belong to the group of earliest $CO_2$ inclusions. The high density is not likely to be the relic of a higher P condition earlier than the main migmatization episode because: 1) the peak P-T estimates for migmatization are 4 kb and 700°C (in sillimanite field) but P needed for the densest inclusion is >7.5 kb (in kyanite field) and no kyanite (nor any other relict high P phase) has been found in the Precambrian Front Range; 2) they are rare in zones with least signs of deformation and melting (paleosomes and quartz inclusions within a feldspar grain) which instead contain relatively undisturbed early inclusions; 3) alteration of plagioclase, to which high density inclusions are related, was a late event in leucosome formation. Further, there is evidence for postentrapment change(s) in density: an intragranular trail in quartz contains $CO_2$ inclusions that exhibit almost whole range in Th (-40° to +24°C) as by the entire population of the early $CO_2$ inclusions (-66° to +30°C). Densities of inclusions in the trail are not related to the individual inclusion size but to the position of an inclusion relative to an apparent micro-shear plane crossing the 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. It is postulated that these high density inclusions occur selectively in the zones with abundant plagioclase alterations because of hydrolytic weakening of quartz which made the volume change possible. (Author's abstract)

O'NIONS, R.K., OXBURGH, E.R. and MATTHEWS, A., 1987, Tracing carbon sources in tectonically active areas (abst.): EOS, v. 68, no. 16, p. 465. First author at Dept. Earth Sci., Univ. Cambridge, Cambridge CB2 3EQ, UK.

Volatile C-species, principally $CO_2$, are present in many tectonically active areas and $\delta^{13}C$ is often close to bulk-Earth carbon. $CO_2$ is also found as inclusions in samples of the deep crust and the provenance of such C and its role in transporting heat-producing and related elements is a matter of some debate. $\delta^{13}C$ is often unhelpful in distinguishing between mantle and crustal C-sources, particularly where $\delta^{13}C$ is close to bulk Earth C. All carbon in the crust is mantle-derived <u>sensu stricto</u>; the real question concerns its residence time and chemical history in the crust.

$CO_2$ and associated rare gases have been investigated in active fluid systems in W. Europe where the distribution of $^3He$ is well established. The Massif Central of France has $CO_2$-rich mineral springs with $\delta^{13}C$ in the range -4 to -6‰ and R/Ra values up to 5.1. Similar spring systems in Switzerland have $\delta^{13}C$ in this range but R/Ra values show a dominance of radiogenic crustal He. Xenolithic materials from active areas have variable $\delta^{13}C$ but R/Ra close to mantle values. $C/^3He$ ratios in these systems vary widely from ~$10^9$ (similar to spreading ridges) to ~$10^{13}$. Simple mixing relationships between mantle fluids ($C/^3He = 10^9$) and crustal sources with variable radiogenic He and C/He are investigated. Crustally derived carbon appears to dominate fluids in the upper crust, but carbon derived by contemporary mantle degassing is significant locally. (Authors' abstract)

ONO, S., KONISHI, E. and SATO, J., 1987, Fluid inclusion data from the veins in the northwestern area of the Toyoha mine (abst.): Mining Geol., v. 37, no. 1, p. 70-71 (in Japanese).

O'REILLY, S.Y., 1987, Volatile-rich mantle beneath eastern Australia, <u>in</u> Mantle Xenoliths, P.H. Nixon, ed.: John Wiley & Sons, p. 661-670. Author at Sch. Earth Sci., Macquarie Univ., North Ryde, NSW 2113, Australia.

Evidence for the geochemical characteristics of mantle metasomatism in eastern Australia is provided by primitive magma compositions and by mantle-derived xenoliths. Trace element and isotopic compositions of the magmas indicate the presence of definable heterogeneous mantle domains on three scales; centimeter, kilometer, and fifty kilometers. High $^{87}Sr/^{86}Sr$ values in the basaltic rocks correlate with the presence of amphibole ± mica ± apatite in deep-seated xenoliths entrained in these or associated host rocks in the same province. The xenoliths may also contain fluid inclusions which reflect the composition of trapped mantle fluid phases. Both isotopic data and xenolith microstructures suggest that repetitive, discrete episodes of mantle metasomatism have occurred throughout the evolution of the eastern Australian lithosphere. Therefore the timing of mantle metasomatism relative to a given volcanic episode is variable: it may be precursory (on a long or short time-scale), or contemporaneous, or a combination of these. Mechanisms of metasomatism are also variable and may range from percolation of a volatile flux only, to infiltration by a silicate melt, or a combination of both. (Author's abstract)

ORTIZ HERNANDEZ, L.E. and MEDINA ESCUTIA, F.J., 1984, Metallogenic analysis in polymetallic deposits of the Tahuahueto mining district, Durango (Mexico): Geomimet, v. 129, p. 69-80 (in Spanish).

Au, Ag, Pb, Zn, Cu, and Sb mineralization occurs in veins and in tectonic breccias along the contacts with granodiorite intrusive rocks, and andesitic volcanic rocks. The initial pneumatolytic event formed microveinlets of quartz with chlorite, tourmaline, pyrite and chalcopyrite, in a stockwork manner. The second hydrothermal event produced a system of four stages in order: 1) quartz-pyrite-chalcopyrite-sphalerite-galena, formed between 265-250°C, 2) quartz-pyrite-chalcopyrite-sphalerite-galena-bornite-tetrahedrite, formed at 250-180°C, 3) quartz-pyrite-galena-stromeyerite crystallized at 190-170°C, and 4) quartz-calcite-fluorite-chalcedony-opal-zeolites formed between 170-149°C.

The associated hydrothermal alteration consists of propylitic, phyllic, argillic, and locally potassic assemblages. The character and distribution of stages and alteration in the deposits studied, suggest the persistence of mineralization to depth in El Creston and El Rey mines. Likewise, in the Cinco de Mayo deposit excellent prospects exist for disseminated copper occurrences. (From the authors' abstract, translated by G. Landis)

OSICHKINA, R.G. and TILLYAKHODZHAYEV, Kh.N., 1986, Distribution of copper, manganese, and iron(II) between phases in aqueous systems containing sodium, potassium, and magnesium chlorides: Geokhimiya, no. 4, p. 522-528 (in Russian; translated in Geochem. Int'l., v., 23, no. 8, p. 107-112, 1987). Authors at Inst. Chem., Acad. Sci. Uzbek SSR, Tashkent.

Isothermal saturation at 25 and 50°C has been used to examine the partition coefficients of copper, manganese, and iron in the fields of halite, sylvite and carnallite in aqueous salt systems containing the chlorides of sodium, potassium and magnesium. These coefficients in all cases are <1, which implies accumulation in the liquid phases. A study has been made of the mechanism of trace-component trapping by the solid phase by calculating the coefficients from formulas given by Khlopin and by Dorner and Hoskins, as well as by recording the ESR spectra. (Authors' abstract)

OSORGIN, N.Yu., PAL'YANOV, YU.N., SOBOLEV, N.V., KHOKHRAYAKOVA, I.P., CHEPUROV, A.I. and SHUGUROVA, N.A., 1987, Inclusions of liquified gases in diamond crystals: Dokl. Akad. Nauk SSSR, v. 293, no. 5, p. 1214-1217 (in Russian).

OSTERBERG, S.A., MORTON, R.L. and FRANKLIN, J.M., 1987, Hydrothermal alteration and physical volcanology of Archean rocks in the vicinity of the Headway-Coulee massive sulfide occurrence, Onaman area, Northwestern Ontario: Econ. Geol., v. 82, p. 1505-1520. First author at Dept. Geol., Univ. Minnesota-Duluth, Duluth, MN 55812.

The Headway-Coulee Zn-Pb-Cu-Ag prospect occurs as a series of 13 lenses of vein and disseminated-type sulfides which are associated with hydrothermally altered Archean mafic lavas and felsic hydroclastic rocks. Sericite is thought to have formed from a low-T, evolved seawater fluid which circulated only in the very upper portions of the hydrothermal system. At low water/rock ratios this fluid became enriched in K and Si and was heated enough to rise buoyantly along fractures and more permeable lithological units. Water-rock interactions formed sericite and quartz at the expense of plagioclase feldspar.

Iron chlorite-type alteration is believed to have formed from an evolved, high-T seawater fluid which circulated at depth. Interaction with mafic rocks at low water/rock ratios enriched the fluid in Fe, Mn, $H^+$ while depleting it in Ca and Na. (From the authors' abstract)

OXBURGH, E.R. and O'NIONS, R.K., 1987, Helium loss, tectonics, and the terrestrial heat budget: Science, v. 237, p. 1583-1558. Authors at Dept. Earth Sci., Univ. Cambridge, Cambridge CB2 3EQ, UK.

It has been known for the last decade that primordial He incorporated in Earth at the time of its formation is still being degassed during the formation of new ocean crust at spreading ocean ridges. It is now clear that somewhat contrary to expectation, substantial degassing is also taking place through the continental crust. In western Europe the escape of mantle volatiles seems to occur largely where the crust is undergoing active extension. Although it is known that melting is the principal process for extracting and concentrating He from the mantle at ocean ridges, the equivalent subcontinental process remains poorly understood. The same elements that are responsible for most of Earth's radiogenic heating (U and Th) are also responsible for the generation of radiogenic He. The present rate of mantle heat loss, however, is out of equilibrium with the rate of He loss--too large by about a factor of 20. Either radiogenic He is accumulated in the mantle while heat escapes or current models for the bulk chemistry of Earth are in error and much of the terrestrial heat loss is nonradiogenic. (Authors' abstract)

OXBURGH, E.R., O'NIONS, R.K. and HILL, R.I., 1987, Helium isotopes in sedimentary basins: Nature, v. 324, p. 632-635. First author at Dept. Earth Sci., Univ. Cambridge, Downing St., Cambridge CB2 3EQ, UK.

Measurements of helium isotopes in the ground waters and natural gases of sedimentary basins reveal that some possess a major component of mantle-derived helium, apparently related to their mechanism of formation. Neogene basins formed by loading do not involve introduction of significant mantle helium, whereas those formed by extension do. (Authors' abstract)

PABALAN, R.T. and PITZER, K.S., 1987, Thermodynamics of concentrated electrolyte mixtures and the prediction of mineral solubilities to high temperatures for mixtures in the system Na-K-Mg-Cl-$SO_4$-OH-$H_2O$: Geochim. Cosmo. Acta, v. 51, p. 2429-2443.

PABALAN, R.T. and PITZER, K.S., 1987, Thermodynamics of NaOH(aq) in hydrothermal solutions: Geochimica Cosmo. Acta, v. 51, p. 829-837.

PAGEL, M., 1987, Thermal history of sedimentary basins by fluid inclusions (abst.): Terra Cognita, v. 7, no. 2-3, p. 481. Author at CREGU and GS CNRS-CREGU, Vandoeuvre-lès-Nancy, France.

A review. (E.R.)

PAN, C.-F. and ARGERSINGER, W.J., Jr., 1987, Isopiestic determination of the osmotic and relative activity coefficients in $BaCl_2$-$ZnCl_2$-$H_2O$ at 25°C: J. Chem. Eng. Data, v. 32, p. 205-210.

PANIAGUA, Andrés, LOREDO, Jorge and GARCIA IGLESIAS, Jesús, 1987, Epithermal mineralization in the Aramo mine (Cantabrian Mountains, NW Spain):

Correlation between paragenetic and fluid inclusion data (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 97-98. First author at Dept. Geol., Univ. de Oviedo, Spain.

The Aramo mine is a Cu-(Ni-Co)-S-As carbonate-hosted ore deposit. By a study of fluid inclusions in quartz, two principal types of inclusions are observed: the major group is formed of P inclusions, with Th from 85 to 170°C, and a maximum of 120-125°C; the second, with Th between 40°C and 50°C, is formed of only S inclusions. The first group of inclusions shows Te from -55°C up to -75°C, having Tm[ice?] from -15°C to -30°C. It is a system clearly different of pure NaCl-$H_2O$, with significant presence of Ca and Mg. For the S inclusions, Tm varies from 0°C up to -5°C, related to a NaCl-$H_2O$ system.

With respect to the paragenesis, the presence of minerals such as bravoite, talnakhite and S-rich bornite, with upper temperature limits of 137°C, 186°C and 125°C [references given in original] is in good agreement with the fluid inclusion data.

One may conclude then the Tt -- without pressure correction, because it must be low -- correspond to an epithermal environment, with moderate and stable conditions during the major phases of the mineral deposition. (From the authors' abstract)

PANKINA, R.G., MEKHTIYEVA, V.L. and GURIYEVA, S.M., 1986, Sulfur isotope compositions of Caspian-depression evaporites: Geokhimiya, no. 4, p. 559-562 (in Russian; translated in Geochem. Int'l., v., 23, no. 8, p. 141-144, 1987).

PAPIKE, J.J., 1987, Proceedings of the Intl. Min. Assoc. Symposium: Mineralogy and geochemistry of granites and pegmatites: Geoch. Cosmo. Acta, v. 51, p. 387.

This introduces 11 papers (pp. 389-540) dealing with the subject and containing many discussions of the interrelations of volatiles and granites, of pertinence to all studies of inclusions in such rocks. (E.R.)

PARILOV, Y.S., KAYMAKOV, A.K., KOBZAR', K.P., LEVIN, V.L. and MIKHALEVA, V.A., 1987, Features of fluid inclusions in coarsely crystalline magnetite ores of the Aleshinsk deposit: Izvest. Akad. Nauk Kazakh. SSR, Ser. Geol., v. 1(293), p. 58-64 (in Russian). Title incorrectly translated as "crypto crystalline" in some data banks. (E.R.)

PARK, H.-I., WOO, Y.-K. and BAE, Y.B., 1987, Silver ores and fluid inclusions of the Cheolam silver deposits: Jour. Korean Inst. Mining Geol., v. 20, no. 1, p. 1-18 (in Korean; English abstract).

The Cheolam Ag deposits are emplaced along the fractures in breccia dike and the Hongjesa granite. Six stages can be recognized: I, base metal sulfides; II, base metal sulfides and Ag minerals; III, carbonates; IV, Ag minerals and base metal sulfides; V, Ag minerals; VI, barren quartz.

Fluid inclusion studies on stages I, II, IV and VI quartz and stage III calcite, respectively, yielded Th: 225° to 360°C; 145° to 220°C; 175° to 240°C; 130° to 185°C; 120° to 145°C. Salinities were 4 to 10 wt.% eq. NaCl for stage I and VI. Mineralogical T for each stage are within the range of Th and sulfur fugacities declined steadily from $10^{-9.7}$ atm to $10^{-18.7}$ atm from stage I to stage V. (From the authors' abstract)

PARRY, W.T. and BRUHN, R.L., 1987, Fluid inclusion evidence for minimum 11 km vertical offset on the Wasatch fault, Utah: Geology, v. 15, p. 67-70. Authors at Dept. Geol. & Geophys., Univ. Utah, Salt Lake City, UT 84112. (Continued)

The footwall of the Wasatch fault in the Corner Creek area near Salt Lake City is hydrothermally altered and deformed quartz monzonite of the Oligocene Little Cottonwood stock. S fluid inclusions are associated with hydrothermal alteration minerals and structural deformation. Thermometric measurements of fluid inclusion characteristics indicate entrapment of a $CO_2$-$H_2O$-NaCl fluid at minimum T of 223-353°C and minimum fluid P of 900-2800 bar. The 2800-bar fluid P is near lithostatic P at a depth of 11 km, the minimum displacement of the fault that is required for exhumation of the observed alteration and fluid inclusions and more than three times greater than most previous estimates. The large displacement estimate is supported by the occurrence of pyrophyllite in shales in the footwall, by the petrology of metamorphosed shale surrounding an unroofed pluton in the footwall, and by geologic reconstruction of the eroded footwall. (Authors' abstract)

PASALSKAYA, L.F., KALINICHENKO, A.M. and MATYASH, I.V., 1986, On the nature of light gases giving off during heating in inert atmosphere of thin mineral fractions: Dokl. Akad. Nauk Ukrain. RSR, Ser. B, Geol., Khim., and Biol. Nauk, 1986, no. 12, p. 7-10 (in Ukrainian).

Analyses given for $H_2$, $CH_4$ and CO. (E.R.)

PASTERIS, J.D., 1987, Fluid inclusions in mantle xenoliths, in Mantle Xenoliths, P.H. Nixon, ed.: John Wiley & Sons, p. 691-707. Author at Dept. Earth & Planet. Sci., Washington Univ., Campus Box 1169, St. Louis, MO 63130, USA.

Fluids are important in the upper mantle because of their implications for the oxidation state, their effect on partial melting, and their role in scavenging and metasomatism in the mantle. One method of study is the analysis of fluids trapped as inclusions in mantle minerals. The inclusions have been studied individually by microthermometry and laser Raman spectroscopy, and in bulk by techniques such as heating-decrepitation followed by mass spectrometry. Most fluid inclusions in mantle rocks are less than 15 μm in diameter and consist dominantly of $CO_2$. Small amounts of $N_2$, sulphur species, rare gases, and CO also have been reported. The densities of the fluid inclusions and their concentration along healed fractures suggest that most of the inclusions are secondary in origin, i.e., captured during upward rise of their entraining melt, not at the deeper mantle source. This is in accord with the models of Eggler and Baker (1982) and Schneider and Eggler (1984), which postulate that at depths exceeding ~70 km, a separate volatile phase does not exist; rather, the mantle fluids probably are C-O-H volatiles dissolved in silicate melts. Oxygen fugacities ($fO_2$) inferred from mineral assemblages and from analyses of intrinsic $fO_2$ indicate a range in the upper mantle from QFM to IW. Calculations of C-O-H equilibria show that the fluids should be dominantly $CO_2$-$H_2O$ at the higher inferred $fO_2$'s and $CH_4$-$H_2O$ at the lower $fO_2$'s. The fact that the inclusions instead are almost pure $CO_2$ is another indication that they do not represent volatiles from the upper mantle source of their host xenoliths. Other probable reasons for the $CO_2$ composition are post-trapping reequilibration of the fluids, as by diffusion and by reaction-precipitation. Study of fluid inclusions in mantle rocks provides important information therefore on secondary magmatic processes. It provides evidence of different fluid regimes and helps confirm mineralogical geothermobarometry. Such study also may contribute to our understanding of $fO_2$ variations and changes in upper mantle. (Author's abstract)

PASTERIS, J.D. and WANAMAKER, B.J., 1987, Use of the laser Raman microprobe to monitor reactions in individual fluid inclusions (abst.): Geol. Soc.

Am. Abstracts with Programs, v. 19, p. 800. First author at Dept. Earth & Planet. Sci., Washington, Univ., Box 1169, St. Louis, MO 63130.

A simplifying assumption often made in interpreting fluid inclusions is that there has been essentially no change in fluid composition and density since trapping. However, reequilibration of the fluid does not preclude useful interpretation of an inclusion if the post-trapping reaction(s) can be determined; such information helps establish a more detailed history of the host rock. The laser Raman microprobe (LRM) provides pinpoint analyses of inclusions and their phases, which aids in the interpretation of such reaction mechanisms. Two natural occurrences of apparently reequilibrated fluid inclusions and a natural sample that was experimentally reequilibrated have been analyzed. 1) In partially serpentinized olivine from the Kao kimberlite, Lesotho, the originally pure $CO_2$ inclusions have no detectable gases, but rather contain granular graphite plus calcite or a graphite film plus magnesite. LRM spectra show both types of graphite to be well ordered. $H_2$ released during serpentinization may have brought the $CO_2$ inclusions to graphite saturation. 2) Olivine grains in troctolites from the Duluth Complex, MN, have numerous fluid inclusions containing low-density $CH_4$, magnesite, and well ordered graphite. E. Ripley and coworkers (pers. comm.) have inferred that fluids interacting with the Duluth melts were 50 mole % each of $CH_4$ and $CO_2$. The present inclusion assemblage in part may be the result of consumption of $CO_2$ in the reaction forsterite + $CO_2$ = magnesite + enstatite, with $CH_4$ unreacted. If so, the fluid and olivine equilibrated at >18 kb, for 1000°C (Newton and Sharp, 1975). 3) A polished wafer of San Carlos olivine that contained pure $CO_2$ fluid inclusions was taken to 1400°C at $fO_2$ $\sim 10^{-8}$ (buffered by $H_2O$-$CO_2$ mixtures). After heat treatment, the fluid inclusions had ~40 mole % CO and 60 mole % $CO_2$ according to LRM analyses. (Authors' abstract)

PASTERIS, J.D. and WOPENKA, Brigitte, 1987, Use of a laser Raman microprobe to trace geological reactions, in Roy H. Geiss, ed., Microbeam Analysis - 1987: San Francisco Press, Inc., San Francisco, CA, p. 205-209.

A review of several applications, including analysis of fluid and solid inclusions in mantle xenoliths. (E.R.)

PATERSON, C.J., UZUNLAR, N. and LONGSTAFFE, F.J., 1987, Epithermal Au-Ag deposits in the northern Black Hills: A variety of ore-forming fluids, in Proc. of the Third Western Regional Conf. on Precious Metals, Coal and Environment, K. Han and Kliche, C., eds., Dept. Min. Eng., S. Dakota School Mines Tech.

PAULAITIS, M.E. and ALEXANDER, G.C., 1987, Reactions in supercritical fluids. A case study of the thermodynamic solvent effects on a Diels-Alder reaction in supercritical carbon dioxide: Pure & Appl. Chem., v. 59, no. 1, p. 61-68. Authors at Chem. Engrg. Dept., Univ. Delaware, Newark, DE 19716, USA.

The fundamental aspects of chemical reaction kinetics at near-critical conditions are discussed within the framework of transition state theory and the thermodynamics of critical phenomena for multicomponent systems. This discussion emphasizes the geometric analysis of Griffiths and Wheeler which describes the manner in which various thermodynamic properties behave on approaching mixture critical points for multicomponent systems. This analysis is used to explain experimental observations of the reaction kinetics for the Diels-Alder cycloaddition reaction of maleic anhydride with isoprene in supercritical $CO_2$ at conditions near the critical point of $CO_2$. The practical aspects of supercritical fluids as solvents for reacting systems are also discussed. (Authors' abstract)

PAVLUN', N.N., 1986, Physico-chemical conditions of ore mineralization in the Verkhne-Kayrakta wolframite-scheelite stockwork of the Central Kazakhstan: Izvestiya Vyssh. Uchebn. Zaved., Geologiya i Razvedka, no. 7, p. 29-36 (in Russian). Author at the L'vov State Univ., L'vov, Ukraine, USSR.

The stockwork deposit occurs in the Uspenskaya folded zone, in sandy-shaly Silurian beds and effusive-terrigenic Devonian-Carboniferous complex. The deposit is a typical above-intrusive quartz-wolframite-scheelite stockwork with other subordinate minerals (about 80 species), and with extensively developed metasomatism: K-feldspathization, albitization, chloritization, sericitization, silicification, pyritization and weak greisenization. The following mineral associations were recognized: molybdenite-feldspar-quartz (in parentheses are listed in sequence the mineral used for Th measurements, Th in °C, type of homog. and P in $10^7$ Pa) (quartz, 435-385 in G, 425-340 in L, 10), molybdenite-pyrite-wolframite-quartz (quartz, 405-400 in G, 390-265 in L, 14-10, fluorite 345-250), chalcopyrite-pyrite-scheelite-quartz (quartz 385-250 in L, scheelite 370-260 in L, 6.5-5.0), galena-sphalerite-quartz (quartz 295-180 in L, 4.5-3.0), fluorite-quartz (quartz 195-75 in L, fluorite 160-80 in L), zeolite-calcite (calcite 130-55). Two triple water leachates from quartz of the early associations: molybdenite-pyrite-wolframite-quartz and chalcopyrite-pyrite-scheelite-quartz, yielded the following results (in mg per 250 ml of leachate): Li 0.002-0.018, Na 1.43-2.39, K 0.50-0.98, Ca 0.09-0.23, Mg 0.04-0.08, Sr 0.03-0.05, Ba 0.001-0.15, total Fe nil-0.01, sum of cations 2.01-2.08, $HCO_3$ 1.57-2.57, Cl 2.01-2.08, F nil-0.20, $SO_4$ 0.02-0.13, HSiO(sic) 2.03-2.18, sum of anions 7.05-6.16. The essential mass of W ores formed at 385-260°C during the scheelite-quartz stage, probably partly by replacement of the earlier wolframite. $LCO_2$ was found in inclusions in minerals of the scheelite and sulfide (galena-sphalerite) stages. The pH values of water leachates were 5.7-6.1 (Abstract by A.K.)

PAVLUN, N.N., KOSTENKO, A.I. and KOSTIN, V.A., 1986, Methodological aspects of mass-spectrometric chemical analysis of the gas phase of fluid inclusions of mineral-forming solutions in minerals: Mineral. Sb. (Lvov), v. 40, no. 2, p. 18-22 (in Russian). Authors at L'vov Gos. Univ., Lvov, USSR.

See same authors, Fluid Inclusion Research, v. 19, 1986, p. 331-332. (E.R.)

PAYETTE, C. and MARTIN, R.F., 1987, Chemical features of magmas in the Topaz Mountain area, Utah, as revealed by melt inclusions (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 801. Authors at Dept. Geol. Sci., McGill Univ., 3450 University St., Montreal, QC, Canada H3A 2A7.

Tertiary rhyolitic rocks of Topaz Mountain, Utah, provide information on the compositional variations among adjacent batches of magma. The crystal tuff member of the Joy Tuff, at the base of the sequence, contains relatively abundant and large (150 µm) melt (glass) inclusions trapped in quartz phenocrysts. The inclusions are round (i.e., primitive) and contain trapped liquidus phases (e.g., apatite, amphibole?). The glass is K-rich, peraluminous and rhyolitic: $SiO_2$ 70.8, $Al_2O_3$ 14.5, $K_2O$ 5.9, $Na_2O$ 3.0%, with low Fe, Mg, Mn and Ca concentrations. Contents of fluorine and chlorine also are low: F 0.06, Cl 0.11%. The melt contains 7 to 9% normative corundum; the analytical totals (n = 25) are close to 95%, leading us to infer that the explosively emplaced melt contained close to 5% dissolved $H_2O$. In a Qtz-Ab-Or plot, many compositions cluster near $Qtz_{53}Ab_{14}Or_{33}$ (molar proportions).

Pristine melt inclusions are scarcer and smaller (50 µm) in units of Topaz Mountain that are stratigraphically above the Joy Tuff. The glass is F-rich (1.7% F, 0.3% Cl), potassic, peraluminous (8% normative corundum) and rhyodacitic: $SiO_2$ 68.9, $Al_2O_3$ 17.6, $K_2O$ 6.5, $Na_2O$ 4.3%, with low Fe, Mg, Mn and Ca concentrations. The analytical totals for the glass are close to 99%; the magma, which was emplaced as flows and domes, was much poorer in $H_2O$ than that which erupted to give the Joy Tuff. Apatite is a liquidus phase. In a Qtz-Ab-Or plot, the glass is close to $Qtz_{45}Ab_{22}Or_{33}$, i.e., less siliceous than that found in the Joy Tuff. In terms of bulk compositions, however, the Joy Tuff is more primitive than the Topaz Mountain flows. The vitrophyric flow-rocks may well have undergone metasomatic adjustments (e.g., silicification) upon devitrification. A systematic study based on melt-inclusion chemistry and included liquidus phases will shed light on fractionation trends. (Authors' abstract)

PEABODY, C.E., 1987, The association of petroleum and cinnabar at the Culver-Baer mine, Sonoma County, California (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 801. Author at Dept. Applied Earth Sci., Stanford Univ., Stanford, CA 94305.

Petroleum occurs with cinnabar in virtually every mercury district in the California Coast Ranges. This association has been studied in detail at the Culver-Baer mine (Mayacmas District), located within the strike-slip Mercuryville fault zone at the margin of the Geysers geothermal area. Host rocks are large boudins of Franciscan Complex serpentine, graywacke, and shale.

Petroleum, cinnabar, and silica commonly occur together in high angle quartz/chalcedony veins and low angle planar breccia veins which cut and are spatially coincident with silica-carbonate rock, the altered equivalent of serpentine. Petroleum coats and is intergrown with cinnabar, and rarely, fills cinnabar-lined vugs. Locally, the two substances occur independently. Liquid petroleum occurs between or within quartz crystals as light brown, 2-phase (L+G) inclusions which fluoresce bright yellow or dull orange under ultraviolet excitation. Th (minimum trapping) range from 130 to 145°C. Gas chromatography shows that oil from a breccia consists of n-alkanes (C14 to C24) together with numerous cyclic and aromatic components. The former positions of petroleum droplets are locally demarcated by fibrous needles of residual solid petroleum, probably N, S, O heteroatomic polycyclic aromatics, which fluoresce yellow and occur within quartz and chalcedony. Given the regional geology, the most likely source of this petroleum is the Franciscan Complex. Future work will test the hypothesis that the petroleum and mercury have a common sedimentary source. (Author's abstract)

PEARCE, T.H., RUSSELL, J.K. and WOLFSON, I., 1987, Laser-interference and Nomarski interference imaging of zoning profiles in plagioclase phenocrysts from the May 18, 1980, eruption of Mount St. Helens, Washington: Am. Mineral., v. 72, p. 1131-1143. First author at Dept. Geol. Sci., Queen's Univ., Kingston, Ontario K7L 3N6, Canada.

See also Nixon and Pearce, this volume. (E.R.)

PEARCY, E.C. and PETERSEN, Ulrich, 1987, Mineralogic and fluid inclusion study of ore fluids of the Cherry Hill gold/mercury deposit, northern California, and the relation to extant hot springs (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 802. Authors at Harvard Univ., 20 Oxford St., Cambridge, MA 02138.

The paragenetic sequence at Cherry Hill began with an early adularization stage; this was followed by an alternating series of five carbonate and four silica stages. Fluid inclusion evidence indicates that boiling of fluids during the two early silica stages occurred at approximately 180°C. These two stages contributed little Au mineralization. The two later silica stages contain the bulk of the Au at Cherry Hill. During these stages fluid T was ca. 165°C with no evidence of boiling. Apparent salinities during the boiling stages range from 3 to 14 wt % NaCl equivalent. During the main stage of Au deposition, the apparent salinity was approximately 2.5 wt %. Mercury is restricted to the third silica stage and occurs as cinnabar and as a constituent of electrum (up to 12 wt % Hg). After the main stage of Au mineralization, the T dropped off steeply while the salinity remained constant at 2.5 wt %. The lowest T measured in the last silica stage is 100°C.

The active hot springs at Cherry Hill are spatially coincident with the highest Au and Hg concentrations as determined by surface rock chip analyses; they have a minimum T of 60°C and a salinity of approximately 2.5 wt %. Sediments currently forming from these hot springs are anomalously enriched in Au, Hg, As and Sb. The similarity of the current hot spring waters to the fossil fluids indicates that the present hot springs represent the waning stages of the Cherry Hill mineralizing system. (Authors' abstract)

PEARSON, J.W. and PORTER, E.W., 1987, Characteristics of the ore fluid, Phillipsburg area, northern Black Range, New Mexico (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Authors at Dept. Geol. Sci., Univ. Texas at El Paso, El Paso, TX 79968.

The Phillipsburg area lies ~50 miles northwest of the city of Truth or Consequences in the northern part of the Black Range in southwestern New Mexico. Ore deposits in the area consist mainly of gold and silver mineralization in irregular shoots from 50 to 500 feet below the surface, and lie on a north-south trend following the strong fissure veins of the district. Tertiary andesites of the Rubio Peak Formation are the primary host rocks and exhibit a high degree of propylitic alteration.

Samples for the study of fluid inclusions were collected from the Great Master Lode, Bullion, Elephant Lode, and Headframe veins. A total of 183 fluid inclusions in quartz (mostly amethyst) were measured for Th and freezing point. Inclusions range in size from 2 to 30 microns, with an average of 6 microns. Measurements were concentrated on P inclusions. Two-phase, liquid-rich inclusions (Type 1) are the most abundant. A small number of dms were observed and consist of two types: quartz crystals and an unidentified, opaque mineral.

Th (not corrected for P) range from 144 to 327°C. A small but distinct population of inclusions fall in the range between 155 and 170°C (11 inclusions), the largest populations of inclusions occur between 220 and 270°C (122 inclusions), and another small but distinct population is found in the range between 290 and 305°C (10 inclusions). Tm ice range from -1.9 to +0.6°C[sic]. This indicates salinities of <3.52 wt.% NaCl equiv. Considering the relatively low Th and salinities for the ore fluids, the Phillipsburg area can be classified as an epithermal environment. (Authors' abstract)

PEDERSEN, J.L. and STENDAL, H., 1987, Geology and geochemistry of tungsten-antimony vein mineralization on Ymers Ø, East Greenland: Trans. Inst. Min. Metall. Sect. B, v. 96, p. B31-B36. First author at Nunaoil A/S, Greenland.

Vein- and breccia-type mineralization occurs in east-west-striking tensional faults, which intersect a sedimentary sequence of late Precambrian quartzites, shales, limestones and dolomites. The mineralizing event was contemporaneous with folding and faulting during the Caledonian orogeny. Precipitation of the ore-forming fluids took place at T of 170-240°C from saline solutions with 2-6 wt% NaCl eq. The origin of the hydrothermal solutions may have been either igneous or metamorphic; the fluids were probably channelled to the surface along deep-seated NNW-SSE-striking structures. (From the authors' abstract)

PEDROSA-SOARES, A.C., MONTEIRO, R.L.B.P., CORREIA-NEVES, J.M., LEONARDOS, O.H. and FUZIKAWA, K., 1987, Metasomatic evolution of granites, northeast Minas Gerais, Brazil: Revista Brasileira de Geociências, v. 17, p. 512-518.

See Monteiro (1986), Fluid Inclusion Research, v. 19, p. 295-296, 1986, for fluid inclusion data. (K. Fuzikawa).

PENG, Ligui, 1987a The genesis and evolution of Alpine-type ultrabasic rocks in western Junggar, Xinjiang: Acta Geologica Sinica, v. 61, p. 138-150 (in Chinese, English abstract). Author at Xi'an Inst. Geol. & Min. Resources, Chinese Acad. Geol. Sci., Xi'an, Shaanxi, PRC.

The Alpine-type ultrabasic rocks of the studied area have undergone plastic deformation at ~800°-1200°C, P ~0.9-1.68 G Pa and differential stress of 0.2-0.35 G Pa in dry condition. They changed to mylonites with residual mortar texture and mylonitic texture. P crystallized silicate melt inclusions and melt-fluid inclusions are discovered within residual mortar minerals and rock-forming chrome-spinels. Study denotes that these rocks are formed under relatively stable physical-chemical conditions through liquid immiscibility of silicate melts, ~1200°-1300°C and 1.1-1.38 G Pa, equivalent to a depth of 40-50 km. No inclusion has been found within recrystallized secondary olivine and pyroxene, indicating that the plastic deformation happened after the formation of the rocks. (Author's abstract)

PENG, Ligui, 1987b Silicate melt inclusions in minerals of alpine-type ultrabasic rocks. Kexue Tongbao (Sci. Bull.), v. 32, no. 10, p. 689-693. Author at Xi'an Inst. Geol. & Min. Resources, Chinese Acad. Geol. Sci.

Such inclusions have been found at the bottom of ophiolite suites from Western Zhunger region of Western China, [and are] of significance in revealing the origin of alpine-type ultrabasic rocks and in deeper understanding of the geological process and evolution. [Th = 1200-1300°C; Pt = 11-13.8 kb.] (From the author's abstract)

PERKINS, Caroline, 1987, The Red Rock deposit: A late Permian submarine epithermal precious metal system in northeastern New South Wales: Pacific Rim Congress 87, 26-29 August, 1987, Australasian Inst. Mining & Metallurgy, Victoria, Australia, u . 895-898. Author at Dept. Geol. & Geophys., Armidale, N.S.W., Australia 2351.

The epithermal Ag-Au Red Rock deposit represents one of the few low sulfur epithermal precious metal systems in eastern Australia, and differs from epithermal models in that the hydrothermal system which produced mineralization was active in a shallow water marine environment. Ore was deposited from a boiling fluid in a T range of 222-295°C, and of 0.5-7 wt. % NaCl eq. An upper hydrostatic depth limit of about 800 m is implied for the boiling fluid in an open vein. Sulfur isotopes indicate a magmatic sulfur source, and oxygen isotopes imply a predominantly marine ore fluid. (From the author's abstract)

PERKINS, Dexter, ESSENE, E.J. and WALL, V.J., 1987, THERMO: A computer program for calculation of mixed-volatile equilibria: Am. Mineral., v. 72, p. 446-447. First author at Dept. Geol. & North Dakota Mining Resources Res. Inst., The Univ. North Dakota, Grand Forks, ND 58202, USA.

THERMO is an interactive computer program that conducts thermodynamic calculations of mixed-volatile equilibria. It was written specifically for microcomputers. Its simple commands, large vocabulary, and ease of operation make it ideal for both teaching and research. Copies of the program, for either an IBM or an Apple operating system, are available on floppy disk. A thermodynamic database with data for over 125 minerals and related substances is available with the program. (Authors' abstract)

PETER, J.M. and SCOTT, S.D., 1987, Aqueous and hydrocarbon inclusions in hydrothermal vent deposits of the Guaymas Basin, Gulf of California (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Authors at Dept. Geol., Univ. Toronto, Toronto, Ontario, Canada M5S 1A1.

Numerous hydrothermal mounds and chimneys/spires occur at 2000 m water depth in the Southern Trough of Guaymas Basin, central Gulf of California. Some of these structures are venting hydrothermal fluid in excess of 300°C. Aqueous and liquid hydrocarbon-containing inclusions occur in calcite, anhydrite, barite, and amorphous silica. P aqueous inclusions range in diameter from 1 μ to over 50 μ. They contain two phases (aqueous fluid and a vapor bubble), and typically have uniform phase ratios with the vapor bubble comprising 5 to 20 vol.% of the inclusion. On this basis the inclusion fluids do not appear to have boiled. Hydrocarbon-bearing inclusions are either two-phase (hydrocarbon and vapor bubble) or three-phase (hydrocarbon, aqueous fluid, and vapor bubble) and range in diameter from 2 μ to 50 μ. The hydrocarbon phase varies in color from deep to pale orange-brown. Adjacent inclusions may have extremely variable hydrocarbon to aqueous fluid ratios and indicate that the liquid hydrocarbon was carried as an immiscible phase in the hydrothermal fluid. No microthermometric data has yet been obtained from these inclusions, but work is in progress.

Calcite, the dominant mineral associated with sulfide deposition in the samples, was selected for microthermometric examination. Sections were broken into many smaller sized chips, all freezing work was done prior to any heating runs, and each chip was heated only once to avoid stretching. No evidence of clathrate melting phenomena was observed. Heating and freezing measurements made on P, two-phase inclusions in calcite give mean Th for individual chimneys/spires of 198° to 262°C and mean salinities of 4.1 to 6.4 equiv. wt.% NaCl. A P correction of +15°C must be added to Th to give Tt (213-277°C), in general agreement with the T of venting hydrothermal fluids measured with the thermocouple probe on the Alvin submersible. Salinities of these inclusion fluids are significantly increased above that of seawater (≈3.5 wt.% NaCl), and there is no observable relation between Tt and salinity. Observed hydrohalite melting phenomena indicate that the inclusion fluids contain Na with minor Ca and K as dissolved chloride species.

The frequency distributions of Th for P and S aqueous inclusions from all samples show pronounced negative skewness of -0.84 and -0.66, respectively, with Tt as low as about 125°C relative to a modal value of 261°C. Such skewed distributions can be explained by the cooling of hot, endmember hydrothermal fluid by means of mixing with cold seawater. For individual chimneys/spires, Th of P aqueous inclusions are higher than those for S inclusions by 16 to 37°C in three out of five samples. As well, for two of these three samples, salinities of P inclusions are concomitantly higher than those for S by about 0.2 eq. wt.% NaCl. Non-parametric statistical testing indicates that the observed differences are real. These differences may arise when cold, ambient seawater breaches a chimney wall and enters its interior. The sudden T drop would cause local fracturing, and the mixture of discharging hydrothermal fluid and seawater along these fractures would become trapped as "S" inclusions. Calculations of the extent of mixing for individual chimneys give about 9 to 11.5 parts of hydrothermal fluid to 1 part seawater.

Enigmatically, fluid inclusion salinities cannot be reconciled with those calculated from analyses of endmember hydrothermal fluid (3.8-4.1 eq. wt.% NaCl). This suggests that fluid inclusion studies of chimney minerals have considerable potential for delineating temporal and spatial variations in vent fluid chemistries. (Authors' abstract)

PFEIFER, H., OEHME, W. and SIEGEL, H., 1987, Freezing of water in porous solids, glass- or phase-transition?: Zeitschrift fur Physikalische Chemie Neue Folge, v. 152, p. 215-225. First author at Sektionen Physik & Chemie der Karl-Marx-Univ., Linnestr. 5, Leipzig, DDR-7010.

H nuclear magnetic resonance studies together with measurements of the apparent molar heat capacity of water adsorbed in zeolites, i.e., in pores of a definite size and a homogenous surface (oxygen atoms) show that aggregates containing less than about five water molecules exhibit no phase transition on cooling below 0°C. For aggregates of about ten to thirty water molecules however, phenomena are observed which can be interpreted quantitatively by a diffuse phase transition of the first order with a more or less strongly reduced value for the heat of fusion. (Authors' abstract)

PHILIPPOT, P., 1987, "Crack seal" vein geometry in eclogitic rocks: Geodinamica Acta, Paris, v. 1, p. 171-181. Author at Centre de Géol. & Géophys. U.S.T.L., Place Eugene-Bataillon, 34060 Montpellier Cedex, France.

Fluid-deposited veins occur in eclogite facies rocks in the Mont Viso meta-ophiolitic complex, Western Alps. These veins contain omphacite, garnet, rutile and apatite implying that veining took place at near to peak metamorphic conditions. Two types of omphacitic vein structure are described. (a) Cross-fiber veins and (b) massive, coarse-grained. Fluid inclusion bands are widespread in all types of fibrous omphacitic veins, but judging from their rather random distribution within individual fiber they are not considered to be a rythmic phenomenon, nor to be constrained by the vein or fiber geometry but are interpreted to be sealed microcracks and suggest a growth by a crack-seal mechanism. Rarely successive microcracks can be seen cross-cutting several fibers. In all cases inclusion bands occur normal to the long axis of the fiber. (From the authors's abstract and text)

PHILPOTTS, J.A., ARUSCAVAGE, P.J. and VON DAMM, K.L., 1987, Uniformity and diversity in the composition of mineralizing fluids from hydrothermal vents on the southern Juan de Fuca Ridge: J. Geophys. Res., v. 92, no. B11, p. 11,327-11,333.

PHUTELA, R.C., PITZER, K.S. and SALUJA, P.P.S., 1987, Thermodynamics of aqueous magnesium chloride, calcium chloride, and strontium chloride at elevated temperatures: J. Chem. Eng. Data, v. 32, p. 76-80. First author at Dept. Chem. & Lawrence Berkeley Lab., Univ. California, Berkeley, CA 94720.

Heat capacities and densities of aqueous $MgCl_2$, $CaCl_2$, and $SrCl_2$ from the accompanying paper are combined with literature data up to 473 K to yield temperature-dependent equations by using the ion-interaction model of Pitzer. These heat capacity equations have been integrated to yield the enthalpy and the Gibbs energy. The enthalpy parameters for 298 K are evaluated in separate calculations using published high-temperature osmotic data as well as heats of dilution, while the Gibbs energy parameters for 298 K are taken from the literature. The range of validity of the final equations is described. (Authors' abstract)

PICHAVANT, Michel, 1987, Effects of B and $H_2O$ on liquidus phase relations in the haplogranite system at 1 kbar: Am. Mineral., v. 72, p. 1056-1070.

PICKTHORN, W.J., 1987, Stable isotope characteristics of the Juneau Gold Belt, Alaska (abst.): Geol. Soc. Am. Abst. with Programs, v. 19, p. 440. Author at U.S. Geol. Survey, 345 Middlefield Rd., Menlo Park, CA 94025.

The Juneau Gold Belt in southeastern Alaska stretches for approximately 200 km along the Coast Range megalineament, west of the Coast Range batholith. Host rocks for the deposits consist of deformed slate, phyllite, diorite, and greenstone. Gold mineralization occurs in veins emplaced along shear zones, faults, and joints, and it postdates deformation and regional metamorphism.

Oxygen isotope analyses of mineralized quartz from the Juneau Gold Belt yield $\delta^{18}O$ values rangng from +17 to greater than +22 per mil. Deposits on the west side of the Coast Range megalineament have $\delta^{18}O$ values that are generally heavier than those to the east, and within each group the values are fairly consistent along strike. Ore-stage sericite from the Alaska-Juneau mine (largest producer in Alaska) has a dD value of approximately -60 per mil. Fluid inclusion data indicate a temperature of mineralization of 200° to 325°C. Calculated values for the ore-forming fluid is in the range of $\delta^{18}O$ +9 to >+14 per mil and dD of apporximately -20 per mil. These values are similar to those for the California Mother Lode and other gold deposits occurring worldwide in metamorphic rocks. Fluid this heavy is generally thought to represent evolved connate or metamorphic water and is consistent with a model in which fluid is produced during prograde metamorphic devolatilization reactions. The low hydrogen content of hydrous minerals rules out the possibility that meteoric waters could have undergone such a large deuterium shift (approximately 90 per mil) by exchange with the country rock. (Author's abstract)

PICKTHORN, W.J., GOLDFARB, R.J. and LEACH, D.L., 1987a Comment and reply on "Dual origins of lode gold deposits in the Canadian Cordillera:" Geology, v. 15, p. 471-472. First author at U.S. Geol. Survey, Menlo Park, CA 94025.

A comment on paper by Nesbitt et al. (see Fluid Inclusion Research, v. 19, p. 31), dealing with isotopic data from fluid inclusions. See also Nesbitt et al., this volume, for reply. (E.R.)

PICKTHORN, W.J., GOLDFARB, R.J. and LEACH, D.L., 1987b "Mesothermal" gold - A metamorphic connection? (Extended abst.): U.S. Geol. Survey Circular 995, p. 57.

Worldwide "mesothermal" gold-bearing vein deposits often are found in low- to moderate-grade metamorphic rocks, typically marine in origin, in tectonically disturbed or accreted terranes. Fluid-inclusion analyses of gold-bearing quartz from throughout the Valdez Group, Alaska, yield minimum trapping P of 1.5 kbar and corrected Th ranging from 260 to 330°C. Ore-forming fluids were of low salinity, with gas contents of up to 11 mole %. Analyses of the inclusion gas phase by Raman laser spectroscopy and quadrapole mass spectrometry indicate compositions ranging from pure $CO_2$ to mixtures dominated by $CH_4$ and $N_2$. Stable isotope analyses of the quartz yielded $\delta^{18}O$ values for the ore-forming fluid in the range from +6.5 to +9.6 per mil. Analyses of hydrous ore-phase minerals indicates an ore-fluid $\delta D$ of ~-20 per mil.

Approximately 75 percent of Alaska's total lode gold production was from the Alaska-Juneau Mine; P-T estimates (P, minimum 1.5 kbar; T >200°C) are very similar to the Valdez Group deposits, however the bulk fluid composition and the structural setting are quite different. Most fluid inclusions in samples studied contained $CO_2$ contents in the range from 30 to 60 mole % with minor $CH_4$ and $N_2$. Evidence is good for boiling of the ore fluid.

The stable isotope, fluid inclusion, and inclusion gas chemistry data are consistent with those for fluids derived from metamorphic rocks during devolatilization reactions. We suggest that prograde metamorphism during accretion released the water and volatiles, which migrated into fractures in the previously metamorphosed rocks during a decrease in the confining lithostatic P. (From the authors' abstract)

PIERRE, C., THOURON, D., PUEYO, J.J., UTRILLA, R. and INGLES, M., 1987, Carbon isotope behavior of $\Sigma CO_2$ during sea water evaporation in salt pans (abst.): Terra Cognita, v. 7, no. 2-3, p. 410-411.

PINHO,G.deC.,1987, Diagenetic evolution of the Sergi formation sandstones at the Fazenda Bálsamo oil field, northeastern Reconcavo Basin, Bahia-Brazil: MS thesis; Federal Univ. of Ouro Preto, 177 pp. (in Portuguese; English abstract). Author at PETROBRÁS, CEP 49010, Aracaju-SE, Brazil.

One- or two-phase fluid inclusions were detected in authigenic calcite, dolomite, barite, albite, and in quartz overgrowths from Sergi sandstone samples. The small size of inclusions (1-3 μm) precluded further investigations at the time. Aqueous fluids seem to predominate. (K. Fuzikawa)

PINKSTON, John, STERN, Laura and KIRBY, Stephen, 1987, Hydrothermal reactions on artificial fault surfaces in dunite: Fibrous mineral growth, slickensides and temperature sensitivity of reaction weakening (abst.): EOS, v. 68, p. 405. Authors at U.S. Geol. Survey, 345 Middlefield Rd., MS/977, Menlo Park, CA 94025.

Previously we reported an unusually low sliding resistance on artificial faults in a lightly altered dunite heat treated at 150°C with ~0.1% free water. Shear streses $\tau$ stabilized to values of 30-40 MPa after <1 mm sliding and were independent of normal stress $\sigma_n$ over the range $140<\sigma_n<760$ MPa. Extended prior heat treatment at 150°C (with no change in alteration mineralogy) leads to strengthening, apparently associated with the progressive loss of free water. Samples tested at a confining pressure of 500 MPa and temperatures of 200° and 500-600°C were strong ($\tau$ >200 MPa) whereas the 300-400°C specimens were weak. Lastly, SEM micrographs of the weak samples display fibrous mineral growths (probably chrysotile) and dissolution features indicative of active hydrothermal alteration on the sliding surface. These obervations are consistent with a three-step deformation process in which sliding resistance is governed by (1) dissolution of olivine asperities or other barriers to fault slip, (2) mass transport in the hydrothermal fluid, and (3) subsequent growth of the hydrothermal mineral chrysotile at regions of dilation on the sliding surface. Examples of fibrous growths of hydrothermal minerals on natural faults are common and our findings suggest that the shear stresses supported by these faults may not follow the laws of ordinary friction but may be low due to localized hydrothermal alteration. (Authors' abstract)

PITMAN, J.K. and DICKINSON, W.W., 1987, Petrology and isotope geochemistry of mineralized fractures in Cretaceous rocks: Evidence for cementation in a closed hydrologic system (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 806. First author at Geol. Survey, MS 955, Reston, VA 22092.

Well-developed, partly mineralized, vertical extension fractures containing abundant calcite and minor quartz, dickite, barite, and bitumen commonly occur in overpressured gas-bearing sandstones of Cretaceous age in the Green River Basin, Wyoming, and the Piceance Basin, Colorado. Methane inclusions in calcite (C. Barker, 1987, oral commun.) and the occurrences of bitumen indicate that fracture cementation took place during a period of active hydrocarbon generation. (From the authors' abstract)

PITZER, K.S., 1987, Thermodynamic properties of ionic fluids over wide ranges of temperature: Pure & Appl. Chem., v. 59, no. 1, p. 1-6. Author at Dept. Chem. & Lawrence Berkeley Lab., Univ. California, Berkeley, CA 94720, USA.

The principle of corresponding states is valid in reasonable approximation for ionic fluids but the quantitative behavior differs considerably from that for neutral-molecule fluids. The role of a dielectric is such as to make the $\varepsilon T$ product the effective T. Thus aqueous electrolytes near room T have very high reduced T on a corresponding states basis. The status of knowledge for various aqueous solutes is summarized. The critical region for an ionic system is difficult to treat theoretically and is out-of-range experimentally for simple substances such as NaCl. Current best approximations are discussed. A model, two-component ionic system with an experimentally convenient critical T has been found and its properties investigated. The role of long-range fluctuations on properties in the critical region is considered for ionic systems. Fused salts (without solvent) have low reduced T and they follow corresponding states quite well as has been shown by Reiss and others. Fused salts have a remarkably large coefficient of expansion; its cause is discussed. At low reduced T an ionic-particle vapor is largely associated to neutral clusters -- pairs, quartets, etc. An interesting system of considerable engineering and geological importance is NaCl in steam which has been treated in terms of successive hydration equilibria for the ion-pair. (Author's abstract)

PITZER, K.S., BISCHOFF, J.L. and ROSENBAUER, R.J., 1987, Critical behavior of dilute NaCl in $H_2O$: Chem. Physics Letters, v. 134, no. 1, p. 60-63. First author at Dept. Chem. & Lawrence Berkeley Lab., Univ. California, Berkeley, CA 94720, USA.

The compositions of the saturated vapor and liquid phases are measured for the system NaCl-$H_2O$ at 380°C, which is close to the critical point of pure water. The shape of the phase equilibrium curve is classical, which confirms a conclusion reached earlier on the basis of less accurate data. This implies that the long-range forces introduced by the NaCl suppress the non-classical effects present in pure $H_2O$. An empirical equation of a classical type fits these data. (Authors' abstract)

PITZER, K.S. and PABALAN, R.T., 1987, Thermodynamics of NaCl in steam: Earth Sci. Div. Ann. Report 1986, DOE Contract No. DE-AC03-76SF00098, p. 153-157.

See same authors, Fluid Inclusion Research, v. 19, p. 337, 1986. (E.R.)

PLUMLEE, G.S., BARTON, P.B., Jr. and RYE, R.O., 1987, Diverse chemical processes in the Creede, Colorado, epithermal system: A progress report (abst.): Geol. Soc. Am. Abst. with Programs, v. 19, p. 327. First author at U.S. Geol. Survey, MS 963 Federal Center, Denver, CO 80225.

Strongly zoned, mineralogically complex epithermal ores resulted from complex temporal and spatial interactions of diverse chemical processes in the Creede hydrothermal system. Chemically and isotopically evolved meteoric waters rich in chloride, sulfate, carbonate and soluble hydrocarbons entered the system from Creede caldera moat sediments directly south of the district, and dilute meteoric waters entered from highlands in the northern parts of the district. At depth, these fluids were heated, modified by interactions with wallrocks, and possibly mixed with magmatic fluids. At low temperatures (<200°C) during waxing and waning stages of the system, and on the fringes of the system during all stages, the meteoric-hydrothermal fluids did not reach internal chemical equilibrium, or equilibrium with wallrocks. As a result, isotopically and chemically distinctive, noneconomic gangue was deposited. In higher-temperature stages (200-300°C), most constituents of the deeply-circulating fluids approached equilibrium with volcanic wallrocks, eventually settling on Kspar-Kmica pH values and relatively oxidizing conditions of the pyrite-chlorite-hematite, aqueous $H_2$-$H_2S$ buffer (Barton et al., 1977, Econ. Geol.). Aqueous sulfate-sulfide and hydrocarbon-fluid reactions did not equilibrate, even at temperatures up to 300°C. Under wallrock-buffered chemical conditions, the southern brines picked up and transported from depth large amounts of chloro-complexed metals (Pb, Zn, Ag, Cu), whereas the dilute northern fluids were more enriched in bisulfide- and oxy-complexed metals (Au, Ag, As, Sb, Cu); district-wide variations in metal abundances apparently reflect such spatial asymmetries in fluids salinities. Mixing of dilute northern fluids and saline southern fluids in the system's upwelling plume promoted some metal deposition due to changes in salinity, pH, and temperature. Shallow boiling and mixing further modified fluid chemistries in the system's ore zone. Boiling of more dilute fluids likely produced carbonate-quartz-adularia-precious metal assemblages with complementary sericitic alteration. Chemical modeling suggests that initial boiling of more saline fluids deep in the ore zone, followed by progressive lateral mixing with oxidizing groundwaters, produced zoned pyrite-chlorite-hematite-base metal to silver-rich base metal-barite assemblages. (Authors' abstract)

POLYA, D.A., 1987, Chemical behavior of tungsten in hydrothermal fluids and genesis of the Panasqueira W-Cu-Sn deposit, Portugal: PhD dissertation, Univ. Manchester, 334 pp.

The chemical compositions of the main stage ore-forming fluids at the Panasqueira W-Cu(Ag)-Sn deposit, Portugal have been estimated from a combination of fluid inclusion studies, thermodynamic analysis of vein mineral assemblages, calculated ore mineral solubilities and published T, P, salinity and $CO_2/CH_4$ estimates.

The typical composition of main stage Panasqueira ore-forming fluid at 300°C and 1 m NaCl has been estimated to be: 0.1 m $\Sigma$K; 0.0005 m $\Sigma$Fe; 0.02 m $\Sigma$Ca; 0.01 m $\Sigma$Mg; pH = 4-1/2 to 5-1/2; log $f(O_2)$ = -34 to -35 (i.e., about 4 orders of magnitude lower than the hematite-magnetite buffer); log $f(S_2)$ = -12-1/2; log $\Sigma$S = -2-1/2. Such a fluid is essentially in equilibrium with the granitic assemblage of quartz + K-feldspar + albite + muscovite. Readily leachable sulfides and wolframite within the subjacent granitic bodies are therefore likely sources of S, As, Cu, Zn and W in the ore veins. (Abstract by A. Gize)

Note also Polya, 1986, Fluid Inclusion Research, v. 19, p. 342. (E.R.)

POMÂRLEANU, V., 1986, The significance of fluid inclusions in mineral paragenesis: Min. Parageneses, J.R. Craig, et al., eds., p. 291-299. Author at Inst. Geol. & Geophys., Str. Caransebes 1, 78344 Bucharest, Romania.

Fluid inclusions have proved to be an appropriate criterion for stating the paragenetic features of minerals. Therefore, the author considered the fluid inclusions in some mineral associations from some ore deposits related to the Laramian magmatic activity and to the Neogene volcanic activity in the Carpathians. The minerals of a certain paragenesis are characterized by the same type of fluid inclusions with the same filling grade and similar Th intervals. (Author's abstract)

POMÂRLEANU, Vasile, 1987, Data on the study of fluid inclusions from Romania (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 99. Author at Inst. Geol.

& Geophys., Str.Caransebes 1, Bucharest 32, Romania.

The crystallogenetic features show that the fluid inclusions in the quartz phenocrysts of some granitoids are assigned to two generations: some of them are parallel to the crystal faces, while others follow the inner fabric of crystals. There are certain relations between Th and the habits of calcite and sphalerite hydrothermal crystals.

For prospecting purpose new decrepitation methods are presented. The prospecting of porphyry copper deposits is considered by taking into account the relation between the inclusion salinity and the copper content of ores and host rocks. (From the author's abstract)

Note: This review paper was not presented at the meeting. (E.R.)

POMÂRLEANU, V. and NEAGU, E.-A., 1987, Significance of fluid inclusions for determining the temperature gradients of hydrothermal solutions and their application to metallogenesis: Chem. Geol., v. 61, no. 1/4, p. 147-151.

Full paper for abstract in Fluid Inclusion Research, v. 18, p. 325, 1985. (E.R.)

POMÂRLEANU-NEAGU, Eleonora and MÂRZA, Ioan, 1987, The fluid inclusion and the hydrothermal quartz geothermometry from the breccia pipe Afinet, at Tarna Mare (Maramures County): Studia Univ. Babes-Bolyai, Geographia, v. 32, no. 1, p. 45-51. First author at L'Inst. de Rech. Ingen. Tech., Conception et Production pour l'Industrie Anorg. et les Metaux non Ferreux, Bucarest, 102, rue Biruintei, 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 metal stages. Quartz I has gas-rich inclusions ($H_2S$) with Th 205-260°C; quartz II apparently crystallized at 130-220°C. Metal deposition of Cu, Zn, Pb and Hg ranged from 265° to <130°C. (E.R.)

POPE, L.A., HAJASH, Andrew and POPP, R.K., 1987, An experimental investigation of the quartz, Na-K, Na-K-Ca geothermometers and the effects of fluid composition: J. Volcan. & Geothermal Res., v. 31, p. 151-161.

POREDA, R.J., CRAIG, Harmon, JEFFRY, Alan, JENDEN, P.D. and KAPLAN, I.R., 1987, Helium isotopes in natural gases (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 808.

PORTNOV, A.M., VLASOVA, E.V. and KHITAROV, D.N., 1987, Carbon dioxide pressure as a factor of transport and deposition in near-surface gold-silver ore deposits: Geol. Rudn. Mestorozhd., v. 29, no. 4, p. 111-114 (in Russian). Authors at VIMS, Moscow, USSR.

High $CO_2$ concentration in vein quartz (Q) in condensed* a prospecting indicator for Au-Ag ore. Indirect determination of the relative $CO_2$ concentration in aqueous solutions can be made by IR spectroscopy of thin sections (0.2-0.3 mm thick) of ore-vein mineral associations. Spectra obtained at 2000-4000 $cm^{-1}$ allow estimation of the variation in $CO_2$, $H_2O$, and OH-group contents across narrow zones in veins. Use of this method established that $CO_2$ is unevenly distributed in Q of ore veins. The $CO_2$ concentration in Q is high at vein edges and decreased markedly in depositional zones of native Au or Ag, Au tellurides, or Ag sulfides. At the time the vein-edge Q precipitated, $P(CO_2)$ was high and the $SiO_2$ precipitated from acidic solutions. In absence of $CO_2$, a Q-adularia association formed. Productive Au-Ag associations form in a zone of abrupt P decrease (in fractured rocks), where degassing, boiling, and alkalinization occurs of a hydrothermal solution. (C.A. 108: 98046r)[*sic; "is considered"? E.R.]

PORTNYAGIN, A.L., FRENKEL', M.Ya. and KADIK, A.A., 1987, Thermodynamic analysis of the decompression melting on the example of system Ab-$H_2O$-$CO_2$: Fractionation of volatiles in the process of evolution of partially melted zones: Geokhimiya, 1987, no. 1, p. 3-16 (in Russian; English abstract).

Based on the experimental data for system Ab-$H_2O$-$CO_2$ a mathematical model of magmatic equilibria with a complex fluid up to 25 kbar has been made. Using this model the T regime, changing of phase composition, volatile content in the melt and composition of fluid phase in the material undergoing the adiabatic decompression during the convective ascent have been studied. A possible role of volatiles, separating from the mantle diapirs, in the processes of fluid exchange between lithosphere and asthenoshere has been considered. A conclusion has been made on the probable relation of the changing conditions of formation of granite magmas in the crust with the changing of volatile regime due to evolution of composition of fluids separating from the ascending mantle flows. (Authors' abstract)

POTY, B., DEREPPE, J.M., LANDAIS, P. and PIRONON, J., 1987, Use of $^1H$ NMR for discrimination of solutions having different proton concentrations. Application to fluid inclusions (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 101-102. First author at CREGU, BP 23, 54501 Vandoeuvre-les-Nancy, France.

The knowledge of pH of hydrothermal solutions is of importance since many reactions between minerals and solutions involve proton exchanges. Furthermore solubility measurements and calculations display minimum values in restricted ranges of pH which are probably the reason for deposition of many ores. Unfortunately determination of pH by destructive methods is usually not convincing. Dilution of inclusion material after crushing with a huge quantity of solvent precludes obtaining of reliable data.

Nuclear Magnetic Resonance of protons gives intense and sharp peaks. This property has been used to measure, in a nondestructive manner, the proton concentrations in fluid inclusions. $^1H$ NMR spectra were obtained with a Brücker CXP 100 Spectrometer (90 MHz) using a spectral slit of 20 KHz and a magnetic field externally locked at ± 1.5 Hz. About 100 Spectra were co-added for each run. Signal/noise varies from 20 to 50.

Quartz samples gathered for this study came mainly from alpine fissures but also from several ore deposits. Efforts were made to select samples with one generation of fluid inclusions. Artificial [i.e., synthetic] fluid inclusions were also used for calibration.

The main results of this study are the following:

1 - Free water from fluid inclusions is readily visible by $^1H$ NMR,

2 - In the same experimental conditions $H^+$ and $OH^-$ from the lattice of very impure natural quartzes do not show any signal.

3 - Standard acid solutions with different pH (from -0.4 to +7) display a large range of resonance frequencies.

4 - Different samples from the same origin give the same resonance frequency.

5 - Samples containing different types of fluid inclusions show different resonance frequencies that we can interpret in terms of proton concentrations. The magnitude of this variation versus peak width suggests that if those two fluids had been trapped in the same crystals they would have been distinguished. (Authors' abstract)

POULSON, S.R. and OHMOTO, Hiroshi, 1987, The behavior of sulphur in granodiorite magma during emplacement, and during subsolidus hydrothermal alteration (abst.): EOS, v. 68, p. 1522.

PRASOLOV, E.M., TRAVNIKOVA, L.G., VERKHOVSKY, A.B., KAMENSKY, I.L., MESHIK, A.P. and SHARIF-ZADE, V.B., 1987, Isotopic composition of gases of saline deposits: Inert gases: Geokhimiya, 1987, no. 2, p. 290-300 (in Russian; English abstract).

Isotopic characteristics of inert gases (He, Ne, Ar) of various morphologic types (crystalline lattice, micro- and macroinclusions) in the saline deposits of the Pripyat depression and other areas have been studied. The differences in the composition of gases of this type are due to migrational fractionation. Coefficients of loss of radiogenic gases from the crystalline lattice are 0.67 for helium, 0.57 for neon, 0.17 for argon. Two genetic varieties of inert gases have been distinguished: authigene ones, formed in situ, and atmospheric ones, captured by salts in the crystallization process. Mantle-derived helium is absent in the salts. The difference in chemical composition of the salts and other rocks of the sedimentary sequence determines the specifics of the nuclear processes and, as a result, the specifics of the isotopic ratios of inert gases: sharply lowered ratios of $^{3}$He/$^{4}$He ($<10^{-8}$), $^{4}$He/$^{40}$Ar(rad) = 0.03 to 2 and increased $^{40}$Ar/$^{36}$Ar = (2 to 50) x $10^{3}$ as well as $^{4}$He/$^{21}$Ne(rad) in sylvinite ($>10^{8}$). The latter is low in the rock-salt, (0.7 to 1.8) x $10^{6}$. This is due to the formation of $^{21}$Ne in the salts near the surface under the influence of meson cosmic radiation. The Pripyat depression salts were formed probably as a result of the precipitation in a shallow-water basin. (Authors' abstract)

PREWITT, C.T., COPPENS, P., PHILLIPS, J.C. and FINGER, L.W., 1987, New opportunities in synchrotron X-ray crystallography: Science, v. 238, p. 312-319. First author at Geophys. Lab., Carnegie Inst. of Washington, 2801 Upton St., NW, Washington, DC 20008.

A discussion of instrumentation and capabilities of a procedure that may prove of considerable use in inclusion analyses. (E.R.)

PREZBINDOWSKI, D.R. and LARESE, R.E., 1987a Experimental stretching of fluid inclusions in calcite - implication for diagenetic studies of carbonates (abst.): Abstracts, SEPM annual midyear meeting 20-23, Aug. 1987, v. 4, p. 50. First author at International Petrology Research, Tulsa, OK.

Th of fluid inclusions trapped in calcite crystals change with increased heating (burial). Diagenetic studies which depend on these data to determine calcite cementation T will be biased toward higher T. This bias will lead to an over estimation of the importance of burial cementation. Fluid inclusions entrapped in calcite during basin subsidence will tend to yield Th approaching maximum burial T. This information can be used cautiously to help study basin evolution.

Coarse crystalline calcite containing saline fluid inclusions were used to examine the influence of increased T and P on measured Th. Stepped heating experiments conducted at 1 atmosphere over a T range of 90 to 245°C document significant and consistent stretching (volume change) of the fluid inclusion population. Hydrothermal experiments were also conducted at 2,500 and 10,000 psi and T of 160, 250 and 350°C. In all cases, significant upward changes in the Th of the inclusion populations were recorded. Stresses generated during the thermal expansion of the trapped fluids exceeded the strength of the calcite crystal causing volume increases. As a result, the measured Th also increased. Size, shape, composition and mineral strength are secondary factors controlling fluid inclusion stretching. Recent diagenetic studies tend to support the conclusions drawn from these experiments. (Authors' abstract)

PREZBINDOWSKI, D.R. and LARESE, R.E., 1987b Experimental stretching of fluid inculsions in calcite - Implications for diagenetic studies: Geology, v. 15, p. 333-336. See previous item.

PROKOF'EV, V.Yu. and NAUMOV, V.B., 1987, Geochemistry of ore-forming solutions of the Zyryanovskoe pyrite-polymetallic ore deposit, Rudnyi Altai: Geokhimiya, 1987, no. 3, p. 375-386 (in Russian).

PROKOF'EV, V.Yu., SEMENOV, Yu.V., RYABENKO, S.V. and KORYTOV, F.Ya., 1987, Conditions of formation of cryolite-bearing mineral paragenesis in hydrothermal processes: Geokhimiya, 1987, no. 6, p. 824-832 (in Russian; English Summary). First author at Akad. Nauk, SSR Inst. Geokhim, Moscow, USSR.

Study of fluid inclusions in cryolite of various deposits of the World has shown its hydrothermal genesis. Thermodynamic calculations permit to estimate effect of chemical composition of the solution of the stability fields for cryolite-bearing mineral parageneses at the T range of 300 to 100°C. (Authors' Summary)

PYTSKAYA, Ye.A., 1986, Criteria for distinguishing the productive mineral associations as exemplified by a study of typomorphism of pyrrhotite and quartz: Izvestiya Vyssh. Uchebn. Zaved., Geologiya i Razvedka, no. 12, p. 103-105 (in Russian). Author at the Moscow State Univ., Moscow, USSR.

Quartz from a deposit of the sulfide formation (pyrrhotite, arsenopyrite, pyrite, chalcopyrite, marcasite, berthierite, antimonite, quartz, carbonates) "in one of the regions of Siberia" [i.e., a gold deposit?] bears four types of fluid inclusions: euhedral gaseous, and anhedral gaseous, gas-liquid and liquid ones. Ore-bearing quartz is "saturated" with fluid inclusions, barren quartz contains relatively few inclusions. All studied inclusions are "subgenetic* PS or S ones," Th 240-330°C (12 determinations) for ore-bearing quartz; the latter has abundant low-T decrepitation effects on Td curves, while barren quartz has weakly discernible low peaks on Td curves. (Abstract by A.K.) *A misprint for "subsyngenetic"? A.K.

QUAN, R.A., CLOKE, P.L. and KESLER, S.E., 1987, Chemical analyses of halite trend inclusions from the Granisle porphyry copper deposit, British Columbia: Econ. Geol., v. 82, p. 1912-1930. First author at 6655 North Fresno St., 165, Fresno, CA 93710.

High-salinity fluid inclusions from many porphyry Cu and skarn deposits fall on linear trends in the $H_2O$-NaCl-KCl system, called the halite trend, and they have been interpreted to result from separation of KCl-bearing halite before entrapment of the fluid in the inclusions. In addition to Na, K, and Cl, halite trend inclusions can also contain abundant Fe, Ca, and S, all of which could have an effect on the orientation of the trend in the $H_2O$-NaCl-KCl system, making halite subtraction a less likely explanation for the observed compositional trend. We have attempted to evaluate this possibility by analysis of inclusion dms, decrepitates, and leachates, as well as phase volume measurements for dms, in fluid inclusions from the Granisle porphyry Cu deposit. These observations show that $FeCl_2$ composes 31 to 45 wt % of the inclusion and that the resulting halite trend inclusion salinities range from 70 to 84 wt % of NaCl + KCl + $FeCl_2$. $CaCl_2$ and $MnCl_2$ are minor components. The liquid contains smaller but significant amounts of sulfur, probably as $HSO_4^-$ and its complexes, as well as $CO_2$, CO, and $CH_4$ in minor amounts. Trends established by these data point toward NaCl in multicomponent space, thus supporting halite (or halite solid solution) subtraction over the alternative mechanisms proposed to explain the halite trend. (Authors' abstract)

RABENANDRASANA, S. and ARNOLD, M., 1987, Mineral veins in Rhine graben margins: Region of Colmar and Ribeauville (Middle Vosges, France) (abst.): Terra Cognita, v. 7, no. 2-3, p. 322-323. Authors at CRPG, Vandoeuvre-lès-

Nancy, France.

Quartz, fluorite and barite have mean Th of 120°C, 160, and 150-300°C, respectively. The salinity in barite and fluorite is 7-8 eq. wt. % NaCl. Most of the inclusions in quartz (with a high content of divalent ions) and in barite are however monophase. All the inclusions in fluorite are biphase with a constant liquid/vapor ratio.

These results are interpreted as low T precipitation of these minerals from heterogeneous liquid-gas solutions. These solutions are generated when subsurface fresh waters mix with sursaline waters from coastal sabhkas and lagoons. (From the authors' abstract)

RAGNARSDOTTIR, K.V., WALTHER, J.V. and ARNORSSON, S., 1987, Phase equilibria and mass transfer in the Svartsengi geothermal system, Iceland (abst.): Terra Cognita, v. 7, no. 2-3, p. 128-129.

RAITH, M. and HOERNES, S., 1987, Structurally and fluid-controlled granulitization of hornblende-biotite- and biotite-garnet gneisses in Southern India (abst.): Abstracts, NATO Advanced Research Workshop, Fluid movements, element transport, and the composition of the deep crust, Lindås, Norway, 18-24 May, 1987 (unpaginated). Authors in Bonn, West Germany.

[It is proposed that at Kabbaldurga] influx of external $CO_2$-rich fluids along the ductile shears and foliation planes of the gneisses at P, T conditions of about 700°C and 6 kb led to an almost complete breakdown of hbl and bio, and to new formation of hypersthene by (1) decrease of water activity and (2) metasomatic changes of bulk chemistry. Field evidence shows that this process was not accompanied by volumetric changes. Dissolution of hornblende, biotite, magnetite, apatite, zircon and monazite in the zones of charnockitization resulted in significant loss of Fe, Mg, Ca, Ti, P, Zn, V, Zr, and the HREE. A marked gain in K, Rb, Ba and Si is attributed to intense metasomatic replacement of plagioclase by K-feldspar through cation exchange with the passing fluids. The existence of infiltration zones with complimentary chemistry in gneisses adjacent to charnockite documents small-scale lateral chemical exchange. The most likely source for the $CO_2$-rich fluids is the "fossil" reservoir of carbonic fluids trapped in the deeper crustal granulites underlying the gneiss terrane.

At Kottavattam both gneiss and charnockite are rich in fluid inclusions ($CO_2$, $N_2$, $H_2O$, $CH_4$, $C_2H_6$, Ar, $H_2$). [The authors suggest that] during uplift of the rock complex $CO_2$-$N_2$-rich fluids were released in the gneiss itself from bursting fluid inclusions. The escape of these pore fluids into simultaneously developing fractures resulted in a drop of fluid P (P fluid , P load) which ultimately triggered the dehydration reactions (i.e., the breakdown of biotite and the neoblastesis of hypersthene). Charnockitization at Kottavattam took place under P, T conditions of about 750°C, 5-7 kb and low activity of water in both rock types, and was not accompanied by noticeable changes in rock volume and bulk chemistry.

It is unlikely that this [in-situ] process caused the pervasive granulitization of extensive parts of Precambrian lower crust in Southern India. (From the authors' abstract)

RAJLICH, P., BENEŠOVÁ, Z., ČADEK, J., LENK, J. and ŠMEJKAL, V., 1986, Fluorite metasomatic deposit Čulut Cagan Del, Central Mongolia: Sbor. geol. věd [J. Geol. Sci.]; Ložisk. geol., mineral., v. 27, p. 233-292 (in Russian with English Summary). First author at Geol. Survey, Prague, ČSSR.

The post-Cretaceous metasomatic fluorite deposit occurs ~130 km south of Ulan Batar. The mineralization is in Precambrian metamorphic rocks (phyllite, limestone, and porphyroid), Permian andesite tuff and sandstone, and of Jurassic age. The granite is a leucocratic hypersolvus alkali-feldspar granite with a characteristic morion quartz. Relatively intensively apparent are the postmagmatic-pneumatolytic and hydrothermal activities, with pegmatoid veinlets with miarolitic cavities containing crystals of smoky quartz and nests of pure, coarsely crystalline fluorite. Economically significant mineralization occurs in marbles. The individual phases of the fluorite are manifested by an overall gradual decrease of the rare-earth content, and a decrease in the lattice constant from 5.4531 to 5.4509. Quartz occurs with fluorite in banded textures of the "coon tail" type.

The highest Th were in the pegmatite fluorite 247-243°C and 228-226°C, except a P inclusion gave 365°C. In metasomatic fluorite, Th ranges from 215 to 73°C. Salinity of fluids enclosed in the pegmatitic fluorite is ~8 wt. % NaCl and in the metasomatic fluorites it is near zero.

[These and isotopic data suggest] the deposit originated at near-surface conditions, presumably with the Cretaceous andesite volcanism. The isotopic composition of oxygen in the neighboring marbles suggests a vadose water character. On the basis of our research, we consider the fluorine in the Bajan-Cagan granite was the initial source of the fluorite mineralization in the deposit. (From the authors' 3-page Summary, by E.R.)

RAKSHIT, A.K., 1987, The viscosity of aqueous $BaCl_2$ + NaCl solutions: Z. Naturforsch., v. 42a, p. 903-904.

RAMBOZ, Claire and CHAREF, Abdelkrim, 1987, The role of gases in the generation of abnormal fluid pressures: Fluid inclusion evidence in continental margins, in salt and clay environments (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 103-104. First author at Centre de Recherches Pétrogr. & Géochim., B.P. 20, 54501-Vandoeuvre, France.

In sedimentary basins, normal fluid P is hydrostatic (Pf = Ph= ρfgh at a depth h), however Pf in excess of hydrostatic values may exist in geopressured zones isolated from the surface below a pressure seal. (...) Gas solubility data show that the addition of gases ($CO_2$, $CH_4$, $N_2$...) in the range of a few mole% to an aqueous pore fluid trapped within an impermeable rock or below a pressure seal permits Pf to raise above Ph nearly instantaneously. In this mechanism, overpressuring can occur any time after the beginning of undercompaction.

Case study. In the western continental margin of the Tethys Ocean, the Les Malines Pb-Zn deposit (France) is hosted within metamorphosed Cambrian limestones overlain by Triassic shales. $CO_2$-bearing inclusions are found (i) as S fluid inclusions (FI) in barites crystallized at the end of the main stage and (ii) as P FI in vuggy barites postdating the ore stages.

(1) $CO_2$-bearing FI in late barites, with Th LV-V ranging from 200° to >300°C at nearly constant TmI, cannot result from heterogeneous trapping: they are interpreted to indicate the influx of a hot $CO_2$-bearing fluid in disequilibrium with the wall rock. The oil included in barites has undergone thermal degradation as shown by its color ranging from light yellow to deep brown.

(2) Liquid rich FI with Th = 170°C trapped near boiling conditions (96% $H_2O$ - 2% $CO_2$ - 2% NaCl mole; d = 0.91 $gcm^{-3}$) indicate that, as the hot $CO_2$-bearing fluid mixed with the pore fluid Pf rose to around 300 bar. This P was probably in excess of 60 bar from lithostatic pressure ($P_l$).

(3) The fluid overpressure was released by hydraulic fracturing, with dilution and cooling of the pore fluid related. As a more general conclusion, it can be proposed that fluid inclusions in late stage barites of Pb-Zn deposits, with high and scattered Th and $CO_2$ related can indicate a

thermal event of magmatic origin with possible fluid overpressure in the basin margins resulting from the influx of $CO_2$. (From the authors' abstract; 8 references given in original. E.R.)

RAMBOZ, Claire and DANIS, Michel, 1987a, A high temperature geyser at the bottom of Atlantis II Deep, Red Sea: Is the heat-mass balance of the Deep consistent with mineralogy and fluid inclusion data? (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 105-106. Authors at Centre de Recherches Petrogr. & Géochim., B.P. 20, 54501-Vandoeuvre, France.

Four 200 m-deep pools filled with stratified hot brines and floored by metalliferous sediments are found along the axis of Central Red Sea. AII Deep is most remarkable because it is filled with the hottest brines, it contains a subeconomic deposit of Zn-Cu-Ag-Au and it is still an active geothermal system. The mean T of brine discharge has never been measured directly. The heat-mass balance of AII Deep based on the present variations of the T and of the thickness of the stratified brines provides one of the best ways to approximate this parameter. However, previous calculations have yielded variable estimates in the range 110°-210°C. Such values are in deep contrast with recent mineralogy and fluid inclusion data on epigenetic veins characteristic of discharge area: these veins are equivalent to the hydrothermal vents near 21°NEPR formed in the range 350°-400°C. Fluid inclusions in Red Sea epigenetic anhydrite-barite show that crystals have grown from pulsatory hydrothermal fluids with variable salinities: they are in agreement with present geyser type activity in SW basin. The Th of the inclusions in sulfates are independent of the inclusion size, therefore they can be interpreted in terms of mean discharge T around 320°C, with maximum values at and above 400°C. The balance of internal energy and mass for only the LCL has been reevaluated using published bathimetric data and rising rates of the temperature and of the interface on top of the LCL. (From the authors' abstract)

RAMBOZ, C. and DANIS, M., 1987b, The temperature of the inflowing brine at the bottom of Atlantis II Deep, Red Sea (abst.): Terra Cognita, v. 7, no. 2-3, p. 187. Authors at Centre de Recherches Pétrogr. & Géochim., Vandoeuvre-lès-Nancy, France.

See previous item. (E.R.)

RANKIN, A.H., MILLER, M.F. and CARTER, J.S., 1987, The release of trace elements and volatiles from crinoidal limestone during thermal decrepitation: Min. Mag., v. 51, p. 517-525. First author at Dept. Geol., Imperial College, London SW7 2BP, England.

A suite of coarsely crystalline samples of crinoidal limestone adjacent to a $PbS-CaF_2-CaCO_3$ vein in the North Pennine ore field (Greenhow Rake) was analyzed by three independent methods [Inductively Coupled Plasma emission spectroscopy (ICP), Mass Spectrometry (MS) and Gas Chromatography (GC)], in order to determine the nature and origin of trace elements and volatiles released on heating and thermal decrepitation, to establish whether fluid inclusions from the host limestone differed in composition from those within the vein, and to assess the value of the results obtained for mineral exploration. The ICP method gave reproducible results for Ca, Na and K, and significant values for Pb and Zn. Na and K correlate with $H_2O$ levels determined by MS/volumetric analysis, suggesting their coexistence within fluid inclusions. No such correlation was found for Pb and Zn, suggesting that these elements were derived by volatilization, perhaps from traces of galena and sphalerite. Methane showed no correlation with $H_2O$ and a source other than aqueous fluid inclusions is thought probable for this volatile.

The vein calcite showed much lower K/Na fluid ratios (0.05 cf 0.1-0.2), than the limestones. The limestone-hosted fluids occur predominantly in crinoid ossicles and are believed to represent early pre-mineralization fluids, unrelated to those associated with veining. Combined ICP and MS techniques may be of value in investigating samples where fluid inclusions are too small for microthermometric and optical analysis. (Authors' abstract)

RARD, J.A. and MILLER, D.G., 1987, Isopiestic determination of the osmotic and activity coefficients of aqueous mixtures of NaCl and $MgCl_2$ at 25°C: J. Chem. Eng. Data, v. 32, p. 85-92. Authors at Univ. California, Lawrence Livermore Nat'l. Lab., Livermore, CA 94550.

The osmotic and activity coefficients of aqueous mixtures of NaCl and $MgCl_2$ have been determined at 25°C by using the isopiestic method. These measurements extend from low concentrations to the crystallization limits of the mixtures. They are critically compared to published isopiestic, direct vapor pressure, and emf data for this system. Our data agree well with previous isopiestic data and two sets of emf values, but direct vapor pressure data are significantly discrepant. Osmotic and activity coefficients for NaCl-$MgCl_2$ mixtures are fairly reliably represented by both Pitzer's equations and Scatchard's neutral electrolyte equations. (Authors' abstract)

RAVENHURST, C.E., 1987, An isotopically and thermochronologically constrained model for lead-zinc and barium mineralization related to Carboniferous Basin evolution in Nova Scotia, Canada: PhD dissertation, Dalhousie Univ.

See next items. (E.R.)

RAVENHURST, C.E., REYNOLDS, P.H., ZENTILLI, Marcos and AKANDE, S.O., 1987, Isotopic constraints on the genesis of Zn-Pb mineralization at Gays River, Nova Scotia, Canada: Econ. Geol., v. 82, p. 1294-1308. First author at Dept. Geol., Dalhousie Univ., Halifax, Canada B3H 3J5.

The Gays River Zn-Pb deposit is hosted in a Carboniferous carbonate bank on the southern marginal platform of the major (>8 km deep) Fundy-Magdalen basin. Fluid inclusion homogenization temperatures (130°-215°C) and structural control of the mineralization (determined in our previous study of the immediate mine area) suggest affinities with both Mississippi Valley-type and Irish-type deposits. New isotopic work, extending to within a 2-km radius of the mine area, significantly constrains genetic hypotheses for the deposit. Preliminary hydrogen isotope measurements of inclusion fluids, together with calculated oxygen isotope compositions, suggest that the mineralizing fluids were basinal brines ($\delta D = -39‰$; $\delta^{18}O = +3.3‰$). Sr isotope composition of ore-stage calcite($^{87}Sr/^{86}Sr = 0.7117$) indicates that components of the Sr and Ca had a source considerably more radiogenic than Mississippian carbonate or evaporite ($^{87}Sr/^{86}Sr = 0.7085-0.7090$). These and limited lead isotope data suggest that the fluids had a Sr and metal source in Cambro-Ordovician basement rocks on their immediate clastic derivatives.

Sulfur, probably derived from the voluminous Mississippian evaporites ($\delta^{34}S = 14 \pm 1‰$) was probably carried as sulfate (in a fluid with neutral pH) to the depositional site where complete (nonbiogenic?) reduction (at ≈200°C) occurred. This is supported by the lack of extensive dissolution and brecciation and the close similarity of the $\delta^{34}S(\Sigma S)$ values for the mineralizing fluids and the $\delta^{34}S$ value of the evaporites. The carbon budget of the ore-forming fluids was dominated by oxidized carbon from a carbonate source with a $\delta^{13}C$ value near 2 per mil, locally influenced by organic carbon with low $\delta^{13}C$ values which is abundant in the Gays River carbonate bank.

A basinal brine expulsion model is favored. The hot mineralizing fluid must have originated at a >4-km depth and interacted with clastic, carbonate, and evaporite sedimentary rocks on its way to the depositional site. The likely age for this mineralizing event is approximately 300 m.y. (Authors' abstract)

RAVENHURST, Casey and ZENTILLI, Marcos, 1987, A model for the evolution of hot (>200°C) overpressured brines under an evaporite seal: The Fundy/Magdalen Carboniferous basin of Atlantic Canada and its associated Pb-Zn-Ba deposits, in Beaumont, C. and Tankard, A.J. (eds.), Sedimentary Basins and Basin-Forming Mechanisms: Can. Soc. Petr. Geol., Memoir 12, p. 335-349. First author at Dept. Geol., Dalhousie Univ., Nova Scotia B3H 3J5, Canada.

Mineralizing fluids for Pb-Zn-Ba deposits located on the platform of the Fundy/Magdalen Basin, were hot (150-250°C) saline brines that were very similar isotopically and chemically to oil-field and basinal brines. The brines probably originated from under the Windsor Group evaporites in the southern part of the deep Magdalen Basin. Horton Group clastic rocks and the Pembroke Breccia were likely aquifers for the brines. A Rb-Sr isochron indicates a homogenizing event at 300 ± 6 Ma in the Horton strata directly below the Pembroke Breccia; an event that coincides with a pulse of regional tectonism recorded in the stratigraphic succession.

Mathematical modelling of excess pore P buildup under the evaporite seal was carried out using the TWODEPEP finite element program. Results indicate that during periods of rapid sediment or tectonic loading, fluid P could have approached the lithostatic load. At least one sudden massive hydrofracturing, fluid expulsion event occurred by 300 Ma and possibly as early as late Windsor time (336 Ma). (Authors' abstract)

RAYNAUD, D., MAZAUDIER, D., LORIUS, C., BARKOV, N.I. and LIPENKOV, V., 1987, Elevation changes over the past 160,000 years near Vostok, east Antarctica, from air content in ice (abst.): Int'l. Union of Geodesy & Geophys., XIX Gen. Assembly, Vancouver, Canada; Aug. 9-22, 1987; Abstracts, v. 3, p. 936. First author at Lab. de Glaciologie & Géophys. de l'Environment, BP 96 38402 Saint-Martin d'Hères Cedex, France.

In the melting-free zone of the ice sheets the inter-grain spaces of the firn are first connected with the atmosphere. The spaces become progressively isolated from the free atmosphere under the form of bubbles by sintering of the ice grains. The volume of air thus trapped is theoretically a function of the space volume (VC) and of the pressure(PC) and temperature (TC) of the bubbles when they close off from the atmosphere. Because of the strong dependence of the air pressure in the firn spaces with the surface atmospheric pressure, the measurement of the volume of air enclosed in ice resulting from the firn transformation provides information about the past surface elevation of the ice sheet at the site where the glacier ice was formed, if VC and TC are known. The air content, V, has been measured in more than 200 ice samples taken along the 2083 m deep Vostok ice core, i.e., on ice accumulated during the last 160,000 years. Due to the fractures in the ice the measurements are scarce above 775 m (about 45,000 years BP). The air content profile is interpreted in terms of changes in atmospheric pressure and hence in elevation of the ice formation site. VC is assumed to change linearly with TC according to the semi-empirical relationship given by Reynaud and Lebel (Nature, 281, 289-291, 1979). TC changes are accounted for by using the temperature signal given by the isotopic composition of the ice. The changes in elevation thus deduced cannot be explained by the horizontal advection (upslope origin effect due to the flow of the ice) and consequently suggest changes in ice thickness. This empirical record of surface elevation in the central part of East Antarctica over the last climatic cycle is well correlated with the climatic record deduced from stable isotope measurements of the Vostok core (Lorius et al., Nature, 316, 591-596, 1985). Higher (lower) elevations are associated with warmer (colder) climatic periods, which suggest that the ice thickness modifications inferred are driven by the changes in snow accumulation rate. This kind of palaeo-data could provide important constraints for the modelling of the ice sheet-climate interactions. (Authors' abstract)

READ, W.F., 1987, At least three bubble-bearing layers of impact spherules in the Ordovician of Wisconsin (abst.): Meteoritics, v. 22, p. 487.

REARDON, E.J. and ARMSTRONG, D.K., 1987, Celestite ($SrSO_{4(S)}$) solubility in water, seawater and NaCl solution: Geochimica Cosmo. Acta, v. 51, p. 63-72.

REEDER, R.J. and GRAMS, J.C., 1987, Sector zoning in calcite cement crystals: Implications for trace element distributions in carbonates: Geochimica Cosmo. Acta, v. 51, p. 187-194. Authors at Dept. Earth & Space Sci., State Univ. New York at Stony Brook, Stony Brook, NY 11974, USA.

Compositional sector zoning in calcite cement crystals from a sedimentary limestone is represented by differences of Mg content of over 1300 ppm, or 95%, and of Sr and Mn contents of up to 400 ppm, or roughly 50% and 80% respectively, between crystallographically nonequivalent, time-synchronous growth sectors. $\{10\bar{1}1\}$ sectors are enriched with both Mg and Mn relative to $\{10\bar{1}4\}$ sectors, and other sectors show both greater and lesser enrichment. This systematic zoning pattern requires effective distribution coefficients for these trace elements to have been different for growth on different faces. Differential growth rate effects for nonequivalent faces are shown to be unimportant relative to differential growth face/element preferences. Surface crystal structure and differing coordination environments are regarded as the principal factors influencing sector-related elemental partitioning differences in calcite and dolomite. (Authors' abstract)

Pertinent to inclusion studies, both in the study of trapping mechanisms, and in the possibility of coeval but variable composition inclusions from reequilibration with host mineral after trapping. (E.R.)

REIMER, G.M. and KURZ, M.D., 1987, Terrestrial helium investigations in earth science: J. Geophys. Res., v. 92, no. B12, p. 12,475. First author at U.S. Geol. Survey, Denver, CO.

This is a preface to a special section on "Helium studies in geology" (p. 12477-12603), consisting of 12 papers on various apsects. (E.R.)

REJEBIAN, V.A., HARRIS, A.G. and HUEBNER, J.S., 1987, Conodont color and textural alteration: An index to regional metamorphism, contact metamorphism, and hydrothermal alteration: Geol. Soc. Am. Bull., v. 99, p. 471-479.

RENDERS, P.J. and ANDERSON, G.M., 1987, Solubility of kaolinite and beryl to 573 K: Applied Geochem., v. 2, p. 193-203. First author at DSIR Chem. Div., Private Bag, Petone, New Zealand.

Compositions of aqueous solutions in equilibrium with quartz ($SiO_2$), kaolinite ($Al_2Si_2O_5(OH)_4$) and beryl ($Be_3Al_2Si_6O_{18}$) in the system $BeO-Al_2O_3-SiO_2-H_2O$ have been measured along the 5 phase subcritical curve for temperatures up to 573 K. Hydrothermal transportation of Be as hydroxy-complexes appears adequate to explain the presence of beryl (emerald) deposits such as those found in the Muzo and Chivor districts of Columbia. Complexing by other ions such as chloride and fluoride has not been investigated but would presumably enhance the solubility. If transport is dominantly as hydroxy species in slightly acid waters, cooling cannot be a precipitating mechanism, but a pH shift caused by wall rock alteration, or by loss of $CO_2$, would suffice. (From the authors' abstract)

REUSCHLE, T., DAROT, M. and GUEGUEN, Y., 1987, Crack growth and fluid-rock interactions (abst.): Terra Cognita, v. 7, no. 2-3, p. 127.

REUTEL, Chr. and HORN, E.E., 1987, Fluid mapping using microthermometry and the Raman microprobe (western margin of the Bohemian Massif) (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 107-108. Authors at Inst. Geol. & Dynamik der Lithosphäre, Goldschmidtstr. 3, D-3400 Göttingen.

The Oberpfalz on the western margin of the Bohemian Massif, the largest exposure of Varisan basement in Europe, is characterized by numerous element concentrations and fluid systems. The wide spectrum of fluid phases contains gas inclusions ($CO_2$, $CH_4$, $N_2$) and aqueous fluid inclusions of differing composition, salinity, and Tt. Based on the analysis of fluid inclusions a sequence of generations was reconstructed which fits in excellently with the tectonometamorphic development of the basement.

It appears that the oldest proven generations are marked by the differing development of the MP-metamorphic allochthonous units and the LP-metamorphic parautochthonous units. A similar fluid history is first observed in both the MP and LP metamorphics following the emplacement of the MP complex. This was seen in the decrease in Pt, the cooling, and the retrograde mineral formation.

Whereas these generations represent internal fluid systems, highly saline, low-T fluids dominate the younger mineralizations which discordantly overlie the metamorphics; they were transported from outside of the molasse basin of the foreland and brought mineral parageneses of quartz, fluorite, barite, and calcite via solution mixtures. (Authors' abstract)

REYNOLDS, J.H. and OZIMA, Minoru, 1987, Terrestrial rare gas seminar: Eos, v. 68, p. 1587-1588.

A report on the second Japan-US Seminar on Terrestrial Rare Gases, Yellowstone National Park, Wyoming, September 1986. Twenty-eight papers were presented in 8 categories, each consolidated here to a brief abstract by a "reporter:" Rare gases in diamonds; Mantle noble gases; Origins of rare gases in methane; Rare gases in ocean sediments; Rare gas contributions to hydrology; Primordial atmospheres; Rare gases in meteorites; and Physicochemical behavior of the rare gases. (E.R.)

RICHARDSON, C.J., CANN, J.R., RICHARDS, H.G. and COWAN, J.G., 1987, Metal-depleted root zones of the Troodos ore-forming hydrothermal systems, Cyprus: Earth & Planet. Sci. Lett., v. 84, no. 2-3, p. 243-325.

RIEKEN, R., HORN, E.E. and NEUSER, R., 1987, Fluid inclusion systems in diagenetic environments at depths of 1000-6000 m (North German basin) (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 109-110. Authors at Inst. Geol. & Dynamik der Lithosphäre, Goldschmidtstr. 3, D-3400 Göttingen.

Fluid inclusions from core samples of the Mesozoic and Paleozoic (North German basin) were studied. Various diagenetic stages in the diagenetically formed mineralizations (cements, growth rims on quartz, authigenic minerals) were identified in the sedimentary environment. The development of the formation water regime was reconstructed using fluid chemistry.

Formation T and salinities of the fluid inclusions in the diagenetic mineralizations are correlated with depth. A continuous increase in solution salinity from 1200 to 5000 m and an increase in the formation T were observed.

With increasing depth the following fluid systems are recognized:

$NaCl-H_2O$;
$NaCl-CaCl_2-H_2O$; and
$CaCl_2-MgCl_2-NaCl-H_2O$

In addition, Mesozoic core samples from below 1800 m contain $CO_2$- and methane-bearing fluid inclusions in the cements and growth rims which allow an estimation of the (minimum) Pt. In Paleozoic core samples methane inclusions occur between 3800 and 4700 m depth and $CO_2$-bearing inclusions occur between 4500 and 6200 m.

Geothermometric and geobarometric determinations, which could be of great importance in reference to hydrocarbon migration, are possible through the cogenetic occurrence of gas inclusions with aqueous inclusions. Cathodoluminescence studies of the diagenetically formed cements and minerals yield further information on the various systems of formation waters. (Authors' abstract)

RIPMEESTER, J.A., TSE, J.S., RATCLIFFE, C.I. and POWELL, B.M., 1987, A new clathrate hydrate structure: Nature, v. 325, p. 135-136. First author at Div. Chem., Nat'l. Res. Council, Ottawa K1A 0R6, Canada.

Clathrate hydrates, ice-like host-guest systems containing guest molecules in cages of hydrogen-bonded water molecules exist in three well-characterized cubic forms, and a less well-characterized tetragonal form. On the basis of $^2H$ and $^{129}Xe$ NMR measurements and X-ray and neutron powder diffraction results, we now report a new hexagonal hydrate structure requiring both large and small guest molecules to stabilize the structure. This hydrate is expected to be isostructural with the hexagonal clathrasil dodecasil-1H (see ref. 14 for clathrasil nomenclature). As for the cubic clathrate hydrates, the new hydrate structure may occur naturally. (Authors' abstract)

RIRIE, G.T., 1987, Evaporites and stratabound tungsten deposits (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 820-821. Author at Unocal Corp., Sci. & Tech. Div., Geol. Res., P.O. Box 76, Brea, CA 92621.

Gypsum and/or anhydrite casts occur in quartzites that host varying amounts of tungsten mineralization for several kilometers along strike in northern Western Australia. Tungsten mineralization is stratabound, with no evidence of exhalative or intrusive rocks in the section. Textural, fluid inclusion, and oxygen isotope data document that the scheelite was present in the host rocks prior to the regional metamorphic event and imply that the tungsten may have originally accumulated in an evaporitic environment. (From the author's abstract)

RITGER, Scott, CARSON, Bobb and SUESS, Erwin, 1987, Methane-derived authigenic carbonates formed by subduction-induced pore-water expulsion along the Oregon/Washington margin: Geol. Soc. Am. Bull., v. 98, p. 147-156.

RIZVI, S.S.H. and HEIDEMANN, R.A., 1987, Vapor-liquid equilibria in the ammonia-water system: J. Chem. Eng. Data, v. 32, p. 183-191.

ROBERT, Francois and KELLY, W.C., 1987, Ore-forming fluids in Archean gold-bearing quartz veins at the Sigma mine, Abitibi greenstone belt, Quebec, Canada: Econ. Geol., v. 82, p. 1464-1482. First author at Mineral Resources Div., Geol. Survey of Canada, 601 Booth St., Ottawa, Canada K1A 0E8.

Archean Au-bearing quartz veins at the Sigma mine occur in deformed metavolcanics intruded by two generations of preore porphyries. The veins were emplaced during a late compressional tectonic event and they consist primarily of quartz, tourmaline, carbonates, pyrite, and scheelite. Vein minerals have been deformed and are also cut by abundant healed fractures outlined by fluid inclusions. In the veins, Au typically occurs in late fractures and in recrystallized quartz. Microthermometric, SEM-EDA, leachate analysis, and gas chromatographic techniques were used to study fluid inclusions in quartz.

Most fluid inclusions at Sigma occur in late fractures and are S. The fluid inclusions are commonly found in fractures parallel to, or less commonly within, Au-bearing fractures and are genetically related to Au. Three types of fluid inclusions are identified: (1) high-salinity Na-Ca-Cl aqueous inclusions (25-34 wt % salt) with small amounts of $CO_2$, some containing halite, calcite, and nahcolite(?) as dms; (2) $CO_2$-rich inclusions containing small amounts of $H_2O$ and $CH_4$; and (3) low-salinity $H_2O$-$CO_2$ inclusions (<10 eq. wt % NaCl) with $CO_2$ contents which are variable but commonly in the range of 15 to 30 mole % $CO_2$. Leachate analyses show that, in addition to Na and Ca, the aqueous fluids contain minor amounts of K, Fe, Mg, and Li. Th of $H_2O$-$CO_2$ inclusions with constant phase ratios range from 285° to 395°C; those of aqueous inclusions range from 60° to 295°C.

The aqueous and $CO_2$-rich inclusions are interpreted to have trapped two coexisting fluids resulting from the unmixing of a homogeneous $H_2O$-$CO_2$ parent fluid, itself occasionally trapped in late fractures. The ore-bearing fluid is interpreted to be a low-salinity (<10 eq. wt % NaCl) fluid containing 15 to 30 mole % $CO_2$, a minimum T in the range of 285° to 395°C. The relatively low Th of aqueous inclusions are interpreted to be the result of $CO_2$ effervescence from a $CO_2$-saturated aqueous fluid due to P fluctuations at the time of entrapment. It is also proposed that the onset of Au deposition is related to the onset of fluid unmixing. (Authors' abstract)

ROBERTS, P.J., 1986, Recovery of gold and silver from active geothermal systems: Paper presented at annual meeting of New Zealand branch of Australian Inst. of Mining and Metallurgy, 1986, and reported in Newsletter, Int'l. Liaison Group on Gold Mineralization, no. 4, 1987, p. 47-49.

Dr. Kevin Brown of DSIR noted in 1983 that deposits on pipelines and pressure plates in Broadlands geothermal field well BR 22 contained 4.5% Au, 6.9% Ag, and 21% Cu. Even richer deposits were found at Kawerau. The BR 22 data suggested <10.5 ppb Au; 44-day accumulation corresponded to 1.5 ppb in the total fluid flow. Commercial recovery will be attempted. (E.R.)

ROBERTS, R.G., 1987, Ore deposit models #11. Archean lode gold deposits: Geosci. Canada, v. 14, no. 1, p. 37-52. Author at Dept. Earth Sci., Univ. Waterloo, Waterloo, Ontario N2L 3G1, Canada.

Refers to literature data on inclusions only. (E.R.)

ROBERTSON, Kay, 1987, Fadenquartz or string quartz - an American locality: Min. News, v. 3, no. 4, p. 1. Author at 10334 Ilona Ave., Los Angeles, CA 90064.

Fadenquartz crystals have an elongated central zone that is milky with fluid inclusions, usually as multiple curving planes approximately perpendicular to c. These crystals came from Saline County, Arkansas. (E.R.)

ROBINSON, A.L., 1987, Probing interfaces involving liquids: Science, v. 236, p. 150-151.

A review of a seminar held by the National Academy of Sciences that includes various surface phenomena of pertinence to fluid inclusion studies. (E.R.)

ROBINSON, D., 1987, Two-phase flow in crust and mantle: J. Geol. Soc., London, v. 144, p. 257-258. Author at Dept. Geol., Univ. Bristol, Wills Mem. Bldg., Queen's Road, Bristol BS8 1RJ.

A review of a series of papers given at a 1986 meeting on the subject of particular interest to the nature of fluid inclusions in mantle materials such as olivine nodules. (E.R.)

ROEDDER, E., 1987, Fluid Inclusions in Minerals: Moscow, Izdat. "Mir", v.1 (Chpts. 1-10) 557pp; v.2 (Chpts. 11-19) 631 pp. (in Russian).

A translation by D.N. Khitarov of MSA Reviews in Mineralogy v.12, 1984. 1300 copies printed; sold out immediately. (E.R.)

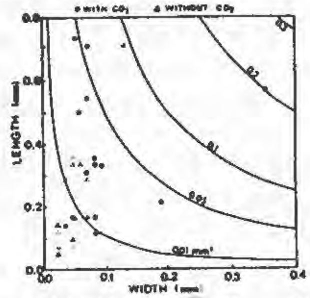
ROEDDER, Edwin and COOMBS, D.S., 1987, Inclusions indicating crystallization at depth of plagioclase microphenocrysts in a New Zealand dolerite (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). (Same abstract in ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 111.) First author at U.S. Geol. Survey, Reston, VA 22092, USA.

It is commonly assumed that sub-millimeter crystals of plagioclase in fine-grained basaltic rocks formed by crystallization in place, after extrusion or intrusion. We present evidence here that some very small lath-like crystals of plagioclase have formed at depth.

During the Cenozoic, basaltic magma intruded into soft, wet, shallow marine muds at Tawhiroko Point, Moeraki Peninsula, on the east coast of South Island, New Zealand. A sample from the chilled glassy selvage of this Tawhiroko Dolerite intrusion consists of (modal %): glass - 71.1, olivine - 8.4, plagioclase - 18.2, and augite - 2.3. The glass has 53.49 $SiO_2$, the olivine is found as pseudomorphs only, the plagioclase is $\sim An_{59}$, and the augite is $\sim Ca_{37}Mg_{50}Fe_{13}$ (Coombs et al., Roy. Soc. N.Z. Bull. 23, 1986). Preliminary studies of this sample show that many of the plagioclase crystals contain small P inclusions of $CO_2$ liquid + vapor, most of which homogenize in the liquid phase. Most occur toward the centers of the crystals, but some are within 10 µm of the edge. If we assume pure $CO_2$ and 1200°C at the time of trapping, a <u>minimum</u> P of 2000 bars is required, or 4.7 km depth of basaltic magma of density 2.7 (Roedder, Am. Min. 50, 1965). If we assume 1100°C, these depths would decrease by ~0.2 km.

Liquid $CO_2$ inclusions are common in phenocrysts, xenocrysts, and xenoliths in basalts, and provide valuable constraints on the depth of crystallization of the host phases in these magmas. What is unusual here is the small size of the host crystals in this rock. All the larger plagioclase crystals in a randomly chosen area of one slide of this rock were measured (length and width), and then examined under oil immersion at 1500X magnification. Of these 32, 14 contained recognizable $CO_2$ liquid plus vapor inclusions <6.7 µm in diameter (see plot). The seven smallest crystals examined (<50 µm wide and <115 µm long) contained no inclusions, and a cursory check of the abundant still smaller plagioclase crystals (minimum thickness ~1.5 µm) revealed no $CO_2$. However, some crystals as thin as 35 µm, and others as short as 118 µm did contain them. Probe studies are in progress, but at present we see no difference between those with and without inclusions, and assume that the difference lies in the vagaries of the inclusion trapping process.

The existence of the $CO_2$ inclusions in plagioclase microphenocrysts in this sample, and of similar inclusions in several other basaltic intrusions, tephra, and breccias in the area proves that even very small plagioclase crystals can form at considerable depths, and may eventually provide some constraints on the rates of ascent of basaltic magma. (Authors' abstract)



Plot of length vs. width of the 32 largest plagioclase crystals in one thin-section area, showing occurrence of visible $CO_2$ inclusions. The curves show the cross-sectional area of the crystals, as seen in the slide.

ROEDDER, E., d'ANGELO, W.M., DORRZAPF, A.F., Jr. and ARUSCAVAGE, P.J., 1987, Composition of fluid inclusions in Permian salt beds, Palo Duro Basin, Texas, U.S.A.: Chem. Geol., v. 61, no. 1/4, p. 79-90.

Full paper for abstract in Fluid Inclusion Research, v. 18, p. 343, 1985. (E.R.)

ROEDDER, Edwin and HOWARD, K.W., 1987, Fluid inclusions in SSSDP core: Preliminary results (abst.): EOS, v. 68, p. 439. Authors at MS 959, U.S. Geol. Survey, Reston, VA 22092.

Eighty-six fluid inclusions were examined in calcite, quartz and anhydrite from thin (~1 mm) veinlets crosscutting the SSSDP core, from 1983-7400 ft (605-2256 m) depth in the Salton Sea geothermal field, California. Preliminary data were obtained on the homogenization temperatures (Th; all in liquid phase), melting of ice (Tm), and eutectic melting (Te). No daughter minerals were seen, and no clathrates were recognized on freezing. Most inclusions adequate for both Th and Tm range in Th from 217 to 350°C and vary widely in salinity (as indicated by Tm, -0.7 to -26.8°C), suggesting a complex history of fluid circulation in the past. Te values are all in the range -40 to -62°C (mean ~-51°C). The data are too few for correlation with inclusion origin or host mineral.

Extensive speculation on the origin and nature of these various fluids is premature, but several points are noteworthy: 1) with one exception, all inclusions with highly saline brines (i.e., Tm below -15°C, >18.8 wt% NaCl eq.) were from >1700 m depth; 2) very low salinity fluids (Tm -0.7 to -2.4°C, 1.2 to 4.0 wt% NaCl eq.) circulated as deep as 1939 m; 3) the Te values almost certainly require $CaCl_2$ as a major component; 4) on a plot of Tm vs. Th, most of the data points are clustered, suggesting a series of discrete fluids. The data obtained can be explained by combinations of the processes suggested by other workers (e.g., McKibben, and Oakes & Williams, ACROFI, 1987) on the basis of fluid inclusion and other studies from other wells in the Salton Sea geothermal field. These processes include thermal metamorphism of evaporites, local igneous intrusions or fracturing of deep overpressured zones, and mixing of water from dehydration of gypsum with partly evaporated Colorado River water. (Authors' abstract)

ROMBERGER, S.B., 1985, Transport and deposition of uranium in hydrothermal systems at temperatures up to 300°C, with genetic implications (abst.): The Canadian Inst. Mining & Metal. Spec. Volume 32, Geology of uranium deposits, Sibbald, T.I.I. and Petruk, W., eds., p. 255.

ROMBERGER, S.B., 1986, The solution chemistry of gold applied to the origin of hydrothermal deposits, in Clark, L.A., ed., Gold in the Western Shield: The Canadian Inst. Mining & Metal., Special Vol. 38, p. 168-186.

ROSE, A.W. and KUEHN, C.A., 1987, Ore deposition from acidic $CO_2$-rich solutions at the Carlin gold deposit, Eureka County, Nevada (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 824. Authors at Geosci. Dept., Pennsylvania State Univ., University Park, PA 16802.

Fluid inclusion and stable isotope data indicate that the Carlin deposit was formed by two fluids. A "deep" hydrothermal fluid was saturated with $CO_2$ at 500-800 bars and 210± 25°C, requiring depths of about 3 km. This originally meteoric fluid was low in salinity, probably containing less than 0.2 m NaCl equiv., and may have acquired its $CO_2$ largely from contact metamorphism at greater depth. Mixing with cooler, dilute, meteoric "shallow" water is required to account for highly variable $\delta^{18}O$ of quartz, cooling to cause quartz deposition, and light $\delta^{18}O$ values in hanging wall calcite veins locally containing realgar ± barite, as well as fluid inclusions with freezing point depressions commonly <0.5°C in barite, calcite and other minerals.

Illite-bearing silty dolomitic limestones near structural or stratiform conduits of the deep fluid are altered to quartz-dickite or quartz only (jasperoid), indicating $K/H<10^{2.8}$ at 210°C, and the ability to transport Al locally. Given an Na/K of 10, the pH of the deep fluid was low, approximately 3.5, attributed mainly to dissolved $CO_2$, which also accounts for extensive dissolution of carbonates. At these low pH and Cl values, and with moderate $H_2S$ ($10^{-2}$ m), sulfides of Ag, Pb, Cu, and Zn are negligibly soluble. Au, which is deposited mainly in zones of carbonate dissolution outside the jasperiods, may be transported as $AuHS^{\circ}$, as an $Au^{+}$-$Cl^{-}$ complex more stable than published values, or as an Au-As or other poorly documented complex. Any sulfate in this deep fluid would occur as $HSO_4^-$, allowing transport of Ba. Organic matter was pre-ore, had already matured to a pyrobitumen and probably had little or no influence on ore deposition. Initial ore controls include local zones of increased permeability, such as thin bioclastic calcarenite beds, but structural collapse and brecciation caused by extensive carbonate dissolution and possibly dilation of the ore zone caused by high $CO_2$ pressures and two-phase separation were also important. (Authors' abstract)

ROSEN, O.M. and SONYUSHKIN, V.E., 1987, Characteristics of inclusions and deformation features of quartz from polymetamorphic rocks of the Anabar Shield: Zap. Vses. Mineral. O-va, v. 116, no. 5, p. 602-609 (in Russian). Authors at Inst. Litosf., Moscow, USSR.

The Anabar Complex of the Anabar Shield (USSR) consists of rocks metamorphosed under granulite-facies conditions; fluid inclusions in quartz (Q) from these metamorphic rocks are composed predominately of $CO_2$ with small amounts of $H_2O$. These inclusions were formed at 860-890° and 10-11 kbars. The associated Lamuisk Complex contains rocks subjected to areal diaphthoresis under amphibolite- and epidote amphibolite-facies conditions. Fluid inclusions in Q from the Lamuisk Complex consist mainly of $H_2O$ and some gas-phase components ($CO_2$). The thermodynamic parameters vary widely from a Tf of 780-810° (at 6-6.5 kbars) through 500° (at 4-5 kbars) to 200-300° (at 0.7 kbar); these values reflect successive stages of metamorphic evolution. Electron microscopic study of deformation structures in Q indicate that paleostresses in the granulite-, amphibolite-, and epidote-amphibolite facies occurred at 87, 148, and 237 bars, respectively. (C.A. 108: 171032q)

ROSENBAUER, R.J. and BISCHOFF, J.L., 1987, Pressure-composition relations for coexisting gases and liquids and the critical points in the system NaCl-$H_2O$ at 450, 475, and 500°C: Geochim. Cosmo. Acta, v. 51, p. 2349-2354. Authors at Pacific Marine Geol., U.S. Geol. Survey, Menlo Park, CA 94025

Pressure-temperature-composition (P, T, x) relations for the coexisting vapor and liquid phases in the system NaCl-$H_2O$ were determined experimentally at 450, 475, and 500°C. Data for each isotherm include P-x relations near the critical point and extend to the three-phase assemblage vapor-liquid-halite on the vapor side. On the liquid side the P-x data range from the critical point to the room-temperature halite saturation point (~25 wt.% NaCl). Critical pressures were calculated from measured pressures and compositions and classical theory. The results generally support the few data points of Urusova (1974, 1975) and Olander and Liander (1950) but differ markedly from the extensive data of Sourirajan and Kennedy (1962). (Authors' abstract)

ROSING, M.T., 1987, The theoretical effect of metasomatism on $\varepsilon_{Nd}$ (abst.): Abstracts, NATO Advanced Research Workshop, Fluid movements, element transport, and the composition of the deep crust, Lindås, Norway, 18-24 May, 1987 (unpaginated).

ROSLYAKOVA, N.V., SHCHERBAKOV. Yu.G., BORTNIKOVA, S.B., RADOSTEVA, N.E., TSIMBALIST, V.G. and SHUGUROVA, N.A., 1987, Geochemistry of the formation processes of gold-ore deposits: Geokhimiya, 1987, no. 9, p. 1327-1336 (in Russian).

ROSSMAN, G.R., WEIS, D. and WASSERBURG, G.J., 1987, Rb, Sr, Nd and Sm concentrations in quartz: Geochim. Cosmo. Acta, v. 51, p. 2325-2329. First author at Div. Geol. & Planet. Sci., California Inst. Tech., Pasadena, CA 91125, USA.

The concentrations of Rb, Sr, Nd and Sm in quartz crystals from Crystal Peak, Colorado; Stewart Mine, California; Tomas Gonzaga, Minas Gerais, Brazil; and Coleman Mines, Arkansas, were determined by isotope dilution mass spectrometry. Concentrations ranged from: 1.17 to 177 ppb Rb; 3.26 to 1027 ppb Sr; 0.0159 to 0.48 ppb Sm; 0.127 to 2.81 ppb Nd. In the Brazilian crystal, concentrations of these elements were correlated with the amount of fluid inclusion water measured visually by turbidity and quantitatively with infrared adsorption spectroscopy. The highest Rb content was found for a crystal free of visible inclusions, indicating that small amounts of Rb can also occur in quartz itself. Rb and Sr contents are much lower in synthetic quartz grown commercially from the Arkansas quartz. (Authors' abstract)

ROVETTA, M.R., BLACIC, J.D. and DELANEY, J.R., 1987, Microfracture and crack healing in experimentally deformed peridotite: J. Geophys. Res., v. 92, no. B12, p. 12,902-12,910. First author at Geophys. Group, ESS-3, Los Alamos Nat'l. Lab., Los Alamos, NM.

S $CO_2$ fluid inclusion arrays in peridotite xenoliths from basalt are formed by the healing of $CO_2$-filled microcracks. We have produced healed microcracks and deformation textures comparable to those in xenoliths by deforming peridotite in the presence of excess $CO_2$ fluid at a constant strain rate of $10^{-5}s^{-1}$, a confirming[sic; confining?] P of 1.0-1.5 GPa, and 800°-1050°C. Plastic and microclastic deformation textures coexist, and healed microcracks extending out of (100) and (011) olivine deformation lamellae have the crystallographic orientation of microcracks nucleated on pileups of (100)[010] and (011)[100] edge dislocations. Healed microcracks in olivine grains without deformation lamellae tend to be in these orientations or in the orientation of microcracks nucleated on pileups of (110)[001] and (010)[001] edge dislocations. The same crystallographic orientation of healed microcracks is present in peridotite xenoliths from basalt. The steady flow stress data of the experiments without added $CO_2$ fluid fit a power law with a stress exponent n of 3 and a thermal activation coefficient of 410 ± 50 kJ $mol^{-1}$. The maximum stress that can be supported by samples with added $CO_2$ fluid is 100-300 MPa less than the flow stress of samples without added $CO_2$ fluid. The reduction in mechanical strength correlated with an increase in the concentration of intragranular healed microcracks and an increase in the proportion of healed microcracks inclined to the maximum compressive stress direction. Strength and microcrack characteristics of experiments with $CO_2$ performed at 1.5 GPa are similar to experiments without $CO_2$ and 1.0 GPa. The dependence of strength and microcrack concentration on confining P suggests that the principal effect of the $CO_2$ fluid is to reduce the effective confining P and to promote microclastic deformation mechanisms. The similarity of experimental textures to xenoliths suggests that $CO_2$ fluid may produce semibrittle mechanical behavior in the regions of the lower lithosphere where xenoliths originate. (Authors' abstract)

RUA-FIGUEROA, A., LLAVONA, M., LOREDO, J. and GARCIA IGLESIAS, J., 1987, Fluid inclusions in quartz from a gold-mineralized granodioritic intrusion at Carlés, Asturias, Spain: Chem. Geol., v. 61, p. 217-224. Authors at Dept. Metal., Escuela de Ingenieros de Minas, Independencia 13, 33004 Oviedo, Spain.

The granodioritic stock of Carlés, located near Oviedo (Asturias, Spain) intruded Devonian limestones which are transformed by contact metamorphism. Small inclusions of native gold are associated with arsenopyrite in the granodiorite and metamorphic aureole, either in quartz veins or in fractured rocks.

Heating and freezing measurements carried out on the fluid inclusions in the quartz veins reveal the presence of four types of fluid inclusions: aqueous two-phase inclusions (type A); carbonic two-phase inclusions (type B); aqueous three-phase inclusions containing a halite cube (type C); and $CO_2$-rich three-phase inclusions (type D).

Aqueous inclusions (types A and C) show two generations, the homogenization of the whole occurring in a wide interval (100-380°C).

The carbonic and hydrocarbonic inclusions (types B and D, respectively) show each a single generation, with Th of the $CO_2$ component occurring - either in the liquid or in the vapor phase - from 21° to 26°C, and the total Th for type D varies between 280° and 380°C. Estimated P and T from the stated inclusions would have maximum values of 2.4 kbar and 550°C.

Two very important aspects of the fluids associated with the mineralization are: (1) the presence of $CO_2$ as a factor which could help the Au mobilization; and (2) the occurrence of important differences in density and salinity for apparently contemporaneous fluid inclusions, which could be related to boiling phenomena - by P drop - facilitating the Au precipitation. (Authors' abstract)

RUAYA, J.R. and SEWARD, T.M., 1987, The ion-pair constant and other thermodynamic properties of HCl up to 350°C: Geochimica Cosmo. Acta, v. 51, p. 121-130.

RUBIN, J.N., PRICE, J.G., HENRY, C.D. and KOPPENAAL, D.W., 1987, Cryolite-bearing and rare metal-enriched rhyolite, Sierra Blanca Peaks, Hudspeth County, Texas: Am. Mineral., v. 72, p. 1122-1130. Authors at Bureau Econ. Geol., The Univ. Texas at Austin, University Station, Box X, Austin, TX 78713, USA.

The Round Top intrusion, one of five shallow rhyolite laccoliths in the Tertiary Trans-Pecos Texas magmatic province near Sierra Blanca, Texas, was chemically modified by pegmatitic vapor-phase crystalliztaion. Evidence of pegmatitic crystallization includes the presence of cryolite ($Na_3AlF_6$), Li-rich trioctahedral micas with variable Fe contents, rutilated quartz, and vapor-rich fluid inclusions defining quartz overgrowths on magmatic grains. The presence of cryolite and strong HREE enrichment, which may also be the result of vapor-phase crystallization, sets the Sierra Blanca rhyolites apart from otherwise chemically similar topaz-bearing rhyolites. (From the authors' abstract)

RUBIN, J.N., PRICE, J.G., HENRY, C.D., WITTKE, J.H. and KOPPENAAL, D.W., 1987, Cryolite rhyolite: Rhyme or reason? (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 177. Authors at Bureau of Econ. Geol., Univ. Texas, Austin, TX 78713-7508.

A peraluminous rhyolite laccolith near Sierra Blanca, Texas, is enriched in most incompatible elements, notably Be, F, Y, Zr, Nb, Sn, REE, and Th. The rhyolite, which contains 72.5 wt.% $SiO_2$, 1.3% F, and 170 ppm Be, is the probable source of F and Be in fluorspar replacements of Cretaceous limestones along the intrusive contacts. The rhyolite contains cryolite (2.5 vol.%) and trace amounts of Yb-rich xenotime, yttrocerite, zircon, columbite, Pb- and Nb-rich cassiterite(?), bastnaesite, and thorite. Rutilated quartz occurs consistently with cryolite, and contains vapor-rich fluid inclusions. (From the authors' abstract)

RUDNICK, R.L. and WILLIAMS, I.S., 1987, Dating the lower crust by ion microprobe: Earth & Planet. Sci. Letters, v. 85, p. 145-161. First author at Max Planck Inst. für Chemie, Saarstrasse 23, Postfach 3060, D 6500 Mainz, FRG.

Ion microprobe U-Th-Pb ages of zircons from granulite facies lower crustal xenoliths from north Queensland, Australia, correlate well with the ages of major orogenic episodes manifest at the earth's surface. About half of the xenoliths contain Proterozoic zircons which are similar in age to the episodes of high-grade metamorphism of the older surface rocks. All the xenoliths contain late Paleozoic zircons which show a real 100 Ma range in $^{206}Pb/^{238}U$ ages (from ~320 to 220 Ma), which is attributed to granulite facies metamorphism followed by slow cooling in deep crust. Some of the zircons from the felsic xenoliths contain $CO_2$-rich fluid inclusions, indicating that those zircons grew during high-grade metamorphism. (From the authors' abstract)

Includes two analyses of melt inclusions from zircons and descriptions of $CO_2$, sulfide and amphibole daughter phases in others. (E.R.)

RUDOWSKI, Luc, GIULIANI, Gaston and SABATE, Pierre, 1987, The emerald-bearing phlogopitites in the proximity of the granites of Campo Formoso and Carnaiba (Bahia, Brazil): An example of Be, Mo, W Proterozoic mineralization in metasomatic ultramafics: C.R. Acad. Sci. Paris, v. 305, Ser. II, no. 18, p. 1129-1134 (in French; English abstract).

Associated with two-micas transamazonian (± 2000 M.y.) granites, the hydrothermal fluids related with aplopegmatites veins, develop phlogopitites with original metasomatic zoning into the chromite-bearing ultramafics of the country rocks. They are responsible for beryl (emerald), molybdenite and scheelite mineralizations. The parent magmas were generated under fluid saturated conditions. (Authors' abstract)

RUMBLE, Douglas, III, CHAMBERLAIN, C.P. and ZEITLER, Peter, 1987, Hydrothermal graphite in New Hampshire, USA (abst.): Abstracts, NATO Advanced Research Workshop, Fluid movements, element transport, and the composition of the deep crust, Lindås, Norway, 18-24 May, 1987 (unpaginated). First author at Earth Sci. Div., Nat'l. Sci. Foundation, Washington, DC 20550, USA.

[On the basis of isotopic studies] it is proposed that carbon was mobilized from sediments as $CO_2$ and $CH_4$ during metamorphic devolatilization reactions. The carbon-bearing species were transported in aqueous fluids through hydraulic fractures. Graphite precipitated when aqueous fluids with different $CO_2/CH_4$ ratios were mixed in fractures. The co-location of granulite-facies metamorphic hot spots with graphite veins suggests that rocks made permeable by fracturing may be heated by hot, flowing fluids 100°C higher than adjacent, unfractured rocks, during regional metamorphism. (From the authors' abstract)

RUSSELL, J.K., 1987a Crystallization and vesiculation of basalt magmas (abst.): Hawaii Symp. on How Volcanoes Work, Abst. Volume, Hilo, Hawaii, Hawaiian Volcano Observatory, p. 215. See next item.

RUSSELL, J.K., 1987b Crystallization and vesiculation of the 1984 eruption of Mauna Loa: J. Geophys. Res., v. 92, no. B13, p. 13,731-13,743. Author at Dept. Geol. Sci., Univ. British Columbia, Vancouver, Canada.

Calculations based on existing thermodynamic models for silicate melts are used to model the physical and chemical evolution of the 1984 Mauna Loa magma. Specifically, the calculations simulate the vesiculation-induced crystallization of the ascending magma. The calculations provide a physiochemical model to explain the increase in crystallization under isothermal conditions. The evolution of the Mauna Loa magma is modeled in three separate stages corresponding to (1) the subsurface crystallization of the phenocryst assemblage, (2) the crystallization and vesiculation of the magma during its ascent from depth, and (3) the crystallization and vesiculation of the lavas at the surface. The preeruptive crystallization of olivine and orthopyroxene phenocrysts began at ≈ 1155°C and 0.2 GPa. Olivine and plagioclase alone crystallized during the ascent of the magma. The bulk of the crystallization and vesiculation of the Mauna Loa magma occurred at pressures less than 20 MPa. Under lithostatic pressures this corresponds to depths as shallow as 600-700 m. Ancillary calculations have established the net heat effect of the prescribed ascent path and demonstrate that the heat associated with vesiculation easily compensates for the heats of crystallization. The calculations suggest that the near-surface processes can be quite endothermic depending on the initial $H_2O$ content of the magma. For a magma with 1 wt % dissolved $H_2O$ the heat balance demands approximately 5-10°C cooling. Further calulations predict the liquid line of descent for this ascent path and document the corresponding variations in the physical properties of the melt phase. (Author's abstract)

RUTHERFORD, M.J. and DEVINE, J.D., 1987, Experimental investigation of conditions in the 1980 Mount St. Helens magma chamber (abst.): Hawaii Symp. on How Volcanoes Work, Abst. Volume, Hilo, Hawaii, Hawaiian Volcano Observatory, p. 216. Authors at Dept. Geol. Sci., Brown Univ., Providence, RI 02912.

Melt inclusions in the natural amphiboles were identified and analyzed, and the compositions plotted on the $SiO_2$ variation diagrams along with those of experimental glasses [formed in dacitic material]. The amphibole melt inclusions define a liquid line of descent for the magma which extends from more primitive compositions (68 wt% $SiO_2$) to the more evolved plagioclase melt inclusion composition (73 wt% $SiO_2$). The volatile content of the amphibole melt inclusions (difference method) reaches 5.0 ± .5 wt% which compares favorably with the volatile content of the amphibole-bearing experimental melts produced at 0.67 $P(H_2O)/P(Fluid)$. (From the authors' abstract)

RYAN, M.P. and BLEVINS, J.Y.K., 1987, The viscosity of synthetic and natural silicate melts and glasses at high temperatures and 1 bar ($10^5$ Pascals) pressure and at higher pressures: U.S. Geol. Survey Bull. 1764, 563 pp.

RYE, R.O., PLUMLEE, G.S., BETHKE, P.M. and BARTON, P.B., Jr., 1987, Stable isotope geochemistry of the Creede, Colorado, hydrothermal system (abst.): Geol. Soc. Am. Abst. with Programs, v. 19, p. 330-331. First author at U.S. Geol. Survey, MS 963 Federal Center, Denver, CO 80225.

Unique stable isotope systematics of epithermal vein minerals trace fluid evolution and sources of components in the Creede hydrothermal system. Most systematics resulted from mixing of variably exchanged fluids and components at various levels along the north-south trends of the district, and indicate important involvement of moat sediments from at least two nearby calderas. The $\delta D(H_2O)$ and $\delta^{18}O(H_2O)$ systematics of the fluids indicate that the hydrothermal system was dominated by a southern-recharged pore water ($\delta D \approx -55‰$) from Creede caldera moat sediments; this water was modified by mixing with a northern-recharged meteoric water ($\delta D \approx -110‰$), both at depth and along the top of the system. The $\delta^{13}C$ (-9.0 to -4.0‰) and $\delta^{18}O$ (1.7 to 19.2‰) of early carbonates generally decrease northward across the district. The large $\delta^{18}O$ values may reflect low temperature deposition and/or fluid exchange with isotopically heavy sediments; the low values may reflect high temperature deposition and/or mixing with relatively unexchanged waters. The source of $CO_2$ is ambiguous, but some may have been derived from breakdown of moat sediment-derived organic matter. The $\delta^{34}S$ and $\delta^{18}O$ values of main stage barites vary widely (17.0 to 44.4‰, and 3.8 to 18.2‰, respectively). The large $\delta^{34}S$ and $\delta^{18}O$ values require that some sulfate underwent low-temperature bacteriogenic reduction, most likely in Creede caldera moat sediments, prior to recharge into the hydrothermal system. Depending on the depth of recharge, the sulfate was variably reduced to sulfide and equilibrated with wallrocks. The $\delta^{34}S$ values of main-stage sulfides, however, show a narrow range (-3.4 to 1.7‰ for sphalerite), indicating isotopic buffering of aqueous sulfide by contributions from or exchange with a large sulfide reservoir at depth. The occurrence of sulfur isotope redox disequilibrium in the system can be used to constrain residence times and possible flow paths of the fluids from southern recharge areas. Fine-scale $\delta^{34}S$ variations in main stage sphalerites indicate that minor amounts of $^{34}S$-depleted sulfide from buried Bachelor caldera moat sediments to the north were also added to the system. After the collapse of the main stage system, moat sediment sulfur dominated the sulfur isotope geochemistry of the system, producing extreme $\delta^{34}S$ variations (-44 to +48‰) in late stage sulfides. (Authors' abstract)

RYERSON, F.J., DURHAM, W.B., CHERNIAK, D. and LANFORD, W.A., 1987, Oxygen diffusion in olivine (abst.): EOS, v. 68, p. 417. First author at UCLLNL, Livermore, CA 94550.

Oxygen diffusion in olivine very likely influences or controls the creep properties of that mineral. In general, the creep rate of a material can be written $\varepsilon = A(kT)^{-1}f(\sigma)D$, where A is a constant that includes all relevant parameters of the material itself (e.g., grain size, atomic volume, dislocation density), k is Boltzmann's constant, T is temperature, $\sigma$ is the nonhydrostatic component of the stress tensor, and D is the diffusion coefficient of the slowest diffusing species in the material. The effect of T and pressure, P, on creep is expressed primarily through their effect on D, which can be written $D = D_0\exp(-(Q+PV)/RT)$, where $D_0$, Q, and V are material constants called the diffusion constant, activation energy, and activation volume, respectively. In the case of olivine, the presence of a component with multiple valence states (Fe) means that $D_0$ is sensitive to component activities $a_i$ (in particular, oxygen partial pressure) in the material.

We have made measurements of oxygen diffusion in olivine ($Fo_{92}$) at 1200°C and 1300°C along the Ni/NiO buffer. Silicon activity was buffered by the presence of orthopyroxene. Results to date yield diffusivities comparable to those previously obtained for forsterite in the same temperature range, and 7 orders of magnitude lower than that for chemical grain-boundary diffusion of oxygen in dunite. The apparent activation energy, approximately 600 kJ/mole, is also similar to that for forsterite, but is twice that for grain boundary diffusion. (Authors' abstract)

SABOURAUD, C., 1986, Solid and fluid inclusions in an evaporite mineral, gypsum: Les séries à évaporites en exploration pétrolière. Tome I: Méthodes géologiques. Chambre Syndicale de la Recherche et de la Productiondu Pétrole et du Gaz Naturel, Comité des Techniciens et GRECO 52 (CNRS). Editions Technip, Paris, 1986, p. 135-145 (in French). Authur at Cité des Sci. et de l'Industrie de la Villette, 211, Avenue Jean Jaurès, 75019 Paris, France.

Evaporitic gypsum may contain detrital minerals, tests, gypsum nuclei and organic matter as solid inclusions, these yielding information about depositional environments. Th values of P brine inclusions may give climatic data, but such inclusions commonly do not nucleate bubbles by 20°C if formed at T <60°C. Tm (ice) measurements indicate crystallization of gypsum from brines ranging between pure water and >20 eq wt % NaCl, in some cases implying mixing of marine and non-marine waters. In combination with salinity data, neutron activation determinations of Cl/Br may further constrain the origins and evolution of included brines. (Abstract by C.J. Eastoe)

ST SEYMOUR, K. and VLASSOPOULOS, D., 1987, Explosive volcanic activity associated with dome growth, Nisyros, Aegean volcanic arc, Greece (abst.): Int'l. Union of Geodesy & Geophys., XIX Gen. Assembly, Vancouver, Canada; Aug. 9-22, 1987; Abstracts, v. 2, p. 425. First author at Dept. Geol., Concordia Univ., Montreal, Que., H4B 1R6, Canada.

Volatile content of magma appears to be the most reliable indicator of explosive potential in volcanoes with $H_2O$-rich magmas, whereas the degree of crystallinity and composition of the interstitial glass seem to be the key controls of explosivity of $H_2O$-poor magmas. This hypothesis advanced by Newall and Melson (1982), for explosions associated with world-wide examples of historic dome growth, is tested in the Quaternary volcano of Nisyros. This test is designed to elucidate the nature of the most important controlling parameter which resulted in the eruption preceding caldera formation, as well as for monitoring future explosive hazards on this inhabited volcanic island. Recent geophysical evidence indicates the presence of an active magma chamber beneath Nisyros. The simplified volcanic stratigraphy begins with a base of basaltic andesite overlain by progressively more felsic units. The two latest pre-caldera manifestations are associated with two partially preserved centers. In the first, dome growth was exogenous resulting highly porphyritic rhyodacitic flows. At the second center, however, dome growth was highly explosive and resulted in thick rhyodacitic to dacitic pumice air-falls which were followed by caldera collapse. Post-caldera activity is expressed by the intrusion of huge dacite domes that presently occupy almost 70% of the caldera floor. Post-caldera dome growth is accomplished by exogenous growth (lava flows), explosions (block flows), and passive intrusion along caldera fractures. Monitoring explosivity controlling parameters associated with dome growth in Nisyros involves determination of chemical composition (including total volatile content) of matrix glass and melt inclusions in phenocrysts as well as estimation of magma temperatures. Preliminary data from the late pre-caldera porphyritic flows and pumice air-falls indicate that the explosively emplaced air-fall deposits contain less fractionated matrix glass and higher volatile content in melt inclusions than the passively extruded dome lavas. This suggests volatile content to have been the dominant control on pre-cladera explosivity of the Nisyros volcano, and therefore a hydrous magma parentage. (Authors' abstract)

SALUJA, P.P.S and LeBLANC, J.C., 1987, Apparent molar heat capacities and volumes of aqueous solutions of $MgCl_2$, $CaCl_2$, and $SrCl_2$ at elevated temperatures: J. Chem. Eng. Data, v. 32, p. 72-76. Authors at Research Chem. Br., Atomic Energy of Canada Ltd., Whiteshell Nuclear Res. Establ., Pinawa, Manitoba, Canada ROE 1L0.

SAMSON, I.M., 1987, Fluid inclusions in the Mount Pleasant W-Mo-Sn deposit, New Brunswick, Canada (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Author at Dept. Geol, Univ. Windsor, Windsor, Ontario, Canada N9B 3P4.

The Mount Pleasant deposit is hosted by a Lower Carboniferous multiphase, sub-volcanic, granitic stock; intruded at the margin of the Mount Pleasant caldera. There are three types of mineralization at Mount Pleasant:

I. Early porphyry-style W-Mo mineralization is principally hosted by a greisenized (qz-tz-fl) breccia pipe which overlies a fine-grained granite stock. Greisenization was preceded by biotitic and propylitic alteration.

II. Sn-bearing polymetallic veins and replacement zones (chl-fl alteration), which post-date the W-Mo zones, are associated with the intrusion of a granite porphyry.

III. Endogranitic, greisen-hosted Sn mineralization, which post-dates and underlies the W-Mo zones, is associated with a porphyritic granite, which grades upwards into the granite porphyry.

Fluid inclusion type may be subdivided as follows: A. Liquid-vapor-solid inclusions with high L/V ratios and one to seven dms (halite, calcite, hematite, + unidentified solids). These are common in mineralization types I and III, but absent from type II. In most cases, they homogenize by solid disappearance (Th = 200-500°C; SAL = 30-60 equiv. wt. % NaCl); B. Liquid-vapor inclusions. These are ubiquitous in the deposit and are the only type present in stage II mineralization (Th = 100-350°C; SAL = 0-10 equiv. wt. % NaCl); and C. Vapor-liquid inclusions. As with type A inclusions, they are common in stages I and III, but absent from type II.

It is clear that two distinct hydrothermal regimes operated during the life of this deposit. The first was an orthomagmatic system that was responsible for the W-Mo mineralization and associated greisenization. The most plausable model for the data collected to date is that a high salinity, chemically complex liquid was exsolved from the fine-grained granite (type A inclusions) and that periodic drops in P, associated with brecciation, allowed the generation of low density vapors. The scarcity of inclusions that homogenize by liquid disappearance is a problem that has yet to be satisfactorily resolved. Subsequent to the waning of this system, the Sn-bearing polymetallic zones were deposited from a low salinity fluid (meteoric?), related to the intrusion of the granite porphyry. Exsolution of orthomagmatic fluids from the porphyritic granite at depth resulted in the formation of the endogranitic Sn-zones. The absence of type A inclusions from type II mineralization suggests that the two forms of Sn mineralization are not genetically related. (Author's abstract)

[Ed. note: Since publication of the abstract, the author has revised the last paragraph, following the words "(type A inclusions)," as follows: Subsequent to the waning of this system, the Sn-bearing polymetallic zones were deposited from a low salinity fluid (meteoric?), related to the intrusion of the granite porphyry. Exsolution of orthomagmatic fluids from the porphyritic granite at depth resulted in the formation of the endogranitic Sn-zones. The vapor-rich inclusions present in mineralization types I and

III are probably part of the late orthomagmatic system. The absence of type A inclusions from type II mineralization suggests that the two types of Sn mineralization are not genetically related."]

SAMSON, I.M. and RUSSELL, M.J., 1987, Genesis of the Silvermines zinc-lead-barite deposit, Ireland: Fluid inclusion and stable isotope evidence: Econ. Geol., v. 82, p. 371-394. First author at Dept. Geol., Univ. Windsor, 401 Sunset Ave., Windsor, Ontario, Canada N9B 3P4.

The Silvermines zinc-lead-barite deposit occurs adjacent to a major normal fault system within a sequence of Mississippian sediments.

Fluid inclusions within the epigenetic minerals are dominated by a simple liquid-vapor type which in places contains one to five solid phases, the commonest of which is calcite. Single-phase liquid inclusions are commonest in barite; single-phase vapor and vapor-liquid inclusions are occasionally found in quartz, barite, and carbonates, although there is no indication of extensive boiling.

Fluid inclusion salinities range from 8 to 28 eq. wt % NaCl with modes at 14 and 19 wt %. Leachate studies show the fluids to have high Na concentrations with lesser, variable amounts of K and Ca and uniformly low Mg concentrations (K/Na = 0.03-0.23; Ca/Na = 003-0.28; Mg/Ca = 0.1-0.67). Fluid inclusions within synsedimentary-syndiagenetic barite are highly saline, indicating the possible presence of a brine pool at the site of ore deposition.

Th range from 50° to 260°C, with most between 140° and 220°C. There is a mode at 190°C and a subsidiary group at 140°C. Required P corrections are less than 5°C. If the P within the epigenetic ore zones was purely hydrostatic, as is reasonable, a minimum seawater depth of ~80 m is required to prevent boiling of some fluids.

For the whole deposit there is a negative correlation between Th and salinity for quartz-hosted inclusions, which is interpreted as the involvement of two (or possibly three) fluids in the mineralizing process. We suggest that high-T, 8 to 12 eq. wt % NaCl fluids mixed with lower T, 18 to 22 eq. wt % NaCl fluids, both within and below the ore zone during mineralization.

Fluid inclusion waters have $\delta D$ values of -24 to -49 per mil for quartz, -23 to -29 per mil for dolomite, -41 to -55 per mil for barite, -46 per mil for sphalerite, and -58 per mil for galena. The $\delta^{18}O$ values of the mineralizing fluids, calculated from mineral values, range from 1.1 to 7.7 per mil for quartz and 1.8 to 5.7 per mil for dolomite. These data best represent aqueous fluids that have equilibrated with the geosynclinal sequence and granites underlying the deposit. They also suggest that local Carboniferous surface and ground waters may have contained a deuterium-depleted (meteoric?) component.

The fluid inclusion evidence presented refutes a model involving the expulsion of Carboniferous formation waters and indicates little, if any, involvement of magmatic waters. The geologic, geochemical, and fluid inclusion evidence best fits a model involving the convection of Carboniferous surface waters in the putative thick geosynclinal sequence and associated granitoids below the deposit, with a contribution from lower Paleozoic formation waters.

Mineral precipitation resulted from fluid mixing in the ore zone with some contribution from carbonate wall-rock reactions and possibly boiling. (Authors' abstract)

SANDER, M.V. and BLACK, J.E., 1987, 'Pseudoprimary' fluid inclusions in growth-zoned quartz from epithermal systems - artifacts of recrystallization from chalcedony (abst.): Geol. Soc. Am. Abstracts with Programs, v.

19, p. 828. Authors at Sch. Earth Sci., Stanford Univ., Stanford, CA 94305.

One criterion commonly used for recognizing the primary origin of fluid inclusions is their occurrence within a single growth zone of the host crystal (e.g., Roedder, 167, 1979, 1984). Petrographic evidence (including anomalous extinction patterns and distinctive inclusion morphology) from inclusion-rich zones in coarse-grained quartz from some epithermal deposits suggests that at least some such zones were deposited originally as chalcedony or amorphous silica. Fluid inclusions contained within the zones were either created or drastically modified by postdepositional recrystallization of the original host to quartz. We prefer to call such inclusions 'pseudoprimary' to stress that the zones in which they are trapped reflect primary depositional processes but that the inclusions themselves are, at least in part, the product of recrystallization.

Reinterpretation of textures widely reported in the literature suggests that precursor chalcedony recrystallized to coarse-grained quartz may be common in the epithermal environment (e.g., at Rawhide and Round Mountain, Nevada; Gold Road and Kingman, Arizona; Finlandia, Peru; and Talisman, New Zealand). A diagnosis of precursor chalcedony may imply conditions of primary silica deposition markedly different from those inferred by study of the associated pseudoprimary inclusions. The inclusions cannot reflect conditions of priamry silica deposition because necessary assumptions about closed-system behavior after deposition are not fulfilled and microthermometric data derived from them will be misleading. (Authors' abstract)

SANO, Yuji, WAKITA, Hiroshi, OHSUMI, Takashi and KUSAKABE, Minoru, 1987, Helium isotope evidence for magmatic gases in Lake Nyos, Cameroon: Geophys. Res. Letters, v. 14, no. 10, p. 1039-1041. First author at Lab. Earthquake Chem., Faculty of Sci., Univ. Tokyo, Japan.

We have measured $^3He/^4He$ and $^4He/^{20}Ne$ ratios of gas samples collected at Lake Nyos where a toxic gas disaster occurred on August 21, 1986, and at Lake Monoun in Cameroon, East Africa. The $^3He/^4He$ ratios, corrected for air contamination, are 5.39-5.75 $R_{atm}$ (where $R_{atm}$ is the atmospheric ratio of $1.40 \times 10^{-6}$) for Lake Nyos and 3.56 $R_{atm}$ for Lake Monoun. The data suggest a significant contribution of mantle-derived helium in these Cameroon volcanic crater lakes. The origin of $CO_2$ gas "erupted" during Lake Nyos disaster is inferred to be of magmatic origin based on the high $^3He/^4He$ ratio. (Authors' abstract)

SANTOSH, M., 1986, Fluids in deep crustal metamorphism: Data from the Precambrian granulites of Kerala region: Indian Mineral., v. 27, p. 84-94 (in English). Author at Cent. Earth Sci. Stud., Trivandrum, 695 010 India.

See Santosh, 1986b, Fluid Inclusion Research, v. 19, p. 380, 1986, and Santosh 1984c and 1984d, Fluid Inclusion Research, v. 17, p. 295-296. (E.R.)

SANTOSH, M., 1987, Cordierite gneisses of southern Kerala, India: Petrology, fluid inclusions and implications for crustal uplift history: Contrib. Mineral. Petrol., v. 96, p. 343-356. Author at Center for Earth Sci. Studies, P.B. 2235, Sasthamangalam, Trivandrum 695 010, India.

The cordierite-bearing gneisses show mineral associations and reaction textures indicative of partial replacement of high-P assemblages by cordierite-bearing lower-P ones during an event of rapid decompression. T estimates from coexisting mineral phases show 710° to 791°; P estimates from mineral assemblages range from 5.4 to 7 kb. Detailed fluid inclusion studies in quartz associated with cordierite show high-density $CO_2$ (0.80-0.95 g/cm$^3$) as the dominant fluid phase, with traces of probable $CH_4$(?) in the sillimanite-bearing rocks. The isochore for the higher-density fluid inclusions defines a P of 5.5 kb. The fracture-bound $CO_2$ and $CO_2$-$H_2O$ (± $CH_4$?) inclusions indicate simultaneous entrapment at 400°C and 1.7 kb in the cordierite-hypersthene assemblage and 340°C and 1.2 kb in the cordierite-sillimanite assemblage. The P-T path delineated from combined solid and fluid data corresponds to the piezothermic array of the gneisses and is characterized by T-convex nature, indicative of rapid and virtually isothermal crustal uplift, probably aided by extensional tectonics. (From the author's abstract)

SASADA, Masakatsu, 1987a, Fluid inclusions in calcite scale from DY-1 drill hole, Hohi geothermal area, Japan: J. Geotherm. Res. Soc. Japan, v. 9, no. 3, p. 197-205 (in English). Author at Geotherm. Res. Dept., Geol. Survey Japan, Tsukuba, Ibaraki 305, Japan.

Many P liquid-rich inclusions are present along with a few V-rich inclusions in the calcite scale from DY-1 drill hole, Hohi geothermal area. They were studied microthermometrically, using a USGS type gas-flow heating/freezing stage. The data on Th show that the calcite scale precipitated from the two-phase boiling fluid at 165° to 167°C. The NaCl eq. salinity of the fluid is estimated to be 0.2 to 0.3 wt% from the data of melting point of ice (Tm ice) in the liquid-rich inclusions. The P($CO_2$) and pH of the fluid produced the calcite scale are calculated to be 0.2 atm and 6.4 respectively from the data of Th and chemistry of the fluid discharged. (Author's abstract)

SASADA, M., 1987b, Fluid inclusions from VC-2A core hole in Valles caldera, New Mexico, U.S.A.: Evidence for a transition from hot water-dominated system to vapor-dominated system (abst.): 1987 Ann. Mtg. of Geothermal Res. Soc. of Japan, Abstracts with Programs, p. 105.

Hydrothermal history of VC-2A is recorded in the fluid inclusions in hydrothermal and igneous minerals. Hydrothermal quartz and fluorite were precipitated from a boiling fluid in a hot water-dominated system (A). At least 400 m pile above the present land surface was presumably eroded, if the hydrothermal system was not overpressured. When the water table was at 30 m below the present land surface, the supply of hot water stopped, probably because of the hydrothermal mineral precipitation sealing the main conduit. Presently there is a vapor zone above 240 m depth, although it is not a "true" vapor-dominated system (Goff et al., EOS, 1987). But the hot water has been flowing up to 165-169 m depth (B) after the sealing of the main conduit. The cooling range is about 30-50°C, based on the Th of calcite whose minimum Th fits the present bore hole T. (Author's abstract)

SAUNDERS, J.A. and MAY, E.R., 1986, Bessie G: A high-grade epithermal gold telluride deposit, La Plata County, Colorado, U.S.A.: Proc. of Gold '86 Symp., Toronto, 1986, p. 436-444. First author at Dept. Geol. & Geol. Engrg, Univ. Mississippi, University, MS 38677, USA.

Fluid inclusion data indicate that the tellurides precipitated at ~170°C and moderate P from hydrothermal solutions containing $CO_2$. Thermochemical modelling of the conditions of formation for ore, gangue, and alteration minerals suggest that the mineralizing solutions were relatively oxidizing and near neutral pH. In addition, thermochemical data for gold bisulphide and chloride complexes suggest that neither were of major importance in the transport of gold in this system. Instead, complexes such as ($AuTe_2$) are postulated to have been important. (From the authors' abstract)

SAVAGE, David, CAVE, M.R., MILODOWSKI, A.E. and GEORGE, Ian, 1987, Hydrothermal alteration of granite by meteoric fluid: An example from the

Carnmenellis Granite, United Kingdom: Contrib. Mineral. Petrol., v. 96, p. 391-405. Authors at Fluid Processes Res. Group, British Geol. Survey, Keyworth, Notts NG12 5GG, UK.

The interaction of granitic rock with meteoric fluid is instrumental in determining the chemistry of pore fluids and alteration mineralogy in downflow portions of convective groundwater circulation cells associated with many hydrothermal systems in the continental crust. Hydrothermal experiments and a detailed mineralogical study have been carried out to investigate the hydrothermal alteration of the Carnmenellis Granite, Cornwall, UK. Samples of drill chippings from a borehole 2 km deep in the Carnmenellis Granite have been reacted with a dilute Na-HCO$_3$-Cl fluid in hydrothermal solution equipment at temperatures of 80°, 150° and 250°C and a pressure of 50 MPa, with a water/rock mass ratio of 10, for experiment durations up to 200 days. Fluid samples were analyzed for seventeen different chemical components, and solids were examined prior to, and after reaction using SEM, electron microprobe and conventional light optic techniques. Experimental fluids were mildly alkaline (pH 7-8.5) and of low salinity (TDS <800 mgl$^{-1}$). Mineral-fluid reaction was dominated by the dissolution of plagioclase and the growth of smectite, calcite (at all temperatures), laumontite (at 150°C), wairakite and anhydrite (at 250°C). Final fluids were saturated with respect to quartz and fluorite. Certain trace elements (Li, B, Sr) were either incorporated into solids precipitated during the experiments or sorbed onto mineral surfaces and cannot be considered as 'conservative' (partitioned into the fluid phase) elements. Concentrations of all analyzed chemical components showed net increases during the experiments except for Ca (at 250°C) and Mg (at all temperatures). A comparison of the alteration mineralogy observed in the experiments with that present as natural fracture infills in drill core from the Carnmenellis Granite reveals that the solid products from the experiments correspond closely to mineral assemblages identified as occurring during the later stages of hydrothermal circulation associated with the emplacement of the granite. (Authors' abstract)

SAXENA, S.K., 1987, Methane in the mantle (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 830. Author at Brooklyn College, Brooklyn, NY 11210

SAXENA, S.K. and FEI, Y., 1987a High pressure and high temperature fluid fugacities: Geochimica Cosmo. Acta, v. 51, p. 783-791.

SAXENA, S.K. and FEI, Y., 1987b Fluids at crustal pressures and temperatures: I. Pure species: Contrib. Mineral. Petrol., v.95, p. 370-375.

SCHANDL, E.S., SPOONER, E.T.C. and WICKS, F.J., 1987, Carbonate alteration of ultramafic rocks in the Timmins area, Ontario (abst.): GAC-MAC, AGC-AMC Joint Ann. Mtg., Program with Absts., v. 12, p. 86. (See also p. 87) Authors at Dept. Geol., Univ. Toronto, Toronto, Ontario M5S 1A1.

Carbonate altered ultramafic rocks were studied from three locations in the Timmins area; Kidd Creek mine, Kidd Tp., Slade-Forbes asbestos mine, Deloro Tp. and Munro Mine asbestos, Munro Tp., to determine the composition and temperature of the metasomatizing fluid and to fit the events of carbonate alteration into the metamorphic history of the Abitibi greenstone belt. CO$_2$ metasomatism altered the previously serpentinized ultramafic rocks to talc-carbonate and to quartz-carbonate assemblages. Fuchsite and Cr-rich chlorite are accessory minerals in the quartz-carbonate rocks. The composition of carbonates determined by electron microprobe lie in the range of magnesite, dolomite, ferroan dolomite and calcite fields. Petrographic observations and cathode luminescence indicate at least two CO$_2$ metasomatic events. First generation of magnesite is often rimmed by dolomite or calcite, and secondary veins are composed of dolomite. Primary fluid inclusions in carbonates from the quartz-carbonate rocks are predominantly aqueous with 2-7 mole % $CO_2$; m.p. -56.3 ± 0.4°C (1σ), and salinity ranges from 0.8 to 3.0 wt.% NaCl. The homogenization T is 245 ± 4°C (1σ). Primary inclusions in carbonates from the talc-carbonate rocks are predominantly aqueous. Salinity ranges from 2 to 6 wt.% NaCl, and homogenization T was determined at 216 ± 13°C (1σ). The higher $CO_2$ content of the fluid in the quartz-carbonate rocks, and field observations suggest that this assemblage may represent the site of the conduits. The talc-carbonates form larger bodies and are more wide-spread. The first stage of $CO_2$ metasomatism was followed by K-metasomatism and chloritization. These metasomatic events were followed by deformation on a local scale, giving rise to cataclastic textures in some rocks. A second event of $CO_2$ metasomatism formed rims and veins of dolomite. Salinities in the fluid inclusions range from 4 wt.% NaCl to significantly higher, 25 wt.% $CaCl_2$. The homogenization temperature is relatively low at 155 ± 5°C (1σ). (Authors' abstract)

SCHELLEN, A.D. and DUBESSY, J., 1987, Fluid pressure, fluid chemistry, $fO_2$ and $fS_2$ derived from fluid inclusion studies (microthermometry and micro-Raman spectrometry) of the scheelite deposit of Salau (Pyrenees, France) (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 113-114. First author at Univ. Louvain, 3, place Pasteur, 1348 Louvain la Neuve, Belgium.

Salau is known as a skarn deposit, developed at the expense of carbonaceous Paleozoic rocks, close to a granodiorite intrusion. The greater part of the extracted W comes from the scheelite accompanying hydrothermal sulfide development. The quartz and the scheelite of that ore contain P inclusions (~15 µm). At room T, fluid inclusions are filled by an aqueous phase and a $CO_2$-$CH_4$ bearing liquid. The inclusions in quartz show Tm $CO_2$ between -72.0°C and -56.6°C; Th $CO_2$-$CH_4$ rich part (to liquid) between -82.0°C and +20.0°C; Tm clathrate occurs above Th $CO_2$-$CH_4$; a few Th total values occur between 280°C and 360°C but most inclusions decrepitate ~210°C, indicating high fluid density. Natural leakage is observed in scheelite.

Raman spectrometry has been used to specify the amount of $CO_2$, $CH_4$, $N_2$ and $H_2S$ in the non-aqueous phase. Depending on the phase equilibria and their T, the density of the carbonaceous part has been calculated from the works of Heyen et al. (1981), Herskowitz and Kisch (1984) and Swanenberg (1979). Between 350°C and 450°C, the fluid pressure calculated from the equation of state of Jacobs and Kerrick, D.M. (1981) ranges between 2.7 and 4.3 kbar.

$fO_2$ is calculated from the equilibrium $CH_4 + 2O_2 \rightleftarrows CO_2 + 2H_2O$ (Dubessy, 1984; Ramboz et al., 1984). A $fS_2$-T relation is derived from the equilibrium $H_2S + 1/2O_2 \rightleftarrows H_2O + 1/2S_2$ along the fluid inclusions isochores. On the other hand, X-ray diffraction data on pyrrhotite allows us to define a second $fS_2$-T relation (Barton and Skinner, 1977). As pyrrhotite and quartz inclusions are contemporaneous, they must have been formed at the same P-T-$fS_2$ conditions. So, the intersection of the two $fS_2$-T relations composition gives an estimation of fluid Tt. The limitation of this geothermometer is discussed as a function of fluid P and accuracy on fluid inclusion chemistry. T is found ~400°C, P ~3 kbar, log $fO_2$ ~-28.0 and log $fS_2$ ~-8.0 in the stability field of pyrrhotite. The fluid P of 3 kbar brings a new light on the regional geology of the Salau district. (Authors' abstract) (7 refernces given in original. E.R.)

SCHENKER, Franz and DIETRICH, V.J., 1986, The Lake Nyos gas catastrophe (Cameroon). A magmatological interpretation: Schweiz. Mineral. Petrogr.

Mitt., v. 66, p. 343-384.

SCHIFFMAN, P., SMITH, B.M., VARGA, R.J. and MOORES, E.M., 1987, Geometry, conditions and timing of off-axis hydrothermal metamorphism and ore-deposition in the Solea Graben: Nature, v. 325, no. 6103, p. 423-425.

SCHIFFRIES, C.M. and SKINNER, B.J., 1987, The Bushveld hydrothermal system: Field and petrologic evidence: Am. J. Sci., v. 287, p. 566-595. First author at Dept. Earth & Planet. Sci., Harvard Univ., Cambridge, MA 02138.

A systematic search for evidence of fluid-rock interactions in the Bushveld Complex has resulted in the recognition of extensive networks of hydrothermal veins that crosscut the intrusion. The veins were produced by fracture-controlled flow of aqueous fluids during the subsolidus cooling history of the intrusion. Hydrothermal veins occur in each of the major stratigraphic units that comprise the Bushveld Complex. We have observed veins across a stratigraphic thickness of 9 km and along a strike length of at least 100 km. The Bushveld hydrothermal system has affected tens of thousands of cubic kilometers of rock, and it is probably among the largest paleo-hydrothermal systems in the world.

Petrologic studies of the veins indicate that fluid-rock interactions occurred over a wide range of physical and chemical conditions, producing a wide variety of hydrothermal veins. The mineral assemblages in the veins are similar to those found in mafic igneous rocks that were subjected to metamorphism under conditions ranging from upper amphibolite facies to zeolite facies. Many veins that formed at intermediate or high temperatures contain hydrothermal pyroxene that is texturally and chemically distinct from its magmatic counterpart. Hydrothermal clinopyroxene, where present, is enriched in Ca but depleted in non-quadrilateral components relative to magmatic clinopyroxene. The occurrence of hydrous minerals with high concentrations of chlorine (up to 5 wt percent in amphibole) and the presence of fluid inclusions with a halite daughter crystal indicate that many of the fluids that interacted with the Bushveld Complex were chloride-rich brines. Fluids of this type are effective agents for mass transfer, and this raises the possibility that mineralogical, chemical, and isotopic features of the Bushveld Complex may not be due solely to primary magmatic processes but may instead have been influenced by the effects of hydrothermal processes. (Authors' abstract)

SCHIØTTE, Lasse, 1987, Redistribution of U and Pb by fluids suggested as a cause for a Pb-Pb pseudo-isochron obtained on old-Archaean orthogneiss (abst.): Abstracts, NATO Advanced Research Workshop, Fluid movements, element transport, and the composition of the deep crust, Lindås, Norway, 18-24 May, 1987 (unpaginated).

SCHLIESTEDT, Manfred and MATTHEWS, Alan, 1987, Cation and oxygen isotope exchange between plagioclase and aqueous chloride solution: N. Jb. Miner. Mh., v. 6, p. 241-248.

SCHMASSMANN, Hansjörg, 1987, New understanding of the nature of deep groundwaters from northern Switzerland: Eclogae Geol. Helv., v. 80, no. 2, p. 569-578 (in German; English abstract). Author at Geol. Buro, Langhagstr. 7, CH-4410 Liestal.

Since 1981, Nagra has conducted extensive regional studies into the hydrophysical and hydrochemical properties of deep groundwaters from northern Switzerland and adjacent areas. The understanding of the groundwaters in the Triassic and Permian aquifers as well as in crystalline basement has been considerably enhanced by the deep drilling program of Nagra. This paper presents selected results of the investigations and discusses them with respect to deep groundwater flow systems in northern Switzerland.

The composition of dissolved gases present in the groundwaters is very characteristic for each of the different aquifers. Oxygen is almost invariably absent and N is often the dominant gas. High N-Ar ratios, as typical of the Permian and Lower Triassic aquifers, indicate that a part of the N is released from organic compounds. In the vicinity of the Rhine graben, ascending $CO_2$ results in a high concentration of this gas in the deep groundwaters of the crystalline basement. Radiogenic-produced He is enriched in these waters due to the long subsurface retention times. South of the Jura moutnains, high concentrations of $H_2S$ in waters of the Upper Muschelkalk aquifer are related to the occurrence of hydrocarbons. (From the author's abstract)

SCHMETZER, K., 1987, Microscopic observation of twinning microstructure in natural amethyst: Neues Jahrb. Mineral., Monatsh., 1987, no. 1, p. 8-15 (in English).

SCHMETZER, K. and BANK, H., 1987, Synthetic Lechleitner ruby with natural seeds and synthetic overgrowths: Z. Dt. Gemmol. Ges., v. 36, no. 1/2, p. 1-10 (in German; English abstract).

Presents color plates that show the distinguishing liquid and solid inclusions. (H.E.B.)

SCHMIDT-MUMM, A., 1987a Decrepitometry as a tool for studies of fluid inclusions (abst.): Fortschritte der Mineralogie, Bd. 65, Bhf. 1, p. 170 (in German). Author at Inst. Geol. & Dynamics of Lithosphere, Univ. Göttingen, FRG.

The statistical study of a specimen by microthermometry is very time-consuming. Through decrepitometry one may obtain the statistical distribution of the fluid inclusion generations depending on the temperature. Td may be measured in laboratory or under field condition e.g., with the high-resolution decrepitometer developed in the Institute of Geology and Dynamics of Lithosphere of the Göttingen University. The obtained peaks are linked with various P, PS and S generations of inclusions. Due to the large number of parameters influencing Td (e.g., size of inclusions, distance from the grain surface, density and composition of filling, rate of heating), the interpretation of such decrepitograms is reasonable only in connection with microthermometric measurements. The application of decrepitometry in a research project for distinguishing of various fluid inclusion system activities during orogenesis (Schmidt-Mumm et al., 1986, Geol. Sur. S.W. Africa/Namibia, v. 2, in press) indicated that individual fluids flowing in a limited space may vary very strongly. Also zones of alteration in wall rocks can be recognized by decrepitometry, which is important especially for ore prospecting (Roedder, 1977, Fluid Inclusion Research, v. 10, p. 236). (Author's abstract, translated by A.K.)

SCHMIDT-MUMM, A., 1987b, Sedimentary and tectonic brines in the Damara Orogen (abst.): Terra cognita, v. 7, no. 2-3, p. 282.

See next item. (E.R.)

SCHMIDT-MUMM, A. and BEHR, J.-J., 1987, Fluid inclusion studies on hydrothermal mineralization associated with the Duruchaus formation: Genetic aspects of large quartz-dolomite bodies and associated alteration: Communs. Geol. Surv. S.W. Africa/Namibia, v. 3, p. 111-117.

See next two items. (E.R.)

SCHMIDT-MUMM, A.W., BEHR, H.-J. and HORN, E.E., 1987a, Interaction of fluid systems at the front of progressive orogenesis in the Damara Orogen, Namibia (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 115-116. Authors at Inst. Geol. & Dynamik der Lithosphäre, Goldschmidtstr. 3, D-3400 Göttingen.

Three methods were applied to determine the characteristics of the fluid inclusions. Decrepitometry was used in the field and laboratory to distinguish the significance of different fluid generations, microthermometry gave information on physicochemical features of fluid generations present. Single phases of inclusions were analyzed by Raman spectroscopy to obtain detailed information on fluid composition. (From the authors' abstract; see also next item.)

SCHMIDT-MUMM, A., BEHR, H.-J. and HORN, E.E., 1987b Fluid systems in metaplaya sequences in the Damara Orogen (Namibia): Evidence for sulfur-rich brines - general evolution and first results: Chem. Geol., v. 61, p. 135-145. Authors at Inst. Geol. & Dynamik der Lithosp., Univ. Göttingen, D-3400 Göttingen, FRG.

In the Upper Proterozoic rift sediments of the Damara Orogen (Namibia) up to 1000-m thick metaplaya sequences of partly evaporitic origin occur. The playa evaporites include thick layers of scapolite, albite pseudomorphs after Na-carbonates, K-spar pseudomorphs after Ca-sulfate, and other mineralogical and structural features of playa environments.

During metamorphism, large quantities of highly saline fluids were mobilized, which were of major importance for the structual development and the mineralization of Cu, T, U and Au in this region. Within this sequence stratiform tourmalinites of several meters thickness occur, which can be traced over several tens of kilometers. The sedimentary origin of these tourmalinites is substantiated by well-preserved fine-laminated primary bedding features, which indicate a hot-spring activity during the time of deposition. Correlation of F/Cl and FeO/(MgO + FeO) ratios with tourmalines from various strata-bound massive sulfide deposits also indicates a sedimentary origin of the tourmalinites.

The meta-evaporite sequence also contains megaquartz bodies some of which are built of single crystals up to 50 m in size, intergrown with large crystals of dolomite (Ø 1 m). In one locality this quartz-dolomite mineralization shows a high content of native sulfur. Thermometric measurements, verified by Raman probing indicated native sulfur as a dm and dissolved $HS^-$ is suspected to be present in the fluid inclusions in this quartz.

Further microthermometric measurements on fluid inclusions in the tourmalinites, the sulfurous quartz and several other related quartz-dolomite mineralizations (Duruchaus, Tsumeb) confirm the hitherto existing results and strongly suggest a derivation of the mineralizing fluids from the metaplaya sequence. The detailed analyses of fluid inclusions and their various dms within the inclusions allow the estimation of the chemical composition of the mineralizing fluids. (Authors' abstract)

SCHOONEN, M.A.A. and BARNES, H.L., 1987, An approximation of the second dissociation constant for $H_2S$: Geochimica Cosmo. Acta, v. 52, p. 649-654.

SCHULIEN, S., 1987, High-temperature/high-pressure solubility measurements in the systems $BaSO_4$-NaCl-$H_2O$ and $SrSO_4$-NaCl-$H_2O$ in connection with scale studies: 1987 Int'l. Symp. on Oilfield Chem., Proc. [Soc. Petroleum Engineers], p. 233-246.

SCHWAB, R.G. and FREISLEBEN, Brigitte, 1987, Fluid $CO_2$-inclusions in olivine and pyroxenes and their behavior under high P-T conditions (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 117. Authors at Inst. Geol. & Mineral. der Univ.

Erlangen-Nürnberg, Schlostrgarten 5, 852 Erlangen, Germany.

A harzburgitic nodule from Hirzstein (northern Hessia, Germany), rich in fluid $CO_2$-inclusions, was chosen to study their behavior under high P-T conditions. The olivines and pyroxenes (opx and cpx) of this mantle xenolite are scattered with $CO_2$-inclusions of different size (<10-50 μ) and morphology, ranging from round, oval, cylindrical to negative crystal forms. Following Murck's (1976) classification, all groups and types except C are present. A melting point of -56.6 ± 0.6°C indicates a fairly pure $CO_2$-content. The densities of the P inclusions range from 1.00-1.08 $g/cm^3$ in olivine to 1.11-1.17 $g/cm^3$ in pyroxenes. Cylinders 4.5 mm high and 4 mm in diameter were taken from the compact nodule with a small diamond drill and equilibrated up to 43 h under high T and P (1000-1400°C/30-100 kb). Besides slight shrinking no reactions could be noted below 50 kb; at this P formation of carbonate could be observed in the cavities of olivine and at higher P (90 kb) in opx. At 90 kb the carbonate disappears in olivine but persists in opx even at 100 kb. Between 90 kb and 100 kb all bigger cavities are collapsed and the former walls are coated by a greyish substance; however even at these P small (<5 μ) roundish inclusions are still present: they are filled with a two-phase fluid without $CO_2$ but of still unknown composition. Several possibilities of fluid-crystal-reactions are discussed. (Authors' abstract)

SCRIVENER, R.C., SHEPHERD, T.J. and GARRIOCH, N., 1986, Ore genesis at Wheal Pendarves and South Crofty mine, Cornwall. A preliminary fluid inclusion study: Proc. Ussher Soc., v. 6, no. 3, p. 412-416 (in English). Authors at Br. Geol. Surv., Exeter/Devon, UK EX4 6BX.

Two types of mineral paragenesis exist at Wheal Pendarves and South Crofty mine (Cornwall, UK): (1) Sn-W ore mineralization associated with extensive tourmalinization and pegmatitization and (2) Sn-base metal sulfide localization associated with chlorite-fluorite gangue assemblages. Microthermometric data from fluid inclusions in quartz of these deposits are interpreted in relation to the mineral paragenesis in veins and wall rocks. The presence of an early high-salinity fluid of magmatic origin is recognized; there are some evidence of liquid immiscibility events in the subsequent development of the hydrothermal ore mineralization. The mixing of ore-forming fluids with $CaCl_2$ brines, at a relatively early stage, is recognized. (C.A. 108: 41260b)

SEAL, R.R., II, CLARK, A.H. and MORRISSY, C.J., 1987 Stockwork tungsten (scheelite)-Molybdenum mineralization, Lake George, southwestern New Brunswick: Econ. Geol., v. 82, p. 1259-1282. First author at Dept. Geol. Sci., Univ. Michigan, Ann Arbor, MI 48109.

The W-Mo deposit comprises three different scheelite-and/or molybdenite-bearing veinlet types. Type 1 bodies, the earliest formed, are calc-silicate (granditic garnet, wollastonite, clinopyroxene, and calcic amphibole) quartz veinlets, with ubiquitous Ca and H metasomatic alteration envelopes. Mineralogical and fluid inclusion relationships indicate that the fluids ranged from 550° to 228°C and that T decreased away from the cupola. The succeeding type 2 veinlets comprise quartz and lesser amounts of perthitic alkali feldspar, muscovite, calcite,scheelite, molybdenite, and pyrite. Fluid inclusion evidence shows that mineralization dominantly occurred form 400° to 175°C, under a confining P of 1.3 kb. Higher grade scheelite and molybdenite deposition was focused in a lower T zone, to the north of the cupola, in which $CO_2$ effervescence occurred. Type 3 veinlets, the last to form, consist of prehnite, molybdenite, and quartz and represent a volumetrically minor mineralization type.

In both type 1 and 2 systems, scheelite and molybdenite deposition appears to have been controlled by decreasing T and increasing pH. T was a function of distance from the cupola for both veinlet types, but the controls on pH were specific to each. Thus, the pH of type 1 fluids was controlled by wall-rock interaction (H metasomatism), whereas that of type 2 fluids was controlled by $CO_2$ effervescence. (From the authors' abstract)

SEAL, R.R., II and KELLY, W.C., 1987, Rare earth element variations in hydrothermal fluorites, Bayhorse district, Idaho (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 836-837. Authors at Dept. Geol. Sci., Univ. Michigan, Ann Arbor, MI 48109.

Rare earth element (REE) patterns, normalized to chondritic values, exhibit marked systematic variations within a single subtly growth-zoned vein fluorite sample (10 cm: core to rim) from the Bayhorse district of south-central Idaho. Middle REE-depleted patterns occur in the earliest-formed fluorite; relatively flat patterns occur in the intermediate stages of fluorite; and middle and heavy REE-enriched patterns in the latest stages. The REE pattern of the earliest fluorite closely mimics that of the host dolomite, indicating that this pattern was inherited from the wall-rocks. Patterns of later fluorite are distinctly different from those of the host rocks and those of other rock types in the area, suggesting that these patterns were controlled by the REE composition of the hydrothermal fluid. It is unlikely that these REE variations reflect T-dependent variations in the stability of REE-complexes or local fluid mixing because fluid inclusion studies indicate that T (135 ± 2°C) and salinity (0.5 ± 0.2 eq. wt. % NaCl) were nearly constant throughout fluorite deposition.

The fluid-dominated REE patterns of the youngest fluorites, though dissimilar to those of the exposed country rocks, are very similar to published low temperature experimental REE-complexing data. This suggests that the REE contents of the hydrothermal fluid were controlled by REE-complexing with ligands such as fluoride, carbonate or sulfate and/or selective leaching of mineral phases in the source region. (Authors' abstract)

SEIFERT, S., O'NEILL, H.S.C. and BREY, G., 1987, The partitioning of Fe, Ni and Co between olivine, metal, and basaltic liquid: An experimental and thermodynamic investigation, with application to the composition of the lunar core: Geochimica Cosmo. Acta, v. 52, p. 603-616.

SEITZ, J.C., PASTERIS, J.D. and WOPENKA, Brigitte, 1987, Characterization of $CO_2$-$CH_4$-$H_2O$ fluid inclusions by microthermometry and laser Raman microprobe spectroscopy: Inferences for clathrate and fluid equilibria: Geochimica Cosmo. Acta, v. 51, p. 1651-1664. Authors at Dept. Earth & Planet. Sci. & McDonnell Center for the Space Sci., Washington Univ., Box 1169, St. Louis, MO 63130, USA.

Microthermometry (MT) and laser Raman microprobe (LRM) spectroscopy (at room T and at about 0°C) were done on 33 synthetically produced $CO_2$-$CH_4$-$H_2O$ fluid inclusions in quartz (from R. Bodnar and M. Sterner). At room T, the inclusions consist of an aqueous liquid, a $CO_2$-$CH_4$ supercritical carbonic fluid, and (in most cases) graphite. In all these inclusions, the melting T for solid $CO_2$ is less than Th of the vapor bubble in the carbonic fluid.

A method is described whereby MT data for $CO_2$-$CH_4$-$H_2O$ inclusions can be projected within the $CO_2$-$CH_4$ binary phase diagram to infer $CO_2$:$CH_4$ ratios in the carbonic fluid (<2 to >35 mole% $CH_4$ in the inclusions under study). This method takes into account the formation of $CO_2$-$CH_4$ clathrate hydrate during MT analysis. Unless clathrate formation is properly considered, errors arise in the determination of the bulk $CO_2$-$CH_4$ ratio. For the inclusions in our study, these errors are on the order of 5 to 8 mole% $CH_4$. Our interpretation of the MT data indicates that $CH_4$ is preferentially partitioned into the clathrate over the coexisting carbonic fluid, in contradiction to the prediction from Parrish and Prausnitz's (1972) model for clathrate equilibria. Comparison of LRM analyses on the bulk carbonic fluid (in the absence of clathrate) and the residual carbonic fluid (in the presence of clathrate) confirm the preferential partitioning of $CH_4$ into the clathrate. LRM analyses of the clathrate itself indicate that $CH_4$ occupies both types of cage sites in the clathrate structure, whereas $CO_2$ may only occupy one site. Two by-products of the combined LRM and MT analyses of the same inclusions are derivation of empirical ratios of Raman quantification factors for high-density $CO_2$-$CH_4$ fluids and the ability to determine $CO_2$:$CH_4$ ratios of inclusions whose MT data lie near the critical region for $CO_2$-$CH_4$. Thus, the joint use of LRM and MT techniques provides information that could not be obtained by either technique alone. (Authors' abstract)

See also same authors, Amer. Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abst. (unpaginated).

SELBY, Mark and HIEFTJE, G.M., 1987, Inductively coupled plasma-mass spectrometry: A status report: Am. Laboratory, v. 19, no. 8, p. 16-28.

This review (45 references) compares ICP-MS with ICP-OES and ETAAS (inductively coupled plasma optical emission spectrometry and electrothermal atomic absorption spectrometry, respectively). As all three can be used for various metals in the range of 0.01 to 10 ppb on 20-μL samples, they are of interest in fluid inclusion analysis. (E.R.)

SHANKS, W.C., III and SEYFRIED, W.E., Jr., 1987, Stable isotope studies of vent fluids and chimney minerals, southern Juan de Fuca Ridge: Sodium metasomatism and seawater sulfate reduction: J. Geophys. Res., v. 92, no. B11, p. 11,387-11,399.

SHARMA, S.K. and URMOS, J.P., 1987, Micro-Raman spectroscopic studies of materials at ambient and high pressures with CW and pulsed lasers, in R.H. Geiss, ed., Microbeam Analysis - 1987: San Francisco Press, Inc., San Francisco, CA, p. 133-136.

SHARP, Z.D., ESSENA, E.J. and O'NEIL, J.R., 1987, The effect of fluids on oxygen diffusion rates in low quartz (abst.): EOS, v. 68, p. 422. First author at Dept. Geol., Univ. Michigan, Ann Arbor, MI 48109.

The diffusion rate of oxygen in low quartz is constrained by preserved quartz-magnetite fractionations in a granulite-grade iron formation. The iron formation, located in the N. Wind River Range, WY, reached peak metamorphic conditions of 1000 ± 50 K and 4.5 ± 0.5 kbar. The preservation of unaltered orthopyroxene requires either $CO_2$-rich fluid or fluid-absence during retrogression. Temperature estimates based on the oxygen isotopic fractionations among quartz (qz), magnetite (mt), orthopyroxene (opx) and garnet are 873 ± 40 K. The preserved qz-mt fractionations can be used to estimate a diffusion rate of oxygen in qz under water-absent conditions, as the preserved fractionations are related to the blocking temperature. Because other processes such as recrystallization and fluid flooding may enhance oxygen diffusion and reequilibration, the observed fractionations correspond to a maximum oxygen self-diffusion rate.

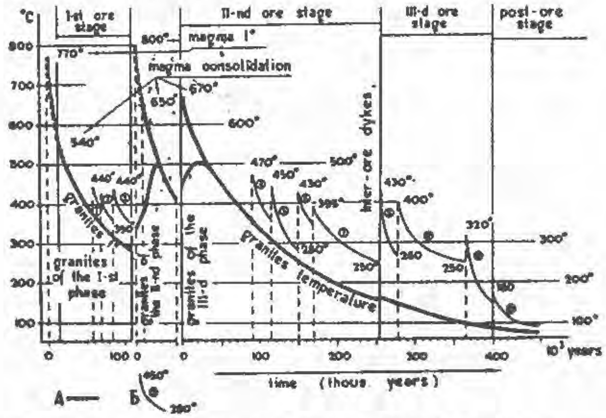
Diffusion rates may be calculated if the grain size, blocking temperature and regional cooling rate are known. The iron formation consists predominantly of qz, mt and opx. It is assumed that the blocking temperature of opx was the highest and the blocking temperature for mt was the lowest, due to its small grain size and susceptibility to recrystallization and exsolution. Under these conditions, the effect of oxygen intracrystalline diffusion on the preserved quartz-magnetite fractionations will be controlled by the diffusion rate of low quartz. Diffusion exchange experiments between water and low quartz have been made by various researchers, and constrain the diffusion coefficient ($D_T$), but not the activation energy, (Q). However, Q can be estimated by combining eq. (23) of Dodson (1973) with the general Arrhenius equation to generate an equation involving grain size (a), cooling rate, closing temperature ($T_C$), $D_T$ and Q. A minimum cooling rate of 790°C/Ma is reached when Q = 163 kJ/mol and $D_O = 1.5 \times 10^{-7} cm^2/sec$ for the conditions $T_C = 873$ K, $D_{833} = 2.5 \times 10^{-16} cm^2/sec$, and a = 0.1 cm. In order to preserve the 873 K closing temperatures for a cooling rate of 1-10°C/Ma, $D_{833}$ must be two orders of magnitude lower than the measured value. Even if magnetite blocked in before quartz, the calculated cooling rates are still an order of magnitude too high. This discrepancy may be due to water greatly enhancing the intacrystalline diffusion rate of oxygen in silicates and oxides. (Authors' abstract)

SHCHERBA, G.N., KORMUSHIN, V.A. and ISAYEVA, L.D., 1987, The formation duration of rare-metal ores with regard for microinclusion analysis (Karaoba, central Kazakhstan) (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 119-120. Authors at Inst. Geol. Sci., Acad. Sci. of Kazakh SSR, 480100 Alma-Ata, Kalinin St. 69-a, USSR.

The greisen-quartz deposit of Karaoba is associated with Permian leucocratic granites. The ore-bearing massif is laccolith of an oval form 12 x 6 km in size and over 2 km in thickness. Ore stockworks are interbedded within the granites of the massif protrusion and the enclosing sedimentary-igneous rocks (D + C).

The deposit was formed in the intrusive-above-intrusive zone at a depth of 2-2.4 km. The formation of greisens and quartz veins interbedded in them passed three stages associated with the subsequent phases of intrusion.

Intrusion [sic] homogenization within quartz of the first ore stage occurred at 440-350°C; of the second, the main one, at 470-250°C; of the third stage, the post-dike one, at 430-160°C (see figure). With the general T decrease of the ore deposition each ore generation started forming at a higher T than



The T regime and the duration of the Karaoba deposit formation

A - the character of granite T variation with time; B - the T variation of mineral generation formation: 1 - microcline-albite, 2 - K-feldspar-quartz, 3 - molybdenite-feldspar-quartz, 4 - microcline-albite, 5 - cassi-terite-quartz, 6 - molybdenite-quartz, 7 - wolframite-quartz, 8 feldspar-quartz, 9 - muscovite-quartz, 10 - sulphide quartz, 11 - post-ore.

the [end of the] previous one.

The density and the length of joint systems, the locality of subsiding phenomena in solidifying granites and their roof defined the boundaries of ore-bearing blocks which enclose partly or completely coincided greisens, veins and veinlets of the eleven mineral generations. The duration of the deposit formation was calculated by the heat loss of the ore-bearing block ranging from the T of granite solidification to that of greisen formation completion, as well as of veins and veinlets within each mineral generation with regard for the block volume, the thermal and physical properties of rocks (thermoconductivity, heat capacity, density and others), the depth of generation and the T of intrusion cooling. The consequent summation of the formation time of all ore-bearing bodies define the duration of the deposit ore formation which is assessed to be not less than 470 thousand years, from which 360 thousand years was taken by the formation of ore greisens, veins and veinlets. (Authors' abstract)

Note: This paper was not presented at the meeting. (E.R.)

SHELTON, K.L., TAYLOR, R.P. and SO, C.-S., 1987, Stable isotope studies of the Dae Hwa tungsten-molybdenum mine, Republic of Korea: Evidence of progressive meteoric water interaction in a tungsten-bearing hydrothermal system: Econ. Geol., v. 82, p. 471-481. First author at Dept. Geol., Univ. Missouri, Columbia, MO 65211.

The Dae Hwa W-Mo mine is in fissure-filling quartz veins in Precambrian granitic gneiss adjacent to a granitic stock of Cretaceous age.

The ore mineral paragenesis can be divided into three distinct stages: a molybdenite-wolframite stage (400°-315°C), an iron sulfide-scheelite stage (315°-230°C), and a late carbonate stage (230°-150°C). There is a nearly monotonic decrease in calculated $\delta^{18}O$ values of hydrothermal waters with decreasing T from ~6 per mil to -3.5 to -7.0 per mil. The H and O isotope compositions are consistent with progressive mixing of a magmatic or highly exchanged meteoric water (exchanged with granitic rocks over a series of T at variable, but low water-to-rock ratios) with an unexchanged meteoric water ($\delta D = -140‰$). Isotope analyses of sulfide vein minerals suggest an igneous source of sulfur with a $\delta^{34}S(\Sigma S)$ value near 3.0 per mil. The stable isotope composition of the tungsten-molybdenum-mineralizing fluid is controlled predominately by the host granitic rocks. (From the authors' abstract)

SHI, Jixi, FU, Jiamo, LI, Benchao and JIA, Rongfen, 1987, Significance of mineral inclusions from carbonate areas in oil and gas prospecting evaluation: Chenji Xuebao, v. 5, no. 1, p. 86-93 (in Chinese).

SHEPHERD, Tom, 1987, Fluid inclusions, ore genesis and mineral exploration: NERC News, p.28-30.

A review of the present status of fluid inclusion research, with some applications to Sn-W deposits. (E.R.)

SHEPHERD, T.J. and SCRIVENER, R.C., 1987, Role of basinal brines in the genesis of polymetallic vein deposits, Kit Hill-Gunnislake area, SW England: Proc. of the Ussher Soc., v. 6, p. 491-497. First author at British Geol. Survey, 64 Grays Inn Rd., London WC1X 8NG, England.

A comparative fluid inclusion and REE study of the fluorite gangue from north-south trending Pb/Zn/Ag veins in the Tamar valley and east-west trending Cu/As/Sn veins in the Kit Hill-Gunnislake area reveals a remarkable chemical affinity between their respective mineralizing fluids. Salinity and T data for the former system demonstrate that the fluid are Na-Ca-Cl brines with a $NaCl/CaCl_2$ wt ratio of 1.2:1. Depositional conditions were more or less uniform throughout the Tamar valley and the fluids display a narrow compositional range (11-15 wt% NaCl, 9-13 wt% $CaCl_2$) and an equally restricted T range (110-170°C). By comparison, fluorites from the east-west veins were deposited at much higher T (215-305°C) from fluids showing a wide range in salinity (3-27 wt% NaCl eq.). Cryometric measurements show that the observed range is due to the mixing of a high salinity component containing 11 wt% NaCl + 16 wt% $CaCl_2$ ($NaCl/CaCl_2$ wt ratio of 2:3) and a low salinity, less calcic component (4 wt% NaCl eq.; $NaCl/CaCl_2$ wt ratio of 1:1) at more or less constant T. REE data show that the fluorites have similar REE abundances and define a common array when plotted according to their Tb/Ca and Tb/La atom ratios suggesting crystallization from the same parent solution. Fluorites from the higher T E-W veins are strongly depleted in Eu but are enriched in the heavier rare earths. By comparison, the lower T N-S vein fluorites show either weak negative or positive Eu anomalies implying $Eu^3$ +/$Eu^2$ + redox changes or variation in the supply of Eu. All fluorites are depleted in the light rare earths. The cooler fluids are chemically similar to the North Pennine ore fluids and post-Variscan fluorite/barite fluids of the Harz Mountains, which are considered to be highly evolved basinal brines. Thus the combined fluid inclusion/REE data support a hydrothermal model whereby the deposition of fluorite at T in excess of 250° is a consequence of early, deep penetration of Na-Ca-Cl brines into the E-W structures during the closing stages of mineral deposition, prior to the reopening of pre-existing N-S structures. The fluorites record a hydrothermal continuum. (Authors' abstract)

SHEPPARD, S.M.F., 1987, Isotopic characterization of crustal fluids (abst.): Abstracts, NATO Advanced Research Workshop, Fluid movements, element transport, and the composition of the deep crust, Lindås, Norway, 18-24 May, 1987 (unpaginated).

SHERRIFF, B.L., GRUNDY, H.D. and HARTMAN, J.S., 1987, Analysis of fluid inclusions using nuclear magnetic resonance: Geochimica Cosmo. Acta, v. 51, p. 2233-2235. First author at Dept. Geol., McMaster Univ., Hamilton, Ontario, Canada, L8S 4M1.

Nuclear magnetic resonance (NMR) spectra from $^{23}Na$ and $^{35}Cl$ in fluid inclusions in samples of quartz and beryl show the potential of NMR as a powerful analytical technique for the study of fluid inclusions. (Authors' abstract)

SHI, Lida, 1987, Critical inclusions and supercritical fluid in minerals and their metallogenesis: Geol. & Prospecting, v. 23, no. 12, p. 34-38 (in Chinese; English abstract). Author at Shenyang Res. Inst. of Geol. & Min. Resources.

The critical inclusion, a special kind inclusion, is formed by mineralizing fluid under a critical or supercritical condition, and from which much more physico-chemical informations can be extracted than from ordinary inclusions. In this paper the origin and classification of the supercritical inclusions as well as their metallogenetic significances are discussed.

The author has studied the critical inclusions in some deposits and found that they are closely related to mineralization activities. So a new metallogenic hypothesis (metallogenesis of supercritical fluid) is suggested by the author. Various expressions of this metallogenesis in some Au, Fe and porphyry Cu deposits are also cited. (Author's abstract)

SHIBUE, Yasuhiro, 1987a Fluid inclusion study on some minerals from the Fujigatani and Kuga deposits, Yamaguchi Prefecture, southwest Japan: Mining Geol., v. 37, no. 4, p. 259-266 (in Japanese; English abstract). Author at Hyogo Univ. of Teacher Ed., Yashiro-cho, Kato-gun, Hyogo 673-14, Japan.

Th and salinities of fluid inclusions in quartz, scheelite, clinopyroxene, and garnet from the Akemidani and Gosento ore bodies of the Fujigatani deposit and the Suo ore body of the Kuga deposit are measured in order to compare the formation T of anhydrous skarns, quartz veins, and scheelite.

Th and salinities of P fluid inclusions in vein quartz from the Fujigatani deposit range from 361° to 191°C and 14 to 1 wt% (NaCl eq.), respectively. P fluid inclusions in scheelite show Th ranging from 308° to 233°C, and the salinities ranging from 9 to 1 wt% (NaCl eq.), respectively. Th and salinities of P fluid inclusions in clinopyroxene range from 361° to 251°C and 11 to 3 wt% (NaCl eq.), respectively.

P fluid inclusions in vein quartz from the Kuga deposit show Th ranging from 373° to 196°C, and the salinities ranging from 12 to 2 wt% (NaCl eq.), respectively. Th and salinities of P fluid inclusions in scheelite range from 376° to 242°C and 9 to 1 wt% (NaCl eq.), respectively. Th of P fluid inclusions in clinopyroxene and garnet range from 370° to 263°C and from 339°C to 275°C, respectively. Salinities of P fluid inclusions in these minerals range from 11 to 2 wt% (NaCl eq.).

It is indicated for both deposits that the formation of quartz veins occurred at lower T than that of skarns. Skarn scheelite precipitated at lower T than clinopyroxene and/or garnet, whereas vein scheelite precipitated at higher T than vein quartz. The temporal relationship between quartz veins and skarns, textural relations of scheelite and other skarn minerals, and the fluid inclusion data suggest that the precipitation of scheelites occurred at the late stage of the formation of skarns, and at the early stage of the formation of quartz veins.

Difference in salinity of inclusion fluid is not observed between scheelites in skarns and in quartz veins. Th data show that vein scheelite from the Fujigatani deposit was formed at higher T than skarn scheelite. On the other hand, vein scheelite from the Kuga deposit was formed at the same T with skarn scheelite. There is a possibility that the T of hydrothermal solutions for these deposits did not decrease monotonously, but fluctuated during the course of the mineralization of the Fujigatani deposit.

No apparent difference in formation T is observed between molybdenite and scheelite in quartz veins of the Fujigatani deposit. (Author's abstract)

SHIBUE, Yasuhiro, 1987, Fluid inclusion study on the Itaga tungsten deposit, Ashio district, Japan: J. Japan. Assoc. Min. Petr. Econ. Geol., v. 82, p. 353-361. Author at Geosci. Inst., Hyogo Univ. of Teacher Education, Yashiro-machi, Kato-gun, Hyogo 673-14, Japan.

Polyphase, vapor-rich, and liquid-rich inclusions are found in quartz of the disseminated ore in the Itaga granite. Vapor-rich and liquid-rich inclusions are found in vein quartz of the disseminated ore in the Itaga granite. Vapor-rich and liquid-rich inclusions are found in vein quartz, scheelite, and topaz from this deposit, but polyphase inclusions are not found in these minerals.

Th of P fluid inclusions in quartz of the disseminated ore, vein quartz, scheelite, and topaz range, respectively, 518° to 261°C, 388° to 265°C, 336° to 301°C, and 420° to 370°C. Salinities of P fluid inclusions [for the same sequence], 45.1 to 0.9, 21.0 to 8.3, 7.9 to 5.3, and 14.3 to 3.1 NaCl eq. wt%. The highest T and salinity reported in the present study are higher than any other data previously obtained for the Japanese W deposits.

Based on the plots of Th against salinity, it is suggested that there were at least two hydrothermal solutions, i.e., very saline and dilute ones, responsible for the mineralization of the Itaga deposit. (Author's abstract)

SHIBUYA, Y., 1987c Fluid inclusion study on some minerals from the Fuji-gatani, Nakatatsu, and Higashiyama mines (abst.): Mining Geol., v. 37, no. 1, p. 62-63 (in Japanese). See previous items. (E.R.)

SHIGENO, H., STALLARD, M.L., TRUESDELL, A.H. and LYON, G.L., 1987, $^{13}C/^{12}C$ and D/H ratios of methane and hydrogen in Cerro Prieto geothermal reservoir, and their indications (abst.): EOS, v. 68, p. 439-440.

SHIRAKI, Ryoji, SAKAI, Hitoshi, ENDOH, Mikiya and KISHIMA, Noriaki, 1987, Experimental studies on rhyolite- and andesite-seawater interactions at 300°C and 1000 bars: Geochem. J., v. 21, p. 139-148. First author at Inst. Industrial Sci., Univ. Tokyo, Minato-ku, Tokyo 106, Japan.

Experiments on glassy rhyolite- and phenocrystic andesite-seawater interactions were carried out at 300°C and 1000 b. The results suggest that two stage alteration episodes existed in Kuroko-type mineralization. The present experimental solutions reproduced the chemical composition of a deep hot water from a bore hole drilled into an andesitic geothermal area. However, shallow thermal waters discharging from andesitic volcanic rocks along some coastal areas of Japan cannot be explained as direct products of high-T interaction of seawater and fresh acid volcanic rocks. (From the authors' abstract)

SHNYUKOV, E.F., KALYUZHNYI, V.A., SHCHIRITSA, A.S., TELEPKO, L.F., KRUGLOV, A.S., SVOREN, I.M. and ALAUI, G.G., 1987, Gaseous fluids of contact-zone basalts of the Indian Ocean floor (based on relict inclusion data): Dokl. Akad. Nauk SSSR, v. 297, no. 6, p. 1457-1460 (in Russian).

SHOCK, E.L., 1987, Metastable equilibria among minerals and organic aqueous species in the diagenetic environment (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 842. Author at Dept. Earth & Planet. Sci., Washington, Univ., St. Louis, MO 63130.

Thermodynamic calculations, as well as recent experimental investigation of carboxylic acid decarboxylation rates (Drummond and Palmer, 1986), indicate that organic species in aqueous solution are not in stable equilibrium with carbon dioxide in the diagenetic environment. The calculations also indicate that $CO_2$ and $CH_4$ are not in stable equilibrium with each other in oil field brines, and that mineral stabilities and solubilities in the diagenetic environment are not controlled by the fugacity of $CO_2$, but rather by the activities of the carboxylic acids which are apparently in metastable equilibrium with one another as well as with dissolved alkylbenzenes. The relative metastabilities of these species in the aqueous phase can be depicted on fugacity/activity diagrams by characterizing metastable equilibrium field boundaries in terms of the activities of various alkanes, carboxylic acids and other aqueous or gaseous species. Calculated apparent molal Gibbs free energies of formation at elevated T and P can then be used to link oxidation-reduction reactions among aqueous organic species to the relative stabilities of mineral assemblages. Preliminary results indicate that the ratios of acetic and propanoic acids in oil field brines near 100°C and 300 bars are consistent with oxygen fugacities controlled by the assemblage magnetite-siderite-graphite rather than the hematite-magnetite assemblage. (Author's abstract)

SHVEDENKOV, G.Yu., KALININ, D.V. and NAZAROV, V.V., 1986, Thermodynamics of liquid-gas equilibrium in the system $H_2O$-$H_2S$: Geokhimiya, no. 4, p. 529-539 (in Russian; translated in Geochem. Int'l., v., 23, no. 8, p. 112-123, 1987). Authors at Inst. Geol. & Geophys., Siberian Div., Acad. Sci. USSR, Novosibirsk, USSR.

P-V-T measurements for pure components and mixtures have been used with the Peng-Robinson equation of state to calculate the compositions of the liquid and gas phases in the system $H_2O$-$H_2S$. (Authors' abstract)

SIBBALD, T.I.I., REES, M.I. and QUIRT, D.H., 1987, Geology of the gold deposits, Goldfields, Saskatchewan (abst.): GAC-MAC, AGC-AMC Joint Ann. Mtg., Program with Absts., v. 12, p. 88. First author at Saskatchewan Energy & Mines, Regina, S4P 4V4.

The Goldfields area on the north shore of Lake Athabasca was the scene of a significant gold rush in the thirties. Between 1939 and 1942, 64,066 oz of gold were extracted underground from the Consolidated Mining and Smelting Company Ltd.'s Box Mine.

Supracrustal rocks intruded by mafic bodies and invaded by 'granite' underlie the area. The supracrustals, of Lower Proterozoic age, are characterized by a shelf succession dominated by quartzites and metamorphosed to lower to middle amphibolite facies. The 'granitic' rocks are of replacement, metasomatic type. Two major deformation events are recognized. The early penetrative event was accompanied and outlasted by prograde metamorphism, whereas the later event, which gave rise to the major upright Goldfields synform, was typified by retrograde metamorphism.

Gold mineralization occurs within discrete lenticular bodies of leucocratic homogeneous 'granite' characterized by disseminated sulphides and cut by stockworks of quartz veins. Gold, typically associated with pyrite ± sphalerite ± galena ± chalcopyrite, occurs primarily in the quartz veins but is also present in the wall rocks. It is found free, in pyrite and as coatings on microfractures. Geochemically the mineralization is simple and expressed by Au ± Ag ± Zn ± Pb ± Cu and Mo. Adjacent to veins wallrock alteration is neither megascopically nor microscopically apparent, although regional retrograde metamorphism in part associated with extensive albitization, accompanied quartz veining. Various hypotheses for the origin of this enigmatic type of gold mineralization will be examined in the context of available petrological, geochemical, geochronological, fluid inclusion and stable isotope data. (Authors' abstract)

SICHEL, S., BROWNING, D. and SIGURDSSON, H., 1987, Pseudo-picritic glass inclusion compositions from the Mid-Atlantic Ridge (abst.): EOS, v. 68, p. 456. Authors at Graduate Sch. Oceanography, Univ. Rhode Island, Kingston, RI 02882.

Melt inclusions trapped in plagioclase and olivine crystals in basalt lavas along the MAR (1°41'S-23°49'S) were studied by microprobe in terms of major elements. Dredge EN63-7D (23°49'S) contains plagioclase phenocrysts with a number of inclusions with MgO 10-19 wt% and $TiO_2$ 0.3-1.95 wt%. Variation diagrams for the 65 analyzed melt inclusions show trends that can be modelled by 1 to 40% of host crystallization of plagioclase An77). Prior to plagioclase host crystallization, initial composition of these melts is: MgO 10.25%, $TiO_2$ 1.13%, Mg# 73, contrasting with that of the matrix glass MgO 8.46%, $TiO_2$ 1.46%, Mg# 65. Results suggest magma mixing where more primitive magma, bearing plagioclase, was carried into a magma reservoir with evolved composition. Plagioclase crystals as inclusions in olivine also attest to an older generation of some plagioclase. Trapped glass in olivine also shows evidence of host crystallization, lowering the MgO content from to 3 wt%. Despite variable composition and a high Mg number, these plagioclase melt inclusions do not represent a great range in the extent of melting, but are due to a variable amount of host crystallization from a homogeneous initial composition. (Authors' abstract)

SIEGEL, D.I., CHAMBERLAIN, S.C. and DOSSERT, W.P., 1987, The isotopic and chemical evolution of mineralization in septarian concretions: Evidence for episodic paleohydrogeologic methanogenesis: Geol. Soc. Am. Bull., v. 99, p. 385-394. First author at Dept. Geol., Syracuse Univ., Syracuse, NY 13244-1070.

Fluid inclusions in the crack fillings (p. 390) are mostly full of liquid; some are full of gas but the interpretation of these is still open. (E.R.)

SIEGEL, D.I., CHAMBERLAIN, S.C. and DOSSERT, W.P., 1987, The isotopic and chemical evolution of mineralization in septarian concretions: Evidence for episodic paleohydrogeologic methanogenesis: Geol. Soc. Am. Bull., v. 99, p. 385-394. First author at Dept. Geol., Syracuse Univ., Syracuse, NY 13244-1070.

Detailed chemical and isotopic studies of mineralization of septarian fractures in concretions in the Devonian Marcellus Shale document a complicated paragenesis involving multiple episodes of metal-carbonate precipitation during methane fermentation. The first episode of carbonate precipitation under conditions of methanogenesis occurred with the formation of a final stage of calcite near the end of diagenesis. The second episode involved the precipitation of strontianite in voids in the septarian mineralization volume that were open to ground water. The third epidsode involved the replacement of barite by witherite in an external zone of each concretion. Fluid inclusions in the carbonate fracture fillings of our concretions are mostly full of liquid and indicate a low temperature of formation. Some small inclusions are empty, which could indicate either low or high temperatures of formation. Petrographically, all carbonate-mineral fracture fillings show no evidence of recrystallization. Both the fluid-inclusion and petrographic data suggest that the carbonate fracture fillings probably formed at temperatures significantly lower than that suggested for the recrystallization of the concretion matrix.

This study demonstrates that precipitation of carbonate minerals during methane fermentation is of greater significance than previously thought. Not only is methane fermentation important in dolomite formation, but it is also an important process in the paragenesis of other metal carbonates such as strontianite and witherite. (From the authors' abstract and text)

SILLITOE, R.H., 1987, Gold and silver deposits in porphyry systems (abst.): Program with Abstracts, Symp.: Bulk Mineable Precious Metal Deposits of the Western United States, April 6-8, 1987, Geol. Soc. Nevada, p. 39.

Precious-metal deposits found in the shallower parts of porphyry systems are epithermal in character. Those from above porphyry Cu deposits are of high-sulfur, acid-sulfate type, whereas those from around porphyry Cu deposits tend to be of low-sulfur, adularia-sericite type.

Much of the Au in porphyry Cu deposits was precipitated early with Cu (± Mo) from hot (400° - >600°C), chloride-rich fluids of magmatic parentage. Au and Ag around porphyry Cu deposits are associated commonly with Zn, Pb, and, locally, As, and were precipitated during one or more late events from cooler (200°-400°C), more dilute fluids, which probably possessed an appreciable meteoric component. A Cu-As association is characteristic of the precious-metal environment above porphyry Cu deposits, in which the acid nature of the cool, moderately to very dilute fluids is attributed to a direct input of late-stage magmatic volatiles. Some of the late-stage precious-metal concentrations in porphyry systems may have been derived by leaching of early mineralization. (From the author's abstract)

SIMMONS, S.F., 1987a-Detailed freezing studies on fluid inclusions from epithermal systems: Examples from the Fresnillo District, Zacatecas, Mexico (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Author at Dept. Geol. & Geophys., Univ. Minnesota, Minneapolis, MN 55455.

The Fresnillo District contains a spectrum of ore deposits ranging from base-metal rich mantos to precious-metal rich vein deposits which span a vertical interval of ~1000 m. In general, solutions responsible for mineralization ranged from 170°-370°C, and 1 to 12 eq. wt. % NaCl, and locally, were boiling. However, results from detailed freezing studies reveal a more complex scenario in which both subtle and distinct compositional variation of mineralizing solutions are recognized. Evidence from two quartz samples are presented as examples and indicate: 1) permissive evidence for the presence of low concentrations $CO_2$ (less than 0.85 molal or 3.7 wt. %); and 2) existence for solutions of disparate origin. The two samples used in this study were collected from the "glory hole" pit, in the center of the district (SS-115-85); and the Ag-rich St. Nino Vein, ~1.7 km southeast (SS-47B-84). For both cases, the fluid inclusions studied consisted of two-phase liquid-rich (± vapor-rich inclusions).

The importance of low concentrations of $CO_2$ (less than 0.85 molal) contributing to freezing point depression was recently emphasized (Hedenquist and Henley, 1985), however, its presence is generally difficult to identify. In the first example, P inclusions situated in a 4 mm wide quartz band from the St. Nino Vein (SS-47B-84) provide indication of dissolved gas. Tm and Th data from two different groups of inclusions are shown in figure 1. The wide range of Th indicate that both groups contain varying L:V ratios characteristic of either necking, or 2-phase trapping. As a result, the gas contents ($CO_2$) of these inclusions, if present, should vary as well, and consequently yield a relatively broad range of Tm, e.g., group A. Tm in this group varies ± 0.8°C and is taken as an estimate of the dissolved gas contribution to the freezing point depression in inclusion fluids. -0.8°C corresponds to a concentration of 1.9 eq. wt. % $CO_2$. An additional concentration of up to 2 eq. wt. % NaCl is also required to account for the total freezing point depression in group A inclusions. In contrast if the solutions contain dissolved electrolytes only, i.e., void of $CO_2$, then the Tm should remain constant, e.g., group B. The Tm of these inclusions indicate salinities of 2 eq. wt. % NaCl. Scatter plots characteristic of group A inclusions have been found in several locales within the St. Nino Vein for which crushing experiments corroborate the presence of gas. Furthermore, a similar Th-Tm variation was obtained for a group of quartz-hosted fluid inclusions from the Baguio Au-bearing veins in the Phillipines, for which quadrupole mass spectrometry had indicated the presence of gas. Therefore it appears that inclusions exhibiting varying L:V ratios can be used to infer the presence or absence of low gas concentrations. This provides the ability to observe subtle variations of inclusion fluid chemistry within a single crystal, at a scale not resolvable by bulk gas analyses.

The second example is a 3 mm diameter quartz chip obtained from a veinlet associated with disseminated Ag-Pb-Zn mineralization (SS-115-85). Three compositionally distinct groups of P and PS inclusions are recognized in this sample of 3, 10 and 18 eq. wt. % NaCl, ranging from 240°C to 300°C (figure 2). Groups I and II were trapped before group III. The tremendous range of salinities cannot be explained by mixing of two end member solutions, or boiling of a single solution alone, and instead suggest pulsating contributions possibly involving more than just meteoric source regions (magmatic? connate?). In addition, P estimates for the respective groups [of] inclusions indicate the presence of a dynamically fluctuating head, from 30 to 90 bars, probably due to changing lithostatic-hydrostatic conditions.

These two examples serve to show how detailed freezing studies can reveal complexities in the composition of mineralizing solutions in epithermal environments. Evidence for low concentrations of $CO_2$ can provide important restraints on the effectiveness of boiling to change pH and precipitate sulfides. Finally, pulsating mechanisms must be considered unraveling the evolution of mineralization in the Fresnillo District. (Author's abstract)

SIMMONS, S.F., 1987b Physio-chemical nature of the mineralizing solutions for the St. Nino vein; results from fluid inclusion, deuterium, oxygen and helium studies in the Fresnillo district, Zacatecas, Mexico: PhD dissertation, Univ. Minnesota, Minneapolis, MN, 254 pp.

SIMMONS, S.F., SAWKINS, F.J. and SCHLUTTER, D.J., 1987, Mantle-derived helium in two Peruvian hydrothermal ore deposits: Nature, v. 329, p. 429-432. First author at Dept. Geol., Univ. Auckland, Private Bag, Auckland, New Zealand.

Strong differences exist between the helium isotopic compositions of mantle-derived magmas, axial vent hot spring fluids, subduction-related magmas and many associated hot springs, and the atmospheric and crustal values (Fig. 1). Here we report helium isotope ratios for two late Tertiary fossil hydrothermal systems responsible for precious-metal, base-metal and tungsten mineralization, and compare them to those of circum-Pacific hot spring emanations. The $^3He/^4He$ ratios of inclusion fluids hosted by gangue and sulphide minerals from Casapalca and Pasto Bueno, Peru, all lie between two and three times the atmospheric value, indicating the presence of a dilute component of mantle helium consistent with previously reported stable isotope evidence of the presence of magmatic fluids during mineralization. Although post-trapping modification of the helium isotope composition is possible, we suggest that these apparently low values represent the composition of helium inherited from contributing magmas. As a tracer of magmatic fluids in hydrothermal systems, helium isotopes are decoupled from the factors that govern other stable isotope signatures. (Authors' abstract)

SIMON, K. and HOEFS, J., 1987, Effects of meteoric water interaction on Hercynian granites from the Südschwarzwald, southwest Germany: Chem. Geol., v. 61, no. 1/4, p. 253-261.

Full paper for abstract in Fluid Inclusion Research, v. 18, p. 380-381, 1985. (E.R.)

SIMONSON, J.M., ROY, R.N. and GIBBONS, J.J., 1987, Thermodynamics of aqueous mixed potassium carbonate, bicarbonate, and chloride solutions to 368 K: J. Chem. Eng. Data, v. 32, p. 41-45. First author at Chem. Div., Oak Ridge Nat'l. Lab., Oak Ridge, TN 37831.

Potentials for the cell without liquid junction $H_2$, Pt[$K_2CO_3(m_1)$, $KHCO_3(m_2)$, $KCl(m_3)$]AgCl, Ag are reported over a wide range of ionic strengths at temperatures to 368.15 K. Analysis of these results with the ion interaction model shows that only very minor changes in the previously reported temperature dependence of the potassium carbonate interaction parameters are required to represent the higher temperature data. Activity and osmotic coefficients for solutions with stoichiometrically equal carbonate and bicarbonate molalities are calculated from 338 to 368 K. (Authors' abstract)

SISSON, V.B., 1987, Halogen chemistry as an indicator of metamorphic fluid interaction with the Ponder pluton, Coast Plutonic Complex, British Columbia, Canada: Contrib. Mineral. Petrol., v. 95, p. 123-131. Author at Dept. Geol. & Geophys., Rice Univ., Houston, TX 77251, USA.

During hydrothermal fluid activity associated with the intrusion of the Ponder pluton, Coast Plutonic Complex, British Columbia, Canada, the halogen composition of biotite, amphibole and apatite is controlled by the composition of the metamorphic fluid. The core of the pluton was not affected by infiltrating fluids, and the fluorine composition of biotite was controlled by the biotite Fe-Mg ratio. The edge of the cooling, crystallized pluton interacted with a chlorine-rich, fluorine-poor fluid which changed the halogen composition of biotite and amphibole. The composition of the metamorphic fluid derived from biotite and apatite compositions was relatively high in chlorine and low in fluorine. The concentration of chlorine in the metamorphic fluid increases towards the pluton, whereas fluorine remains constant. This suggests that the metamorphic fluid near the pluton had the greatest potential for mass-transfer of metals. (Author's abstract)

SISSON, V.B., HOLLISTER, L.S., CLARE, A.K. and AHERNS, L.J., 1987, A fluid inclusion study of pelitic schists and metamorphosed carbonate rocks, south-central Maine (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). First author at Dept. Geol. & Geophys., Rice Univ., Houston, TX 77251.

Petrologic and isotopic studies in south-central Maine by J. Ferry, Johns Hopkins University, have resulted in a model of pervasive water influx (external fluid buffering) during prograde metamorphism. Fluid:rock ratios calculated by Ferry (1983) from mineral equilibria and preliminary stable isotope data in both pelitic schist and metamorphosed carbonates range from 0.2:1 to 5:1. The fluid:rock ratios was highest during greenschist facies and decreased with further metamorphism to ratios of only 0.1-0.5:1 during maximum P-T conditions (e.g, Ferry, 1986).

Our observations of a suite of Ferry's samples from low to high grade are that most of the observed P fluid inclusions have $CO_2$-rich compositions rather than the water-rich compositions calculated from mineral compositions (Table 1). The densities of P fluid inclusions are consistent with metamorphic conditions and change systematically with grade. The $CO_2$ content of fluid inclusions in samples of pelite and carbonate from the same outcrop (675) show predicted differences with rock composition, but none have the same absolute composition as predicted. On the other hand, a sample (1103) of a graphite, sulfide-bearing schist has a primary low salinity fluid more water-rich than calculated by Ferry (1981). Fluid flow was continuous throughout the entire metamorphic event, beginning with infiltration of water, then precipitation of quartz and trapping of P fluid inclusions, and finally cooling in the presence of retrograde fluids. The late fluids (Table 1) seen in S inclusions were derived from hydrothermal activity

Table 1. $CO_2$ content of observed versus predicted fluid compositions.

| Sample | Rock type | T°C | observed | predicted | later fluids | fluid: rock ratio |
|---|---|---|---|---|---|---|
| 7-3 | P | 400 | -- | -- | $N_2$, $H_2O$ | -- |
| 5-b | P | 450 | .7-1 | .14-.16 | $CO_2$ | 1.4:1 |
| 5-d | P | 450 | 1 | .14-.16 | $CO_2$ | 1.4:1 |
| 18a | C | 460 | 1 | .26 | $CO_2$ | -- |
| 18d | P | 460 | 1 | <.96 | $CO_2$ | -- |
| 23c | P | 505 | .8-1 | .31 | $CH_4$, $H_2O$ | -- |
| 23d | C | 490 | .9-1 | -- | $CH_4$, $H_2O$ | -- |
| 971* | C | 530 | .4-1 | .17 | $H_2O$ | 1.9:1 |
| 675a | P | 550 | .67-1 | .2-.38 | $H_2O$ | 3.6:1 |
| 675b | C | 550 | .4-1 | .133 | $H_2O$, $CO_2$ | 3.6:1 |
| 1103 | P | 540 | 0-.05 | .23 | $CH_4$ | 3.5:1 |

*Vassalboro Fm., all others from Waterville Fm.; P = pelite host, C = calcareous host associated with plutons, from retrograde reactions producing methane (and nitrogen?), and from continued entrapment of $CO_2$. A source of primary $CO_2$ could have been the metamorphic reactions. Possible explanations for the discrepancy between observed and predicted compositions are (1) fluid immiscibility and selective entrapment of $CO_2$, (2) post-entrapment leakage of $H_2O$, and (3) entrapment of only retrograde fluids. The latter is unlikely because of excellent agreement between isochores and metamorphic conditions. Selective leakage is unlikely as amphibolite facies rocks elsewhere preserve P fluid inclusions (Stout et al., 1986). Assuming Ferry's predictions are correct, then the first alternative is most likely, as demonstrated by Mullis (1979) for an occurrence of pure methane inclusions in quartz. If this hypothesis is sustained, it implies fluid immiscibility over 400-550°C. An increase in $CO_2$ in the infiltrating water-rich fluid would have decreased $SiO_2$ solubility (Walther and Wood, 1984) and caused the precipitation of quartz. However, quartz precipitation could have been the result of a localized P drop, suggested by the observation that the density of fluid inclusions decreases with proximity to healed fractures. (Authors' abstract)

SKEWES, M.A. and CAMUS, F., 1987, Fluid inclusions in El Bronce de Petorca, Chile: Implications for genesis of a gold epithermal deposit associated with Upper Cretaceous volcanism in the Andes: Acta Del Decimo Congreso Geol. Argentino, v. 4, p. 290-291 (in Spanish). See Translations.

SMITH, D., 1987, Carbonates and Ba-, Cl-rich hydrates in mantle pyrope: Records of subduction, metasomatism, or both? (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 848. Author at Dept. Geol., Univ. Texas, Austin, TX 78713.

One of the rare occurrences of carbonate minerals from the mantle is in the Navajo field on the Colorado Plateau, where carbonates and hydrates are included in discrete pyrope fragments in serpentinized ultramafic microbreccias (SUM). Most inclusions in garnets are monomineralic olivine or pyroxene, but 4 of 6 inclusions of carbonates and hydrates, studied in multiple sections by backscattered electron imaging and microanalysis, are polymineralic. Assemblages include: pargasite-magnesite-dolomite-apatite-spinel; pargasite-dolomite-Ba phlogopite (with 10% BaO); olivine-dolomite-spinel; and edenite-chlorite. Bulk compositional characteristics, such as the enrichment in Ba, are evidence that two inclusions in one garnet formed from trapped melt. Amphibole-garnet and olivine-spinel equilibration temperatures are 500-700°C, so the garnets cooled before eruption; the trapped melt had no direct genetic relationship to the host SUM but may be an exceptionally preserved example of a metasomatic agent in coarse peridotite. The pargasite and mica are F-poor and contain about 0.4 and 1.1 wt % Cl, respectively, more than any other analyzed mantle amphibole or mica. Trapped melts and fluids may preserve Cl/F ratios more representative of those in mantle processes than do typical mantle hydates; Cl may be significant in mantle metasomatism and may be subduction-related or from less-depleted mantle.

All the hydrates and carbonates may have evolved from trapped melt, but a garnet containing chlorite and another with chlorite-edenite plus magnesite plot in a high-Cr203 (4-4.5%), low FeO (8%) field distinct for all but one of the 34 other inclusion-bearing pyropes; the chlorite may document prograde metamorphism of oceanic lithosphere incorporated in continental upper mantle. (Author's abstract)

SMITH, D.C., BOYER, H. and PINET, M., 1987, An indexed catalogue of the Raman spectra of minerals (abst.): Terra Cognita, v. 7, p. 21-22.

SMITH, E.J., KESLER, S.E. and VAN HEES, E.H.P., 1987, Relationship of fluid inclusion geochemistry to wall rock alteration and lithogeochemical zonation at the Hollinger-McIntyre gold deposit, Porcupine District, Canada (abst.): J. Geochem. Explor., v. 29, p. 434. First author at St. Joe Am. Corp., 169 Charles St., Deadwood, SD 57732, USA.

Gas chromatographic analyses of fluid inclusions in quartz-carbonate veins from the Hollinger-McIntyre Au deposit indicate that the mineralizing fluid was a $H_2O$-$CO_2$ mixture. Locally, $CH_4$-rich fluid inclusions are associated with veins that occur in graphitic and/or carbonaceous wall rocks. Fluid inclusions in ore-bearing veins have higher $CO_2$ contents than those in non-ore veins. Extensive sampling and analyses of veins from a 1 x 2 km area surrounding the deposit reveals a well developed zonation of $CO_2$ contents about the main zone of mineralization. Low $CO_2$ levels (1-2 mole %) in veins are peripheral to the deposit and increase to over 12 mole % in mineralized zones.

Wall-rock alteration patterns (...) resulted from the addition of $CO_2$ to the wall rock, which is consistent with the observed zoning of $CO_2$ in the fluid inclusions.

The results of this study indicate that fluid inclusion gas haloes are at least as large as the broadest elemental haloes that surround the Hollinger-McIntyre deposit. Gas haloes such as these should be useful in evaluating areas with scattered outcrops containing veins of unknown potential, particularly in view of the fact that the gas content of the inclusions will be much more homogeneously distributed throughout the veins than will be Au values. (From the authors' abstract)

SMITH, G.I., FRIEDMAN, Irving and McLAUGHLIN, R.J., 1987, Studies of Quaternary saline lakes - III. Mineral, chemical, and isotopic evidence of salt solution and crystallization processes in Owens Lake, California, 1969-1971: Geochimica Cosmo. Acta, v. 51, p. 811-827.

SMYTH, J.R., 1987, $\beta$-$Mg_2SiO_4$: A potential host for water in the mantle?: Am. Mineral., v. 72, p. 1051-1055.

SO, C.-S., CHI, S.-J. and CHOI, S.-H., 1987, Genetic environments of the Geumryong gold-silver deposit, Korea: The J. of the Geol. Soc. Korea, v. 23, no. 4, p. 321-330 (in English). First author at Dept. Geol, Korea Univ., Seoul 123, Korea.

Electrum-galena-sphalerite mineralization of the Geumryong Au-Ag mine was deposited in three stages of quartz and calcite veins which fill fault breccia zones in Cretaceous porphyritic biotite granite. Fluid inclusion and sulfur isotope data show that ore mineralization occurred at T between 270 and 220°C from moderate salinity fluids (1.7 to 6.4 wt. % NaCl eq.). Evidence of boiling indicates P of <120 bars, corresponding to depths of 550 and 1,400 m assuming lithostatic and hydrostatic loads.

Sulfur isotope compositions of sulfide minerals decrease systematically with paragenetic time from calculated $\delta^{34}S$ values of $H_2S$ of +39 to -6.3‰. These values, together with the observed change from pyrite-only to pyrite-specularite assemblages, suggest progressively more oxidizing conditions, with a corresponding increase of the sulfate/$H_2S$ ratio of hydrothermal fluids. Gradual increase in the oxidized/reduced sulfur ratio of ore stage fluids, together with boiling and cooling, led to Au-Ag deposition through breakdown of metal complexes such as $Au(HS)_2^-$ as the activity of $H_2S$ decreased. (Authors' abstract)

SO, C.-S., CHI, S.-J. and SHELTON, K.L., 1987, Stable isotope and fluid inclusion studies of gold-silver-bearing vein deposits, Cheonan-Cheongyang-

Nonsan mining district, Republic of Korea: Nonsan area: Neues Jahrbuch Miner. Abh., v. 158, no. 1, p. 47-65.

See So and Shelton, 1987a, this volume. (E.R.)

SO, C.-S., CHI, S.-J., YOO, J.-S. and SHELTON, K.L., 1987, The Jeoneui gold-silver mine, Republic of Korea: A geochemical study: Mining Geol., v. 37, no. 5, p. 313-322.

See So and Shelton, 1987b, this volume. (E.R.)

SO, Chil-Sup and SHELTON, K.L., 1987a, Stable isotope and fluid inclusion studies of gold- and silver-bearing hydrothermal vein deposits, Cheonan-Cheongyang-Nonsan mining district, Republic of Korea: Cheonan area: Econ. Geol., v. 82, p. 987-1000. First author at Dept. Geol., Korea Univ., Seoul 132, Republic of Korea.

The Cheonan Au-Ag area contains Au-bearing hydrothermal quartz veins that crosscut early Proterozoic gneiss and Jurassic and Cretaceous granites. Mineralization can be separated into three distinct stages (I, II, and III) which fill preexisting fault breccia zones. Stages I and II are terminated by the onset of fracturing and brecciation events. Fluid inclusion data suggest that quartz-sulfide-bearing stages I and II each evolved from initial high T (near 400°C) to later lower T (near 200°C). Each of these stages represents a separate mineralizing system which cooled and largely abated prior to the onset of the next stage. Fluid inclusion data from stage III, a postore carbonate stage of mineralization, indicate a much cooler (240°-115°C), more dilute (3-4 eq wt % NaCl) hydrothermal system which was the result of increasing influx of meteoric waters.

Sulfur isotope and fluid inclusion evidence suggests electrum-sphalerite-galena ore mineralization was deposited during stage I between 170° and 255°C from fluids with salinities between 3 and 9 eq wt percent NaCl. Fluid inclusion evidence of boiling suggests P of <100 to 300 bars. This range of P is consistent with a depth of mineralization near 1 km under P conditions that alternated between hydrostatic and lithostatic. Sulfur isotope compositions of sulfide minerals are consistent with an igneous source of sulfur with a $\delta^{34}S(\Sigma S)$ value near 5.0 per mil.

Measured and calculated $\delta D$ and $\delta^{18}O$ values of hydrothermal fluids in the Cheonan area ore deposits are: stage I, -122 to -127 and 6.2 to 5.9 per mil; stage II, -135 to -143 and 3.6 to 3.2 per mil; stage III, -134 to -137 and 3.4 to -7.4 per mil, respectively. These values are consistent with progressive meteoric water involvement (increasing water/rock ratios) with increasing paragenetic time. Comparison of these values with those of a deeper (2-3 km) Jurassic Au deposit ($\delta D = -78$ to $-102$; $\delta^{18}O = 7.7$-3.7‰) suggests a relationship between depth and water/rock ratio in Korean Au-Ag-bearing vein deposits: the Jurassic Au system has ratios of 0.001 to 0.01; the Cretaceous Au-Ag system, 0.02 to 0.5. The relationships among depth, metal contents, and water/rock ratios in these Korean Au-Ag deposits suggest differences in the hydrodynamics and postmagmatic evolutions of granitic hydrothermal systems and may be indicative of the manner in which Au and Ag are scavenged from cooling plutons. (Authors' abstract)

SO, C.-S. and SHELTON, K.L., 1987b, Fluid inclusion and stable isotope studies of gold-silver-bearing hydrothermal vein deposits, Yeoju mining district, Republic of Korea: Econ. Geol., v. 82, p. 1309-1318. First author at Dept. Geol., Korea Univ., Seoul 132, Republic of Korea.

The Yeoju gold-silver mineralized district is located ~60 km SE of Seoul within the Precambrian Gyeonggi metamorphic belt of the Korean peninsula. Mines of the district are located along gold-bearing hydrothermal quartz veins that crosscut early Proterozoic augen gneiss and Mesozoic granites. Mineralization occurs in three stages (I, II, and carbonate) which fill preexisting fault breccia zones. Fluid inclusion data suggest that quartz sulfide-bearing stages I and II evolved from initial high T (near 350°C) to later lower T (near 180°C). Fluid inclusion data from the postore carbonate stage reflect much cooler (220°-190°C), more dilute (4-5 eq. wt % NaCl) hydrothermal fluids.

Fluid inclusions and stable isotope evidence show that electrum, jalpaite, argentite, galena, and sphalerite were deposited between 285° and 185°C from fluids with salinities between 14.0 and 2.6 eq. wt percent NaCl. Fluid inclusion evidence of boiling suggests P of <100 bars during portions of stage I and II mineralization, corresponding to depths between 500 and 1,250 m, assuming lithostatic and hydrostatic loads.

Sulfur isotope compositions of stage I sulfide minerals decrease systematically with paragenetic time from calculated $\delta^{34}S(H_2S)$ values of 7.7 to 0.7 per mil. A gradual increase in the sulfate/sulfide ratio of the fluid, likely due to $H_2S$ loss during boiling coupled with declining T, not only resulted in the systematic decrease of $\delta^{34}S(H_2S)$ values with time but may also have caused gold deposition by the breakdown of $Au(HS)_2^-$.

The H and O isotope values of hydrothermal fluids in the Yeoju district are consistent with meteoric water dominance approaching unexchanged meteoric water values. Comparison of these values with those of other Korean Au-Ag deposits reveals a relationship between depth and water to rock ratios: Jurassic Au systems are mesothermal and have ratios of 0.001 to 0.01 whereas Cretaceous Au-Ag systems are epithermal with ratios of 0.02 to 0.5. (Authors' abstract)

SOBOLEV, N.V. and SHATSKII, V.S., 1987, Inclusions of carbon minerals in garnets of metamorphic rocks: Geologiya i Geofizika, v.28, no.7, p.77-80 (in Russian; translated in Soviet Geol. and Geophys., v.28, no.7, p.69-71).

Diamonds (and graphite) have been found as inclusions in garnets in garnet-biotite gneisses. The authors believe they grow under static, high pressure conditions, possibly from the partial oxidation of methane (E.R.).

SONG, K.Y. and KOBAYASHI, Riki, 1987, Water content of $CO_2$ in equilibrium with liquid water and/or hydrates: SPE Formation Evaluation, v. 2, no. 4, p. 500-508. First author at Rice Univ.

Experimentally measured water content in $CO_2$-rich fluid in the gaseous or liquid state in equilibrium with liquid water or hydrate is presented for P ranging from 100 to 2,000 psia [0.69 to 13.79 MPa] and T from -19 to 77°F [-28.33 to 25.0°C]. The water content of the $CO_2$-rich phase along the three-phase equilibria, i.e., liquid water/liquid $CO_2$/gas to the three-phase critical endpoint, is also reported. The experimental results from this study on the water content in the $CO_2$-rich phases have been combined with earlier research results of the $CO_2$/water binary system in the hydrate-free region from 77 to 200°F [25.0 to 93.33°C] and P to 3,000 psia [20.69 MPa] to produce a comprehensive plot.

The high degree of complexity in the phase behavior of a $CO_2$/water binary system, which exhibits several pairs of equilibrium phases for the conditions, is shown. To make the data more intelligible than they are in their raw form, the data are presented in terms of the P enhancement of the water content along isotherms. Finally, the activity coefficients of water in the $CO_2$-rich phases are summarized. (Authors' abstract)

SOOM, M., STALDER, H.A. and ARMBRUSTER, Th., 1987, $CO_2$-rich inclusions in quartz crystals from alpine topaz-bearing fissures in Lugnez (ultraHelvetic nappes, Swiss Alps) (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 123. First author at Natural History Museum, Bernastr. 15, CH-3005 Bern.

Microthermometric measurements revealed that topaz crystals from Lugnez (first determination of topaz crystals in alpine fissures) were mainly formed from a $CO_2$-rich fluid phase >230°C. The mineral locality is situated in Triassic dolomites on the southern border of the epimetamorphic sedimentary cover of the Gotthard massif and close to the thrust fault of the Pennine nappes.

Besides OH-rich topaz the paragenesis contains: quartz, dolomite, dickite, rutile, barite, apatite, goyazite, bournonite, tetrahedrite, galena, sphalerite and pyrite.

Microthermometric measurements on more than 100 fluid inclusions in 3 quartz crystals gave the following results:

- all inclusions contain detectable $CO_2$ which melts between -57.2 and -56.6°C, and has a density of 0.80 to 0.1 g/cm$^3$. Tm ice starts between -25 and -22°C and is complete between -7.2 and -1.8°C; this corresponds to a salinity of the liquid phase of 10.8 to 3.1 eq wt% NaCl. Th are between 230 and 300°C. These values represent minimal Tt; since an estimation of the Pt is not possible, a P correction and therefore an indication of the Tt cannot be given.

The evolution of the [physical and chemical characteristics of the] fluid phase is summarized in table 1 [see original]. The $CO_2$-concentration in the early fluid generations (I-II) of more than 10 mol% are characteristic of mesometamorphic fluid compositions in the Alps, but occur in Lugnez within epimetamorphic conditions. This can be explained by fluid circulation from high to low metamorphic terrains along important tectonic sutures (thrust fault of Pennine on Helvetic nappes). The increase of $CO_2$ towards the end of quartz crystallization corresponds to the formation of dolomite and could be caused by a splitting off in a gaseous $CO_2$-rich, and a $H_2O$-rich phase in the system $H_2O$-$CO_2$-NaCl. (Shortened from the authors' abstract)

SORENSEN, S.S. and BARTON, M.D., 1987, Metasomatism and partial melting in a subduction complex: Catalina Schist, southern California: Geology, v. 15, p. 115-118. First author at Dept. Min. Sci., Nat'l. Museum of Natural History, Smithsonian Inst., Washington, DC 20560.

Element-partitioning, phase-equilibrium, and fluid-inclusion data are compatible with partial melting of the amphibolites at P = ~8-11 kbar and T = ~640-750°C, in the presence of a low-salinity aqueous fluid. (From the authors' abstract)

SPECZIK, S. and KOZŁOWSKI, A., 1987, Fluid inclusion study of epigenetic veinlets from the Carboniferous rocks of the Fore-Sudetic Monocline (southwest Poland): Chem. Geol., v. 61, no. 1/4, p. 287-298.

Full paper for abstract in Fluid Inclusion Research, v. 18, p. 397-398, 1985. (E.R.)

SPENCER, R.J., 1987, Origin of Ca-Cl brines in Devonian formations, western Canada sedimentary basin: Applied Geochem., v. 2, p. 373-384. Author at Dept. Geol. & Geophys., The Univ. Calgary, 2500 Univ. Ave., N.W., Calgary, Alberta T2N 1N4, Canada.

The majority of waters in Devonian formations of the western Canada sedimentary basin are high salinity Ca-Cl brines. This relatively rare type of brine is of economic interest because of its association with both oil and hydrothermal ore deposits. These brines are important sources of $Ca^{2+}$, $Mg^{2+}$ and ore metals in sedimentary basins.

It is possible to generate the Ca-Cl brines by modification of residual evaporite brines. The evaporation of Devonian sea water produced large quantities of gypsum and halite such as the Prairie Formation. Residual brines were not retained in the evaporating system. Quantities of dense, halite-saturated brine, sufficient to account for the high salinity formation waters in the basin, were lost syndepositionally. The $Cl^-$ and $Br^-$ content of waters within Devonian formations in the basin can be explained by dilution of the residual evaporite brines.

Brine composition was modified as a result of density driven reflux to depths of several kilometers. This placed concentrated brines in contact with Precambrian basement rocks at elevated temperatures (100-300° C). The most important reactions between the brine and basement rocks appear to involve albitization of feldspars. Further modification of the brines occurred as cements formed in Devonian carbonates. Volumetrically, the most important of these is dolomite, in addition some Devonian carbonates were dolomitized. During ascent along faults $Mg^{2+}$ was lost from hot brines as dolomite formed. (Author's abstract)

SPENCER, R.J. and LOWENSTEIN, T.K., 1987, Origin of potash evaporites: Clues from fluid inclusions and textures in associated halites (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). First author at Dept. Geol., Univ. Calgary, Calgary, Alberta, Canada T2N 1N4.

The timing of formation of potash salts (sylvite and/or carnallite) in many ancient evaporite deposits (Devonian Prairie, Permian Salado, Cretaceous Sergipe and Oligocene Rhine Graben) is difficult to determine from petrographic evidence alone. Carnallite occurs as void-filling cements or as isolated euhedral crystals. Sylvite displays void-filling textures, anhedral mosaic textures and may also replace carnallite. Information from fluid inclusions in the associated halites helps constrain the origin of the potash salts, both in terms of timing as well as the parent brine temperatures and compositions.

Sylvite dxls are common in fluid inclusions outlining primary growth structures in halite. This establishes that syndepositional brines were at or near sylvite saturation, and that halite and sylvite could be produced from the same primary parent brine. Tm KCl are up to 80°C, in the range of modern shallow salt pan brine T, which supports a syndepositional origin. Compositional information is deduced from phase transitions at various T during warming frozen inclusions. The data indicate that primary halite and sylvite in the potash zone of the Prairie evaporite formed from Na-Ca-K-rich chloride brines. The brines responsible for the Rhine Graben salts were Na-Mg-Ca-K-rich chloride brines.

Sylvite and carnallite daughter crystals found in fluid inclusions from clear halite (cements) document a genetic link between halite cementation and brines saturated with sylvite or carnallite. In the Prairie evaporite carnallite is associated with Ca-poor Na-Mg-rich chloride-sulfate brines. (Authors' abstract)

SPIRAKIS, C.S. and HEYL, A.V., 1987, A possible mechanism for fluorite precipitation in the southern Illinois-Kentucky fluorspar district (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 853.

SPIVACK, A.J. and EDMOND, J.M., 1987, Boron isotope exchange between seawater and the oceanic crust: Geochimica Cosmo. Acta, v. 51, p 1033-1043.

SPOONER, E.T.C., BRAY, C.J., WOOD, P.C., BURROWS, D.R. and CALLAN, N.J., 1987, Grant 236: Au-quartz vein and Cu-Au-Ag-Mo-anhydrite mineralization, Hollinger-McIntyre mines, Timmins, Ontario: $\delta^{13}C$ values (McIntyre), fluid inclusion gas chemistry, pressure (depth) estimation, and $H_2O$-$CO_2$ phase separation as a precipitation and dilation mechanism: Ontario Geol. Survey Misc. Paper 136, p. 35-56. Authors at Dept. Geol., Univ. Toronto, Toronto, Canada.

Carbon isotope analyses indicate that carbonate associated with Au-quartz vein mineralization in the McIntyre mine is isotopically similar to that from the Hollinger mine and that carbonate in altered albitite dikes (-3.1‰, -2.8‰) is isotopically similar to that associated with the Au mineralization.

The following gases have been detected in P and strain-related S inclusions in quartz and scheelite from the Hollinger and Renabie mines using a zero blank, high T (~105°C) crushing system attached directly to the inlet system of a gas chromatograph: ($N_2$ ± CO ± Ar ± $O_2$ ± NO), NO, $CH_4$, $CO_2$, $N_2O$, $C_2H_6$, and $H_2O$ (in order of retention time). $CH_4/(CH_4 + CO_2)$ molar ratios decrease upwards in the Hollinger mine from 18.00 ± 7.35% to 1.37 ± 0.81%. This decrease is interpreted to be a result of progressive $H_2O$-$CO_2$ phase separation reflecting the high gas/liquid partition coefficient of $CH_4$. The fact that the ratios decrease to values similar to those found in the Renabie mine which, in contrast, consists of an oxidized Archean Au-quartz vein system (anhydrite; negative $\delta^{34}S$), is evidence for $H_2O$ (liquid) oxidation by reduced gas ($H_2$, $CH_4$, $H_2S$) loss during $H_2O$-$CO_2$ phase separation; a possible mechanism for the generation of oxidized Archean Au-quartz and Cu-Au-Ag-Mo-anhydrite vein systems.

Samples from close proximity to graphitic material from surface show clear, relative $CH_4$ increases to $CH_4/(CH_4 + CO_2)$ ratios confirming C isotope exchange with $CH_4$ as a mechanism for producing isotopically less negative carbonate.

Very approximate P and depth estimates for the upper part of the Hollinger mine, based on fluid inclusion properties, P-T sections through the $H_2O$-NaCl-$CO_2$ immiscibility volume, and evidence for lithostatic fluid P are 500 + 200/-300 bars and 1.9 + 0.8/-1.1 km respectively.

$H_2O$-$CO_2$ phase separation, fluid inclusion evidence for which has been described from the Hollinger-McIntyre and Pamour #1 and other deposits ... [by others] can, together with other factors, explain several features of Archean Au-quartz vein systems including ....

Significant quartz precipitation can only signify a T drop, for T less than the solubility maximum (~385°C at 500 bars). (From the authors' abstract; see also next item (E.R.))

SPOONER, E.T.C., WOOD, P.C. and BURROWS, D.R., 1987, $H_2O$-$CO_2$ phase separation as a precipitation/oxidation/dilation mechanism in Archean Au-quartz systems (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 853. See previous item.

SPRY, P.G., 1987, A fluid inclusion and sulfur isotope study of precious and base metal mineralization spatially associated with the Patch and Gold Cup breccia pipes, Central City, Colorado: Econ. Geol., v. 82, p. 1632-1639. Author at Dept. Earth Sci., 253 Science Hall I, Iowa State Univ., Ames, IA 50011.

See Fluid Inclusion Research, v. 19, p. 418-419. (E.R.)

SPYCHER, N.F. and REED, M.H., 1987, 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.

SRIKANTAPPA, C., 1987, Carbonic inclusions for the Nilgiri charnockite massif, Tamil Nadu, India: J. Geol. Soc. of India, v. 30, p. 72-76.

Author at Dept. Geol., Univ. Mysore, Manasa Gangotri, Mysore 570 006.

Charnockites from the Nilgiri Hills show presence of abundant high-density carbonic (1.05-1.10 g/cm$^3$) inclusions. The P-T conditions recorded by fluid inclusions correspond with the P-T data obtained from mineral assemblages (T = 770 ± 60°C, P = 8-9 Kbar) indicating their entrapment near the peak metamorphic conditions. (Author's abstract)

See also next item. (E.R.)

SRIKANTAPPA, C. and KUMAR, G.R.R., 1987, Gneiss-charnockite relation around Ponmudi, southern Kerala: Evidences and implications of prograde charnockite formation in southern India: Proc. Indian Acad. Sci. (Earth Planet. Sci.), v. 96, no. 1, p. 1-10. First author at Dept. Geol., Univ. Mysore, Mysore 570 006, India.

Isochemical conversion of garnet-biotite-bearing paragneiss to charnockite in the Precambrian Khondalite belt of southern Kerala is described from Ponmudi area. Petrographic evidences indicate the formation of hypersthene by the breakdown of biotite in the presence of quartz following the reaction: biotite + quartz → hypersthene + K-felspar + vapor. The estimated P-T conditions of metamorphism are around 5-7 kbars and 750° ± 40°C. Presence of $CO_2$-rich, mixed $CO_2$-$H_2O$ and $H_2O$-rich inclusions were noticed in gneiss as well as in charnockites. Charnockites contain abundant $CO_2$-rich inclusions. (Authors' abstract)

SRIKANTAPPA, C., RAITH, M. and KLATT, E., 1987, Fluid regime during charnockite formation in the granulite terrane of the Nilgiri Hills, southern India (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 125-126. First author at Dept. Geol., Manasa Gangotri, Univ. Mysore, Mysore 570 006, India.

The granulite terrane of the Nilgiri Hills in southern India is predominantly composed of enderbitic charnockites with enclaves of pyroxenitic and gabbroic rocks. The enderbites are medium- to coarse-grained rocks with the typical assemblage garnet-hypersthene-plagioclase-quartz-biotite-(hornblende). Their granoblastic polygonal microtextures demonstrate a thorough postkinematic recrystallization at granulite facies conditions (7 to 9 kb and 670 to 750°C) around 2.5 b.y. ago. During a later (Proterozoic) phase the enderbites were strained and retrogressed in connection with the development of two major shear belts to the N and S of the Nilgiri Hills.

Samples of enderbites were studied to determine the composition of metamorphic pore fluids. Fluid inclusions present in quartz and garnet consist of two types: $CO_2$-rich and $H_2O$-rich.

Most of the inclusions observed in quartz are 4-12 μm in size and contain carbonic fluids (monophase at 20°C). Their shape varies from irregular to oval to negative crystals. Fluid inclusions in garnet are acicular, measuring 10-35 μm in size. Tm of $CO_2$ inclusions in the older strained quartz grains range from -58.0 to -56.6°C. Laser Raman spectroscopy performed on four samples shows that lowering of $TmCO_2$ is caused by 3-5 mole% $N_2$. $CH_4$ contents are insignificant. Th range from -54.3 to 29°C with two marked peaks at -30°C and 10°C. From these data $CO_2$ densities of 1.076 and 0.860 g/cm$^3$ are derived. $CO_2$ inclusions in recrystallized younger quartz grains do not show significant changes either in Tm (-57.4°C) or in Th (-46 to -32°C) when compared to carbonic inclusions in the older strained quartz. This indicates recrystallization near peak metamorphic conditions. The Th data for inclusions in garnet are always lower and range from -22 to 17°C with a maximum around -20°C, yielding densities of 1.030 g/cm$^3$.

$H_2O$-rich inclusions vary in size from 10 to 15 μm and often crosscut the trails of $CO_2$ inclusions. They show salinities of 10-12 mole% eq.

NaCl. Th ranges from 128 to 435°C with a peak at 390°C corresponding to densities of about 0.6 g/cm$^3$.

The high-density $CO_2$ fluids recorded in the enderbites were probably trapped during the peak of granulite facies metamorphism. The corresponding isochores pass through the P-T field derived by geothermometry and geobarometry. This implies that the fluid regime during granulite formation in the Nilgiri Hills was predominantly carbonic. The low-density $CO_2$ inclusions probably originated by progressive leakage and reequilibration of the older high-density inclusions during uplift of the granulite terrane. The presence of late watery inclusions of low salinity gives evidence of increasing activity of water during the retrogression of the enderbite assemblages in the Nilgiri Hills. (Authors' abstract)

SRIKANTAPPA, C., SATISH, P.N., JAGANNATHAPPA, M.N. and JANARDHAN, A.S., 1987, Retrogression of charnockites from Madukkarai, Tamil Nadu - Evidence from geochemistry and fluid inclusions: Current Sci., v. 56, no. 18, p. 928-932. Authors at Dept. Geol., Univ. Mysore, Manasagangotri, Mysore 570 006, India.

Effect of shearing and retrogression of charnockites is commonly noticed in the area around Madukkarai. Petrographic and geochemical studies suggest uralitization of orthopyroxene and relative elemental mobility during retrogressive stage. Fluid inclusion studies suggest a change in the early carbonic stage to $CO_2$-$H_2O$ to the late aqueous stage during retrogression of charnockites. (Authors' abstract)

STÄHLE, H.J., HOERNES, S. and RAITH, M., 1987, Element mobility during incipient granulite formation at Kabbaldurga, southern India (abst.): Terra Cognita, v. 7, no. 2-3, p. 134. Authors at Min. Inst., Univ. Bonn, Bonn, FRG.

Infiltration of $CO_2$-rich fluids along a system of shear planes about 2.5 b.y. ago induced transformation of Archaean granodioritic hbl-bio gneisses to massive opx-bearing granitic charnockite. It is assumed that shear deformation liberated these fluids from a "fossil" reservoir of fluid inclusions in deeper seated granulites. (From the authors' abstract) See also next item. (E.R.)

STÄHLE, H.J., RAITH, M., HOERNES, S. and DELFS, A., 1987, Element mobility during incipient granulite formation at Kabbaldurga, southern India: J. Petrology, v. 28, Part 5, p. 803-834. Authors at Min.-Petr. Inst., Univ. Bonn, Poppelsdorfer Schlostr., 5300 Bonn, FRG.

At Kabbaldurga, infiltration of carbonic fluids along a system of ductile shears and foliation planes has led to partial transformation of Archaean grey biotite-hornblende gneiss to coarse-grained massive charnockite at about 2.5 b.y. ago. The dehydration of the gneiss assemblage was induced by a marked metasomatic change of the reacting system from granodioritic to granitic, and obviously took place under conditions of an open system at 700-750°C and 5-7 kb. Extensive replacement of plagioclase ($An_{16-30}$) by K-feldspar through Na, Ca-K exchange reactions with the ascending carbonic fluids led to strong enrichment in K, Rb, Ba, and $SiO_2$, and to a depletion in Ca. Progressive dissolution of hornblende, biotite, magnetite, and the accessory minerals apatite and zircon resulted in a marked depletion in Fe, Mg, Ti, Zn, V, P, and Zr. Most important is the recognition of REE mobility: with advancing charnockitization, the moderately fractionated REE distribution patterns of the grey gneisses ($La_N$ ~270; $La_N/Yb_N$ = 5-20; $Eu_N$ ~27; Eu/Eu* = 0.6-0.3) give way to strongly fractionated REE patterns with a positive Eu-anomaly ($La_N$ ~200; $La_N/Yb_N$ = 20-80; $Eu_N$ ~22; Eu/Eu* = 0.6-1.8). The systematic depletion especially in the

HREE is due to the progressive dissolution of zircon, apatite (and monazite), which strongly concentrate the REE.

Stable isotope data ($\delta^{18}O$ of 6.9-8.0 per mil for gneisses and charnockites; $\delta^{13}C$ of -8.5 to -6.5 per mil for late carbonate) indicate a magmatogenic source for the carbonic fluids. In contrast to the currently favored derivation of carbonic fluids by decarbonation of the upper mantle or degassing of underplated basaltic intrusions, it is discussed here that abundant fluid inclusions in lower crustal charnockites provided an extensive reservoir of 'fossil' carbonic fluids. Shear deformation has tapped this reservoir and generated the channel-ways for fluid ascent. Charnockitization of the Kabbaldurga-type thus appears to be a metasomatic process which is tectonically controlled and restricted to the crustal level of the amphibolite of granulite transition. (Authors' abstract)

STALDER, H.A., 1987, Investigation of fluid inclusions in quartz crystals from alpine fissures: Jahrb. Naturhist. Mus. Bern, v. 9, p. 245-266 (in German). Author at Naturhist. Museum, Bernastr. 15, CH-3005 Bern, Switzerland.

A subject which has been systematically worked on by the author for more than 20 years is that of fluid inclusions in alpine fissure minerals. These fluid inclusions are often relatively big and uninfluenced by tectonics. For this reason many such inclusions can be considered as demonstration objects for inclusion studies. (Author's abstract)

Includes some striking photomicrographs. (E.R.)

STANDEN, A.R., 1987, Mineralization characteristics of the Scotia-Vanderbilt vein system, Silverton, Colorado: MS thesis, Univ. Texas, Austin, TX, 128 pp.

STAROSTIN, V.I., NAZAROV, V.N. and TROFIMOV, A.P., 1987, Hydraulic structure of the Maleeva pyrite-polymetallic ore deposit (Rudnyi Altai): Vestn. Mosk. Univ., Ser. 4: Geol., 1987, no. 1, p. 44-58 (in Russian).

STARUKHINA, L.V. and KRUZHANOV, V.S., 1987, Spontaneous motion of liquid inclusions in a crystal near its surface: Soviet Physics. Crystall., v. 32, no. 4, p. 629-630.

STAUDACHER, Thomas, 1987, Upper mantle origin for Harding County well gases: Nature, v. 325, p. 605-607. Author at Lab. Géochimie & Cosmoch., Inst. Physique du Globe & Dépt. Sci. de la Terre, Univ. Paris 6 & 7, 4 Place Jussieu, 75230 Paris Cedex 05, France.

Short-lived radioisotopes such as $^{129}I$ and $^{244}Pu$ represent extremely powerful geochemical tools for tracing the early history of the Earth. Terrestrial $^{129}Xe$ anomalies were first found in $CO_2$-rich well gases from Harding County, New Mexico, and then in gases from mid-ocean-ridge basalts (MORB). Here I show that noble gases and $CO_2$ from Harding County are isotopically indistinguishable from such gases in fresh MORB glasses and that both probably have the same source, namely the upper mantle. (Author's abstract)

STEGEN, R.J., THOMPSON, T.B. and BEATY, D.W., 1987, The origin of the Aspen district, Colorado, based on geochemistry and petrology of the Smuggler mine manto ores (abst.): Geol. Soc. Am. Abst. with Programs, v. 19, p. 336. First author at Colorado State Univ., Ft. Collins, CO 80523.

Karst breccias in the Leadville Dolomite host the manto ores in the Smuggler mine at Aspen, Colo. Barite and metal sulfides fill open spaces in breccia with the following paragenesis: bar → py-marc → sp-gn-cpy → tn → sp-gn-cpy-bor → pear-pyrar-acan-silver. The ore is notably barite-rich (50-70%), pyrite-poor (<1%), and essentially gold-free. Although

Tertiary aplite intrusives in the mine show strong phyllic alteration, the dolomite host rock is unaltered except within about one meter of manto ore.

Fluid inclusions througout the paragenetic sequence homogenize at average temperatures of 280°C (barite), 252°C (early sphalerite), 255°C (tennantite), and 257°C (pearcite). Inclusion salinities average 3.2 equivalent weight percent NaCl in barite. Sulfur isotope ratios in barite ($\delta^{34}S$ = +12.3 to +12.9), early galena (-13.6 to -13.9), chalcopyrite (-12.0) and pyrite (-11.5) indicate sulfate-dominated fluids with $\delta^{34}S(SO_4)$ of about +13. Late-stage galena has $\delta^{34}S$ = -3.2 to -9.4, indicating late $\delta^{34}S(SO_4)$ of about +20. For comparison, disseminated pyrite in the aplite has $\delta^{34}S$ = +0.9 to +1.7. Oxygen isotope ratios in barite ($\delta^{18}O$ = +3.2 to +5.0), the only oxygen-bearing gangue mineral, imply an ore-forming fluid with $\delta^{18}O$ near 0. The altered aplite, which has an uncertain relation to ore, exchanged with a much heavier fluid $\delta^{18}O$ = +3 to +9. The altered dolomite shows a weak $^{18}O$ shift (from +25 to +19).

These data suggest ore deposition from a moderate-temperature, dilute, sulfate-dominated hydrothermal fluid. Within the area of the Smuggler mine, hydrothermal fluid movement was entirely updip and was controlled by paleokarst in the Leadville Dolomite. The manto ores are probably not genetically related to the felsic intrusives, as evidenced by the field relations, the oxygen and sulfur isotope ratios, and the low abundance of gold and pyrite in the manto ores. The most plausible interpretation of fluid origin involves pre-55 Ma derivation from the Eagle Valley evaporitic basin north of Aspen. (Authors' abstract)

STELTENPOHL, M.G. and BARTLEY, J.M., 1987, Thermobarometric profile through the Caledonian nappe stack of western Ofoten, north Norway: Contrib. Mineral. Petrol., v. 96, p. 93-103. First author at Dept. Geol., Univ. North Carolina, Chapel Hill, NC 27514, USA.

Involves only mineral-pair thermometry. (E.R.)

STEMPROK, M., 1987, Greisenization (a review): Geologische Rundschau, v. 76, no. 1, p. 169-175.

STEPANOV, E.R., 1987, Thermobarogeochemical conditions for the formation of the Ilintass cassiterite-sulfide deposit [USSR]: Mineral.-Geokhim. i Genet. Osobennosti Rud i Magmat. Porod Olovonos. Uzlov Yakutii, Yakutsk, 1986, p. 82-92 (in Russian). From Ref. Zh., Geol., 1987, Abstr. No. 1Zh108.

Title only translated. (C.A. 107: 26248q)

STERNER, S.M. and BODNAR, R.J., 1987, Determination of phase equilibria and volumetric properties in the system $H_2O-CO_2-NaCl$ (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Authors at Virginia Polytech. Inst. & State Univ., Blacksburg, VA 24061.

Geologic observations and results of theoretical and experimental studies suggest that extensive fluid immiscibility exists in the $H_2O-CO_2-NaCl$ system at high P and T. For a given P, the addition of small amounts of NaCl increases peak solvus T significantly over those in the $H_2O-CO_2$ binary system, and the presence of geologically reasonable amounts of NaCl in $H_2O-CO_2$ fluids may result in fluid immiscibility over much of the P-T domain inferred for regionally metamorphosed environments.

Preliminary investigations of the volumetric properties and phase relations in this fluid system have been performed using synthetic fluid inclusions. Inclusions were formed at 5 kb and 500°C in the presence of ternary bulk fluid compositions each having an $H_2O:CO_2$ molar ratio of 3:1 and 0, 12, 20, and 25 wt.% NaCl relative to NaCl + $H_2O$. At low T, these inclusions contain an aqueous brine, $CO_2$ liquid and $CO_2$ vapor. At the $CO_2$ liquid-vapor Th the density of the $CO_2$ phase was determined from the known PVT relations along the $CO_2$ solvus. The density of the aqueous brine phase at this T was determined from known properties of $NaCl-H_2O$ solutions. The bulk fluid density was then calculated from the known bulk fluid composition using mass balance considerations. Because fluid inclusions represent isochoric systems, this bulk density is the same as that of the fluid at the P and T of inclusion trapping.

Bulk fluid densities of the above inclusions were found to increase almost linearly with increasing salinity up to 20 wt.% NaCl. The calculated bulk density for the 25 wt.% NaCl fluid was found to deviate significantly from this trend. An analogous situation was found when correlating the measured $CO_2$ liquid-vapor Th with bulk fluid salinities. The T of $CO_2$ homogenization for the 25 wt.% NaCl sample deviates significantly from the trend established by the previous three. These observations indicate that the bulk fluid composition of the most saline sample lies within the two phase field at 500°C and 5 kb.

The position of the solvus may be estimated by observing the break in slope at the high angle intersection in plots of calculated densities or $CO_2$ Th against salinity for fluid compositions along fixed $CO_2/H_2O$ pseudobinaries. This technique is currently being employed to determine the PVTX properties of $H_2O-CO_2-NaCl$ over the range of P-T conditions encountered in regionally metamorphosed terrains. (Authors' abstract)

STERNER, S.M., BODNAR, R.J. and HALL, D.L., 1987, Solubility relations in the system $NaCl-KCl-H_2O$: Experimental determination and computer program (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 855. Authors at Dept. Geol. Sci., Virginia Polytech. Inst. & State Univ., Blacksburg, VA 24061.

Vapor-saturated solubility relations in the system $NaCl-KCl-H_2O$ have been determined using synthetic fluid inclusions and freezing point-depression measurements. Solubilities in the halite and sylvite stability fields were determined by synthesizing fluid inclusions in quartz in the presence of NaCl-KCl brines having known compositions and densities corresponding to those along the vapor-saturated solubility surface. Final dissolution T of halite or sylvite within these inclusions were then determined by microthermometric analysis. The known compositions of these inclusions, therefore, represent vapor-saturated solubilities at the corresponding T. Phase relations within the ice stability field were determined by measuring the total salinity and NaCl/(NaCl + KCl) weight fraction of fluids in equilibrium with ice at different T.

These solubility data along with other published values have been regressed using a stepwise multiple regression procedure to generate equations describing TX relations for the vapor-saturated solubility surfaces in the halite, sylvite, hydrohalite and ice stability fields. TX relations along the five cotectics in this system were determined by simultaneous solution of equations describing solubility surfaces in the adjacent stability fields. The resulting equations have been incorporated into a computer algorithm for determining compositions of fluid inclusions approximated by the $NaCl-KCl-H_2O$ system. The algorithm is valid for all compositions in the ternary system and requires only the temperatures at which the last two solid phases in the inclusion melt to calculate the total salinity and the NaCl/(NaCl + KCl) weight ratio of the fluid inclusions, and these data are obtainable during standard microthermometric analysis of the inclusions. (Authors' abstract)

STOESSELL, R.K., KLIMENTIDIS, R.E. and PREZBINDOWSKI, D.R., 1987, Dedolomitization in Na-Ca-Cl brines from 100° to 200°C at 300 bars: Geochimica Cosmo. Acta, v. 51, p. 847-855.

STOFFREGEN, Roger, 1987, Genesis of acid-sulfate alteration and Au-Cu-Ag mineralization at Summitville, Colorado: Econ. Geol., v. 82, p. 1575-1591. Author at Dept. Geol. Sci., Southern Methodist Univ., Dallas, TX 75275.

The Summitville Au-Cu-Ag deposit occurs within a porphyritic quartz latite, primarily in a zone of "vuggy silica" alteration characterized by leaching of all major elements except silica and iron. Consideration of alunite, kaolinite, and pyrite stability relations and of aluminum speciation at 250°C indicates that a pH of 2 or below and a log $fO_2$ of -31 ± 1 (at 250°C) were necessary to produce vuggy silica alteration.

These textural and geochemical relationships indicate that sulfide and Au mineralization postdate the formation of vuggy silica alteration in the deposit and are not directly related to the highly acidic solutions necessary for this early acid-leaching event. The change from extreme acid-leaching to Cu sulfide and precious metal deposition may represent a transition from a magmatic-vapor-dominated to a liquid-dominated system, leading to more reducing and less acidic conditions during sulfide deposition. (From the author's abstract)

STOIBER, R.E. and CONNOR, C.B., 1987, $SO_2$ flux from Kilauea volcano investigated on two time scales (abst.): Hawaii Symp. on How Volcanoes Work, Abst. Volume, Hilo, Hawaii, Hawaiian Volcano Observatory, p. 242.

STOLPER, Edward, FINE, Gerald, JOHNSON, Thomas and NEWMAN, Sally, 1987, Solubility of carbon dioxide in albitic melt: Am. Mineral., v. 72, p. 1071-1085.

STOLPER, E.M. and HOLLOWAY, J.R., 1987, Experimental determination of the solubility of carbon dioxide in molten basalt at low pressure (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 861. First author at Caltech 170-25 Pasadena, CA 91125.

We report the first measurements of $CO_2$ solubility in molten basalt at P comparable to those at which submarine basalts erupt. Juan de Fuca Ridge MORB glass plus $Ag_2C_2O_4$ was loaded into Fe-doped Pt capsules and held 1-2 hr at 100-1500 bars, 1200°C. Reversals were carried out in two experiments by dropping to the final P and holding for 2 hr after holding at higher P for 2 hr. After quenching, glass was analyzed by IR spectroscopy. No forms of dissolved $CO_2$ other than carbonate were detected.

As expected, $CO_2$ solubility is roughly a linear function of P at these low P. The experimentally determined solubility is lower than the estimate by Harris (J. Geol., 1981) based on $CO_2$ contents of submarine basaltic glasses. Our results are compatible with those obtained at 15-30 kbar by Mysen et al. (Contrib. Min. Petrol., 1975) on a molten Kilauea tholeiite only if there is a significant positive dependence of carbonate solubility in T.

$CO_2$ contents of MORB glasses measured by IR spectroscopy (Fine and Stolper, EPSL, 1986; Dixon et al., EOS, 1986) 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 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 fully degas. In conjunction with our solubility data, the highest $CO_2$ contents allow minimum estimates of depths to magma chambers. Depths > 1.5-2 km beneath the ridge are indicated for the Juan de Fuca Ridge and East Pacific Rise, in agreement with geophysical constraints. (Authors' abstract)

STOWELL, H.H., 1987, Sphalerite geobarometry in metamorphic rocks and the tectonic history of the coast ranges near Holkham Bay, southeastern Alaska: PhD dissertation, Princeton Univ., Princeton, NJ, 376 pp.

STRENS, M.R., CANN, D.L. and CANN, J.R., 1987, A thermal balance model of the formation of sedimentary-exhalative lead-zinc deposits: Econ. Geol., v. 82, p. 1192-1203.

STÖCKHERT, Bernhard, 1982, Deformation and retrograde metamorphism in the Austridic basement south of the western Tauern Window (eastern Alps; Italy): PhD dissertation; Univ. Erlangen, 214 pp. (in German).

In the European Alps a nappe-system composed of pre-Alpine basement rocks ("Altkristallin") detached from the lower levels of the lithosphere has been thrust upon the Mesozoic sequence once deposited in the subducted ocean between the former continents. During thrusting and subsequent strike slip movements the originally medium to high-grade metamorphic basement suffered intense deformation and pervasive retrograde metamorphism. A microthermometric fluid inclusion survey has been performed on preserved (but more or less deformed) pre-Alpine quartz, as well as on quartz reconstituted by recrystallization, polygonization and grain growth during Alpine overprint.

First, an alternative concept concerning formation and destruction of inclusions is discussed. Fluids within a certain volume of rock are considered to be either a part of an open system, extending over at least several grain diameters and reequilibrating with the entire paragenesis, or a closed system with fixed composition and volume just able to reequilibrate with the enclosing crystalline phase. Transition of fluid from the open into closed system is synonymous with formation of an inclusion, the reverse is destruction of an inclusion. Among the various processes supposed to operate in this way are migration of phase- and grain-boundaries during the progress of reactions, recrystallization and grain growth (inclusions formed this way may be called "primary" in metamorphic rocks), as well as the better understood healing of microcracks ("secondary inclusions").

Preserved pre-Alpine quartz crystallized during high-grade metamorphism (migmatites) bears mainly two types of spatially closely related fluid inclusions: $N_2$-rich "gaseous" and highly saline aqueous (up to 5 different dxls at room T). Both these compositions have not been found in Alpine quartz and seem to represent preserved high-grade fluids.

Alpine quartz bears variously composed aqueous brines with low to moderate salinity and occasionally $CO_2$, in part additional $CO_2$-rich "gaseous" inclusions. The latter fluid composition is incompatible with the paragenesis comprising sphene and epidote, suggesting coexistence of immiscible fluids[sic]. These fluids must have been introduced during Alpine overprinting, presumably liberated from the overridden Mesozoic sediments, and reequilibrated on their way through the nappe pile allowing for retrograde metamorphism.

The density of the inclusions is in part compatible with P-T conditions inferred for a late stage of pervasive deformation; the lower values reflect the subsequent stage of rapid near-isothermal uplift, however. The early stages of Alpine metamorphism at rather high P are not reflected by inclusion density, suggesting decrepitation of respective inclusions.

The relations between composition and density of the inclusions, their shape, size, arrangement and the microstructures of the enclosing quartz are discussed individually with respect to trapping and post-trapping processes, and petrological evolution. (From the fluid-inclusion section of the author's abstract, translated by E.E. Horn).

See also Stöckhert et al., 1985, Fluid Inclusion Research, v. 18, p. 403-404. (E.R.)

STUDEMEISTER, P.A. and KILIAS, Stephanos, 1987, Alteration pattern and fluid inclusions of gold-bearing quartz veins in Archean trondhjemite near Wawa, Ontario, Canada: Econ. Geol., v. 82, p. 429-439. First author at Portland Cement Assoc., 5420 Old Orchard Road, Skokie, IL 60077-4321.

Systems of auiferous quartz veins occur in Archean granitic rocks within 1.6 km of the Wawa greenstone belt, 80 km northeast of Wawa, Ontario. Mass balance calculations suggest that the alteration of granititc rocks added K, $CO_2 + H_2O$, Rb, and Ba and removed Na.

Three types of P fluid inclusions coexist in quartz from the auriferous vein systems. Type I, the most abundant type, is an aqueous solution with 10 to 25 vol % $CO_2$ with density of 0.75 g/cm$^3$; Th range from 220° to 360°C. Type II is nearly 100 vol % liquid $CO_2$, with a density of 0.95 g/cm$^3$. Type III, the least abundant type, is an aqueous liquid with 10 to 50 vol % $H_2O$ gas; Th range from 120° to 220°C. Apparent salinities of types I, II, and III, based on clathrate and ice melting points, are estimated to be 4 to 8, 0, and 11 to 14 eq wt % NaCl, respectively.

The preferred interpretation is that the gold-bearing quartz veins formed from $CO_2$-laden fluids of less than 10 eq wt % NaCl during regional greenschist metamorphism of granitic rocks. The three types of fluid inclusions may represent two or three different generations of fluids trapped over a range of T and P. Another possibility is that the fluid inclusions represent samples of a fluid comprised of immiscible $CO_2$ and $NaCl-H_2O$ phases, entrapped during quartz crystallization. The source of the gold is not known. (From the authors' abstract)

SUDHARTO, R.T., 1986, Mineralization at Gunung Limbung, west Java, Indonesia: M. Phil. dissertation, Univ. London.

Quartz veins containing sulphides of Cu, Pb, and Zn and trace Au and Ag occur in a quartz dioritic intrusion at Gunung Limbung in west Java (Indonesia).

The formation of ore resulted in alteration within the wall rock around the mineralization zones, which zonally shows changes toward the ore zone from: propylitization (at the outer margin) to sericitic-silicic-potassic alteration, and advanced argillic alteration at the ore zone.

The origins of the ore metals are still uncertain, but they could have been derived from either the country rock or from the (later) quartz diorite intusion.

The T of the mineralization by the fluids was 260° to 350°. Two fluids were involved, one with a low salinity (0.2%-5% wt NaCl eq.) with a high Ca/Na ratio and one with a higher salinity (10%-15% wt NaCl eq.) with a low Ca/Na ratio. [There was no evidence for boiling.]

The hydrothermal solutions were probably meteoric/connate water mixed with magmatic fluids from the quartz dioritic intrusions. (From the author's abstract)

SUGAKI, Asahiko, SCOTT, S.D., HAYASHI, Kenichiro and KITAKAZE, Arashi, 1987, $Ag_2S$ solubility in sulfide solutions up to 250°C: Geochem. J., v. 21, p. 291-305.

SUGAKI, Asahiko, UENO, Hirotomo, SHIMADA, Nobutaka, KITAKAZE, Arashi, HAYASHI, Kenichiro, SANJINES, Orlando and VELARDE, Oscar, 1986, Geological study on the ore deposits in the Sur Lipez district, Bolivia: The Sci. Repts., Tohoku Univ., v. 16, no. 3, p. 327-352 (in English).

Th and salinity in NaCl eq of liquid inclusion in quartz and sphalerite from San Antonio de Lipez (Systema 1 and 2) and Buena Vista (Once) mines are as follows: 157° to 317°C and 1.2 to 16.1 wt %, and 160° to 305°C and 4.4 to 5.8 wt %, respectively. (From the authors' abstract)

SUGIYAMA, T. and TAKATORI, K., 1987, Exploration of gold deposits using the new decrepitation system (abst.): Mining Geol., v. 37, no. 1, p. 83 (in Japanese).

SULLIVAN, George and BARKER, Colin, 1987a Chemical and volatile analysis of the Banco Bonito obsidian, Valles Caldera, New Mexico (abst.): EOS, v. 68, p. 1512. Authors at Dept. Geosci., Univ. Tulsa, Tulsa, OK 74104.

The VC-1 bore hole penetrated 180 m of the Banco Bonito obsidian on the rim of the Valles Caldera. Samples analyzed by electron microprobe showed two generations of phenocrysts. Resorption, rounding and zoning of one group implied phenocryst-melt disequilibrium, while the other group appeared to be in equilibrium with the high Si, high K glasses. Rapid scanning mass spectrometry was used to determine the composition of volatiles in individual fluid and/or melt inclusions. Heated samples showed a bimodal release of volatiles with the first inclusions rupturing at around 1050°C and containing mainly water. The second group of inclusions ruptured at about 1300°C and were rich in sulfur dioxide with variable amounts of carbon dioxide. Preliminary data suggest that the sulfur-rich gases are associated with the corroded group of phenocrysts. Both the gas composition and microprobe data on the glasses and melt inclusions are consistent with a model of mixing of two acidic magmas. Changing ratios of oxidized and reduced compounds of carbon and sulfur show changing oxygen fugacity during magma development. (Authors' abstract)

SULLIVAN, G.E. and BARKER, Colin, 1987b Volatile content of fluid inclusions in rhyolites and calcite veins from the VC-1 core hole, Valles caldera, New Mexico (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Authors at Geosci. Dept., Univ. Tulsa, Tulsa, OK 74105.

Samples from the VC-1 core hole have been analyzed using rapid scanning mass spectrometry to determine the volatile content in fluid inclusions. The samples are of two types. The first is rhyolitic in composition and consists of three obsidians and one pumice which are all volcanic. In contrast the second type consists of four calcite vein fill material from the Abo and Modera Formations which were introduced later presumably by circulating formation fluids. The obsidians contain $H_2O$, $CO_2$, CO, and $H_2S$ as dominant volatile constituents. These samples showed a bimodal release of volatiles from the inclusions, the first occurring between 1000-1150°C and consisting mostly of $H_2O$ with minor amounts of the other species, and the second occurring between 1200-1400°C and having variable composition but with $CO_2$ and CO usually dominating. The lower T releases from the obsidians were much slower than the higher T releases. The obsidians contained numerous microphenocrysts which may explain the bimodal release, because some of the inclusions could have originated within the glass and others within the microphenocrysts. Inclusions in the pumice began decrepitating at 1272°C and contained variable amounts of $CO_2$, $H_2O$, CO and $SO_2$ with the $CO_2$ dominating. The presence of $SO_2$ is an interesting contrast with the obsidians where $H_2S$ is the dominant sulfur species. The inclusions in the calcite vein fill material decrepitated between 320°-475°C. These inclusions in the calcite vein fill material decrepitated between 320°-475°C. These inclusions contained mostly $H_2O$ with variable, but minor, amounts of $CO_2$ and CO. (Authors' abstract)

SUN, S.-S. and EADINGTON, P.J., 1987, Oxygen isotope evidence for the mixing of magmatic and meteoric waters during tin mineralization in the Mole Granite, New South Wales, Australia: Econ. Geol., v. 82, p. 43-52. Authors at CSIRO Div. Min. Phys. & Mineral., P.O. Box 136, North Ryde, New South Wales 2113, Australia.

Oxygen isotope measurements of quartz in the tin-mineralized, Permian Mole Granite, New South Wales, support a model of progressive mixing of magmatic water and surface-derived water of meteoric origin in mineralizing hydrothermal circulation systems.

The magmatic water, observed as multiphase fluid inclusions in hydrothermal quartz-biotite-orthoclase-topaz-bearing pegmatites, had a high T (550°C), high salinity (55-75 wt %), and a $\delta^{18}O$ SMOW value of about 8.7 per mil. The initial magmatic $\delta^{18}O$ SMOW value of the granite is estimated to be about 9 per mil.

The meteoric water, observed as liquid-rich fluid inclusions in quartz from late veins of quartz-sphalerite-galena, had a low T (250°C), low salinity (3-5 wt %), and a $\delta^{18}O$ SMOW value of -15 per mil. Permian meteoric water is expected to be light isotopically, owing to a near polar (70°) paleolatitude for the New England fold belt.

Quartz from cassiterite-quartz-chlorite-sericite ores has a wide range of $\delta^{18}O$ values, from -2.8 to +6.7 per mil. This is intermediate between the values for quartz deposited from magmatic and from meteoric waters. The fluid inclusions in these samples have Th of ~300°C and a wide range of salinities (25-35 wt %). The variation in isotopic composition observed for quartz is attributed to a fluctuating isotopic composition of the hydrothermal solutions resulting from variable degrees of mixing of magmatic and meteoric water. Cassiterite has a narrow range of $\delta^{18}O$ (-5.9 to -7.2%.), which suggests precipitation of cassiterite over a narrow range of mixing of the hydrothermal fluids. Three cassiterite-quartz mineral pairs, with textures indicating synchronous crystallization, imply cassiterite-water fractionations of -2.2 per mil at 300°C and -4.1 per mil at 370°C.

Hydrogen isotope data are less systematic due to postcrystallization isotopic exchange of hydrous minerals and the presence of younger fluids in secondary fluid inclusions in quartz. (Authors' abstract)

SUN, T.T., 1987, Structural aspects of fingerprint inclusions in corundum: The Australian Gemmol., v. 16, p. 188-190.

SUSHCHEVSKAYA, T.M., 1987, The main peculiarities of chemical composition of tin-bearing fluids (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 127-128. Author at Vernadsky Inst. Geochem. & Anal. Chem., USSR Acad. Sci., Moscow, USSR.

Chemical data on fluid inclusions in minerals from different types of Sn deposits, such as cryometric data, water leachates and gas chromatography analyses, and stable isotopes, can be summarized as follows:

1. The mineral-forming solutions of Sn deposits are characterized by a wide range of salinity (S) values, with a gradual decrease to the end of the process; the interval of 5-10 wt% is the most typical for the deposition of cassiterite ores. The main components of solutions, Na, Cl, $HCO_3$, $CO_2$, prevail over Li, $NH_4$, Mg, Ca, F, $N_2$, $CH_4$, S, CO and such microcomponents, such as rare and ore elements, and rare gases. Dominance of Na and Cl is typical (Na > K > Ca, Cl > $HCO_3$). The $CO_2/CH_4$ ratio averages 10 for the

quartz-cassiterite stage. The sulfide concentration is close to $10^{-3}$ M for the solutions depositing the quartz-cassiterite-arsenopyrite mineral association, and it is $10^{-2}$ M for the solutions forming the mineral association of the main sulfide stage (pyrrhotite-chalcopyrite-stannite). Complexes in the ore-forming solutions are typical for all the main elements, as follows from computer calculations, the degree of complexing of ore, rare elements, of sulfur and fluorine being more than 90%.

2. The evaluation of the acidity of the Sn-bearing solutions shows that the deposition of the main cassiterite ores takes place under the increase in the pH. The transition from the earlier pre-ore mineral associations to productive quartz-cassiterite associations is accompanied by a decrease in acidity, chlorinity, and by the increase in the $\lg f(O_2)$.

3. O and H isotope ratios of the mineralizing fluids, calculated from the analyses of vein minerals of Sn deposits and from water extracted from fluid inclusions, suggest that waters of different chemical composition and origin enter the ore-forming systems.

On the basis of a detailed analyses of the data on several deposits of the Far East of USSR, a physico-chemical scheme of formation of the cassiterite mineralization is proposed according to which the main factor is a regular alteration of the redox conditions. (Author's abstract)

SVERJENSKY, D.A., 1987, The role of migrating oil field brines in the formation of sediment-hosted Cu-rich deposits: Econ. Geol., v. 82, p. 1130-1141.

SVERJENSKY, D.A., SHOCK, E.L. and HELGESON, H.C., 1987a Prediction of the dissociation constants of aqueous inorganic metal complexes to 1000°C and 5 kb (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 861.

SVERJENSKY, D.A., SHOCK, E.L. and HELGESON, H.C., 1987b, Thermodynamics of aqueous metal complexes at high temperatures and pressures (abst.): Terra Cognita, v. 7, no. 2-3, p. 128. Authors at Dept. Earth & Planet. Sci., The John Hopkins Univ., Baltimore, MD, USA.

See previous item. (E.R.)

SWATTON, S., 1987, Structural, mineralogical and isotope study of the Bullmoose Lake gold deposit - N.W.T., Canada: MSc thesis, Univ. Alberta.

The Bullmoose Lake Au deposit is located in Archean metasediments of the Burwash Formation, Yellowknife Supergroup. The majority of the Au was recovered from en echelon blue-grey quartz veins hosted by a relatively narrow zone of silicified metapelites and graded metagreywackes. The auriferous quartz veins were emplaced at sites of dilation that were generated during left-lateral shear. Schistosity and two phases of folding were produced during one continuous metamorphic event which showed an increase in its intensity towards the end of metamorphism.

Isotopic, fluid inclusion, and mineralogical data are consistent with emplacement of Au after peak metamorphism. Available physical and chemical constraints on Au mineralization in volcanic shear zone deposits and their similarity to metasediment-hosted Au deposits, in some respects, makes it likely that the auriferous fluids were derived by devolatilization of the Slave supracrustal rocks during low- and medium grade-metamorphism. The Au was transported by 'single pass' flow mechanisms as a reduced sulphur complex in reduced near neutral fluids of varying $CO_2$, salinity and $CH_4$ content. The fluids were focused locally into horizons and beds which had fractured, due to their relatively low tensile strength.

The mineralogy shows two slightly different paragenetic stages during which Au emplacement occurred. An early stage ('main-phase') in which Au is mainly associated with Fe-sulphides and a later cross-cutting stage ('late-phase') in which Au is more often associated with galena, sphalerite and chalcopyrite. The temperatures of deposition of the 'main-phase' mineralization are unclear; however, the 'late-phase' minerals were deposited between 140° and 300°C.

Deposition of Au took place due to: (1) a fluid-T reduction, (2) reduction of the fluid by interaction with graphitic horizons and/or (3) by sulphidation of Fe-rich host-rocks.

This deposit, and many similar metasediment-hosted Au deposits worldwide, is characterized by very narrow, patch wall-rock alteration, inferring low water to rock ratios. This alteration style and the varied sulphide mineralogy associated with Au mineralization at Bullmoose Lake indicates rapid precipitation of Au from several pulses of fluid. (Abstract as printed in Int'l. Liaison Group on Gold Mineralization Newsletter No. 5, 1987, p. 55.)

SWEENEY, R.L., 1987, Stable isotope geochemistry of calcite and limestone at Naica, Chihuahua, Mexico: MS thesis, The Univ. Arizona, 55 pp.

Fluid inclusion data from ore calcite gave T of 154-327°C, which were consistent with Type B inclusions in fluorite from Erwood, et al. (1979). Water/rock ratios range from 1.0 to >10.0 indicating a large fluid flux. Previous workers suggest a magmatic fluid as the source for mineralization at Naica [but] this study indicates some form of mixing was present, possibly with meteoric water. (From the author's abstract)

SYMONDS, R.B., ROSE, W.I., REED, M.H., BRIGGS, Paul and GERLACH, T.M., 1987, The speciation and fluxes of gases from Augustine volcano, Alaska: A system rich in halides and transition metals (abst.): Hawaii Symp. on How Volcanoes Work, Abst. Volume, Hilo, Hawaii, Hawaiian Volcano Observatory, p. 247.

SYMONDS, R.B., ROSE, W.I., REED, M.H., LICHTE, F.E. and FINNEGAN, D.L., 1987, Volatilization, transport and sublimation of metallic and non-metallic elements in high temperature gases at Merapi Volcano, Indonesia: Geochimica Cosmo. Acta, v. 51, p. 2083-2101.

SZUSTAKOWSKI, R.J. and SIEGEL, D.I., 1987, Chemical evolution of formation brines in western New York (abst.): EOS, v. 68, p. 320. Authors at Dept. Geol., Syracuse Univ., Syracuse, NY 13244-1070.

The chemical composition and isotopic content of brines in Silurian and Devonian rocks of western New York were determined to evalute their chemical evolution. Ratios of the logarithms of calcium, sulfate, sodium and chloride concentrations with respect to bromide suggest that gypsum and halite precipitated from evaporated sea water early in the brine history. Saturation that dolomitization, aluminosilicate mineral formation and multiple episodes of calcite dissolution and precipitation have subsequently modified brine chemical composition. [sic] The DEL 0-18 and DEL D contents of most of the brines are depleted by about -3%. and -40%. respectively (SMOW). This depletion and the plots of the logarithms of major solute concentrations against bromide further suggest that concentrated sea water was diluted as much as one third with normal sea water between the times of initial evaporation and rock-water interactions. (Authors' abstract)

TACKER, R.C. and CANDELA, P.A., 1987, Partitioning of molybdenum between magnetite and melt: A preliminary experimental study of partitioning of ore metals between silicic magmas and crystalline phases: Econ. Geol., v. 82, p. 1827-1838.

TAKACH, N.E., BARKER, Colin and KEMP, M.K., 1987, Stability of natural gas in the deep subsurface: Thermodynamic calculation of equilibrium compositions: The Am. Assoc. Petrol. Geol. Bull., v. 71, no. 3, p. 322-333. First author at Univ. Tulsa, Tulsa, OK 74104.

The deepest hole in a sedimentary section is currently 31,441 ft (9,583 m), but the deepest production is only 26,536 ft (8,088 m); the depth gap between deepest hole and deepest producer is the largest in the history of the petroleum industry. This prompts a critical reevaluation of methane stability in deep potential reservoirs.

We developed a computer program to calculate the equilibrium composition of gases in deep reservoirs of various lithologies, to T and P corresponding to conditions down to 40,000 ft (12,192 m). Calculated equilibrium compositions show that methane alone in an inert reservoir has considerable stability, and 99.4% survives to 40,000 ft (12,192 m). Even in the geologically more realistic system with water, 99.1% survives.

The full capability of the program is demonstrated for a sandstone reservoir with graphite, calcite cement, and a range of minor minerals. There, methane shows considerable stability for average geothermal gradients with both normal and abnormal P. For high geothermal gradients, part of the methane is lost by reaction, and significant amounts of carbon dioxide are added to give a gas composition at 40,000 ft (12,192 m) that contains only 9% methane. The program shows that, in general, T is much more important than P in controlling gas composition, crude oil is not thermodynamically stable at any depth, and a few percent of hydrogen is frequently present in deep gases. (From the authors' abstract)

TATSUMI, Yoshiyuki and NAKAMURA, Noboru, 1986, Composition of aqueous fluid from serpentinite in the subducted lithosphere: Geochm. J., v. 20, p. 191-196. First author at Dept. Geol. & Mineral., Fac. Sci., Kyoto Univ., Kyoto 606, Japan.

High pressure experiments up to 4.0 GPa on natural serpentinite, one of constituent members of the hydrated subducted oceanic lithosphere, show that it decomposes totally below 700°C. The results suggest that the serpentinite-derived aqueous fluid can be supplied to the mantle wedge only beneath the fore-arc region. The concentration of Rb, Sr and Yb in the aqueous fluid released through the dehydration process of serpentinite are estimated on the basis of open-system dehydration experiments under 1.5 and 3.0 GPa, in which the fluid is lost through perforations on a gold sample container; the aqueous fluid transports a larger amount of an element with a larger ionic radius under higher P. (Authors' abstract)

TAYLOR, H.P., Jr., 1987, Comparison of hydrothermal systems in layered gabbros and granites, and the origin of low-$^{18}$O magmas, in B.O. Mysen, ed., Magmatic Processes: Physicochemical Principles: Geochem. Soc. Spec. Pub. 1, p. 337-357.

TAYLOR, Peter and LOPATA, V.J., 1987, Some phase relationships between basic bismuth chlorides in aqueous solutions at 25°C: Can. J. Chem., v. 65, p. 2824-2829.

TAYLOR, W.R. and GREEN, D.H., 1987, The petrogenetic role of methane: Effect on liquidus phase relations and the solubility mechanism of reduced C-H volatiles, in B.O. Mysen, ed., Magmatic Processes: Physicochemical Principles: Geochem. Soc. Spec. Pub. 1, p. 121-138.

TERRINHA, P.A.G., DORIA, A., ALMEIDA, A., NORONHA, F. and BARRIGA, F.J.A.S., 1987, Tectono-thermal variations along the Vilarica fault, NE Portugal: A preliminary textural and fluid inclusion study (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 153. First author at Dept. Geol., Fac. Ciencias de Lisboa, 1294 Lisboa Codex, Portugal.

The Vilarica sinistral wrench fault (NNE-SSW; 250 km) is a major example of late Hercynian fracturing in the Iberian Peninsula. It hosts several important quartz veins, up to ≈ 20 m thick and ≈ 2 km long. Study of these provides one of the best means of placing constraints on the tectono-thermal regime of the fault.

Field, hand specimen and thin section data on outcrops from Pocinho to Franca show that all quartz exposures have experienced significant post-depositional deformation, that took place in a brittle regime in the South, and under progressively more ductile conditions towards the North. Maximum Th found in ≈ 100 fluid inclusions are in good agreement with this: 300°C at Terrincha (to the South), 270°C at Quintela and 380°C at Franca (extreme North). We note however, that at Terrincha and Quintela we found only S, low salinity (<1.6 wt% eq. NaCl) inclusions, possibly unrelated to quartz precipitation. At Franca we were able to study a greater variety of fluid inclusions, in quartz associated with sulphides, carbonates and Au-Ag mineralization.

These include P inclusions, with salinities in the range 1.5-10 wt% eq. NaCl, appreciable $CO_2$ contents (with low density ≈ 0.2 g/cm$^3$) and probably $CH_4$ (≈ 0.05 mole%) and S inclusions with salinities up to 18 wt% eq. NaCl, and undetected $CO_2$ or other volatiles, suggestive of important compositional variations in the course of hydrothermal activity. P estimates (by the method of Malinin and Naumov) suggest 1.3 Kb at the minimum confining P at the time of P inclusion trapping. (Authors' abstract)

THEMELIS, Ted, 1987 "Nailhead" spicule in emerald: Lapidary J., v. 40, p. 19. Author at GEMLAB, INC., P.O. Box 6333, Clearwater, FL 33518.

Diagram and photo shows a fluid inclusion in synthetic hydrothermal emerald in which (apparently) the enclosure of a solid phenacite crystal caused the trapping of fluid (now with a small bubble). (E.R.)

THEODORE, T.G., BLAIR, W.N. and NASH, J.T., 1987, Geology and gold mineralization of the Gold Basin-Lost Basin mining districts, Mohave County, Arizona: U..S. Geol. Survey Prof. Paper, Rept. No. P 1361, 167 pp.

THOMAS, A.V. and SPOONER, E.T.C., 1987, Fluid inclusions in the system $H_2O$-$CH_4$-NaCl-$CO_2$ from the border unit Tanco granitic pegmatite, S.E. Manitoba (abst.): GAC-MAC, AGC-AMC Joint Ann. Mtg., Program with Absts., v. 12, p. 95. Authors at Dept. Geol., Univ. Toronto, Toronto, Ontario, M5S 1A1.

Investigation of 132 inclusions in tourmaline from the border unit of the Tanco pegmatite has revealed the presence of significant $CH_4$ in many of the primary inclusions. These inclusions are hosted in tourmaline which has replaced a thin wall rock screen stopped off into the pegmatite about 1 cm from the main footwall amphibolite contact. At room temperature and pressure the inclusions consist of two phases, liquid $H_2O$ (~80 vol.%) and fluid $CH_4$ (~20 vol.%). On cooling below -95°C a third phase, liquid $CH_4$ nucleates in the inclusions. In many inclusions liquid and vapor $CH_4$ rehomogenize with critical behavior on heating to -83.2 ± 4.1°C, (n = 32). This critical temperature identifies the fluid in the inclusions as $CH_4$. However, in some inclusions the $CH_4$ homogenized into the vapor phase. Densities of the $CH_4$ in the latter inclusions can be calculated using the equations of Jacobs & Kerrich (1981) ($\mu$ = 0.09, $\sigma$ =0.01, n = 17). The salinities of the aqueous phase of these inclusions have been estimated using the intersection of the individual $CH_4$ isochores for the inclusions with melting curves for $CH_4$ clathrate in aqueous solutions of varying salinity. The salinities estimated in this way are 7-10 wt% NaCl. The $CO_2$ to $CH_4$ ratio can be calculated from those inclusions in which the critical point of the $CH_4$ was elevated above that for pure $CH_4$. The elevations observed in this study indicate X $CO_2$ in $CH_4$ = 0-0.02. Such low levels of $CO_2$ have very little effect on the positions of the curves for clathrate melting and, therefore, on salinity. Total homogenization temperatures for the inclusions are 371 ± 36°C (n = 91). These homogenization temperatures are minimum trapping temperatures for the border unit tourmaline. A pressure correction of ~200°C is necessary for the 2 kbar crystallization pressure of the pegmatite giving trapping temperatures of ~550°C. (Authors' abstract)

THOMAS, Rainer and TISCHENDORF, Gerhard, 1987, Evolution of Variscan magmatic-metallogenetic processes in the Erzgebirge according to thermometric investigations: Z. Geol. Wiss. Berlin, v. 15, p. 25-42.

The analysis of more than 30,000 thermometric measurements on melt and gas/liquid inclusions in minerals from deposits and occurrences of the Variscan-ensialic magmatic-metallogenetic stage of the Erzgebirge and Vogtland provided, in connection with age determinations, a wealth of data and information to estimate the evolution of the P-T conditions in space and time and to establish some physicochemical parameters of the hydrothermal systems of the postmagmatic mineralizations.

In the first sections essential results of the investigations on melt inclusions are presented. The remaining sections are devoted to some aspects of evolution of the hydrothermalites connected directly or indirectly with the granites. (Authors' abstract)

THOMPSON, A.B., 1987a Some aspects of fluid motion during metamorphism: J. Geol. Soc., London, v. 144, p. 309-312.

THOMPSON, A.B., 1987b The escape of metamorphic fluids and anatectic melts from rocks undergoing metamorphism (abst.): Abstracts, NATO Advanced Research Workshop, Fluid movements, element transport, and the composition of the deep crust, Lindås, Norway, 18-24 May, 1987 (unpaginated).

THOMPSON, J.M. and FOURNIER, R.O., 1987, Geothermometry and chemistry of the Salton Sea brine, California (abst.): EOS, v. 68, p. 454. Authors at U.S. Geol. Survey, Menlo Park, CA 94025.

The first flow test of the Salton Sea Scientific Drilling Project (SSSDP) on December 29, 1985, tapped fluid from 1865 to 1877 m, at a reservoir temperature of 305 ± 5°C. A second flow test at 5170 m produced brine contaminated by drilling fluid and diesel oil. Therefore, we focus on the first flow test. Five samples were collected at different flashing pressures. Measured potassium and calcium concentrations correlate well with variations in density of the flashed brine. Measured chloride and sodium concentrations do not correlate as well with density. The calculated anion charge is generally about 10 percent greater than the cation charge. With the assumption that the potassium and calcium concentrations were determined more accurately and precisely, the sodium chloride concentration in the brine can be calculated based on a density model for the system $NaCl-CaCl_2-KCl$ at 25°C. The major element concentrations in the reservoir fluid prior

Calculated Reservoir Fluid Prior to Flashing

| Ion | Conc. (ppm) | Geothermometer | Temp °C |
|---|---|---|---|
| Na | 54,800 | Na/K | 325 |
| K | 13,900 | Na-K-Ca | 295 |
| Ca | 26,850 | Mg-K | 340 |
| Mg | 33 | Mg-Li | 270 |
| Li | 147 | Na-Li | 370 |
| Cl | 144,700 | | |
| $SiO_2$ | 777 | | |

to flashing were calculated using enthalpy-dissolved constituent relations. The results are given below along with reservoir temperatures calculated using various chemical geothermometers. A silica value is calculated based upon salinity and temperature of preflashed brine. The amount of flash is 19% at a separation pressure of 19 ± 1.5 bars. (Authors' abstract)

THORR, P.G., 1985, The geology of the Chicote Sn-W hydrothermal system, Bolivia 1985: PhD dissertation, Univ. Aberdeen, U.K.

The Chicote Sn-W hydrothermal system is situated in Lower Paleozoic sediments of the Eastern Cordillera of Bolivia. No igneous rocks are exposed in the project area. W-bearing quartz-sulphide veins are restricted to an area of pervasive sericite-quartz-tourmaline alteration whilst peripheral to this Sn mineralization is found in clayey, fault gouge material. An outermost zone of Pb mineralization is poorly developed. K-Ar dating of whole rock material from the pervasive alteration zone indicate a maximum age of 26.1 My for the mineralization. There appears to be some structural control on the hydrothermal alteration and mineralization from a N-S trending fault and, to a lesser extent, the sedimentary bedding.

A lithogeochemical survey has shown that Cu, Sn, W, As, Rb and the Rb/Sr ratio have positive anomalies centered on the pervasive alteration zone whilst Zn, Pb, Mn and Sr have negative anomalies.

Fluid inclusion studies show that the main stage of mineralization, in which the W was deposited, took place at depths of 2,000-4,000 m from fluids at 335-530°C and salinities of 17-48 eq. wt. % NaCl. Later stage quartz was deposited from fluids at 240-425°C and salinities of 10-22 eq. wt. % NaCl. This gave way to siderite-sphalerite precipitation from fluids at 195-295°C containing 6-11 eq. wt. % NaCl. Stable isotope analyses suggest that the mineralizing fluids were of magmatic origin and that there was little influence from meteoric waters.

The age relationship of the W and Sn mineralizations is not clear but the Sn is considered to be older than the W and was deposited from fluids at 170-390°C.

The Chicote mineralization is considered to have formed from hydrothermal fluids of magmatic origin derived from a buried felsic pluton. The mineral zoning and lithogeochemical zoning patterns are ascribed to magmatic hydrothermal processes. (Author's summary)

TIETZ, G.F., 1987, Solution and healing features in quartz grains from an Upper Cretaceous sandstone (SW-Nigeria): Facies, v. 17, p. 267-276 (in German; English abstract). Author at Inst. Paläontologie der Univ., Loewenichstr. 28, D-8520 Erlangen.

Pertinent to the interpretation of inherited and new primary inclusions in sediments. (E.R.)

TINGLE, T.N. and AINES, Roger, 1987, Infrared spectroscopy and beta track autoradiography bearing on the solubility of carbon dioxide in albite melt at 2.0 GPa and 1450°C (abst.): EOS, v. 68, no. 16, p. 436. First author at Dept. Geol., Univ. California, Davis, CA 95616.

These results indicate that $CO_2$ solubilities in albite determined by IR (Fine and Stolper, 1985; Fine et al., 1987) are to be preferred over those measured by BTA (Mysen et al., 1976). For diopside, $CO_2$ contents measured by BTA agree with the loaded $CO_2$ contents, verifying that $CO_2$ solubilities in diopside melt measured by BTA (Mysen et al., 1976; Mysen and Virgo, 1980) are most likely accurate. (From the authors' abstract)

TINGLE, T.N. and GREEN, H.W., II, 1987, Carbon solubility in olivine: Implications for upper mantle evolution: Geology, v. 15, p. 324-326.

Authors at Dept. Geol., Univ. California, Davis, CA 95616.

Volcanic activity worldwide and carbonaceous phases in mantle xenoliths demonstrate that carbon is present in trace amounts in the modern mantle. We have determined that carbon solubility in olivine at 0.1 GPa and 1200°C is below our detection limit (30 ppm by weight) but dissolves in excess of 100 ppm wt at 3.0 GPa, 1180-1530°C. The significant solubility in mantle silicates may explain the rarity of carbonate-bearing xenoliths and the extreme age of diamonds. We propose a model in which low-P melting during mantle convection scavenges H and C from the primitive mantle and thereby reduces the content of these volatiles to below the silicate saturation limit and restricts carbonaceous and hydrous phases to the roots of continents isolated from convection. (Authors' abstract)

TONN, H., SCHMIDT, F.-P., PORADA, H. and HORN, E.E., 1987, Studies of fluid inclusions in Zechstein as contribution to the genesis of the copper-bearing shales (abst.): Fortschritte der Mineralogie, Bd. 65, Bhf. 1, p. 184 (in German). Authors at Inst. Geol. & Dynamics of Lithosphere, Univ. Göttingen, FRG.

Fluid inclusions were studied in specimens of drill cores from the areas of Richelsdorf and Spessart-Rhön Uplift, as a part of the exploration project led by St. Joe. Th measured for inclusions in detrital quartz ranged from 265 to 420°C with maximum frequency at 285°C and average salinity of inclusion fluids 5-10 wt.% NaCl eq. In Weissliegende sediments, the ratio of the decrepitated inclusions to intact ones is lower than in Kupferschiefer (copper-bearing shales), indicating the different erosion levels of the source areas. Fluid inclusions in carbonate cement in Weissliegende sediments and in authigenic minerals of the Werra carbonates (Zechstein limestone) have high salinity (>23.3 wt.% NaCl eq.) and average Th 120°C. The measured Te (-57 to -66°C) indicate the presence of bivalent cations like Ca and Mg. (...) (Authors' abstract, translated by A.K.)

TORAMARU, Atsushi, 1987, Bubble size distribution and its kinetics in magmas (abst.): Hawaii Symp. on How Volcanoes Work, Abst. Volume, Hilo, Hawaii, Hawaiian Volcano Observatory, p. 256.

TORGERSEN, T., CLARKE, W.B. and HABERMEHL, M.A., 1987, Helium isotopic evidence for recent subcrustal volcanism in eastern Australia: Geophys. Res. Letters, v. 14, no. 12, p. 1215-1218.

TORREY, C.E., KARJALAINEN, H., JOYCE, P.J., ERCEG, M. and STEVENS, M., 1986, Geology and mineralization of the Red Dome (Mungana) gold skarn deposit, North Queensland, Australia: Proc. of Gold '86 Symp., Toronto, 1986, p. 504-517. First author at Geol. Dept., James Cook Univ. of North Queensland, Townsville 4811, Australia.

Primary Au mineralization occurs in an unusual wollastonite-garnet skarn that is spatially and genetically related to porphyritic rhyolite dikes of Permo-Carboniferous age. Au is associated with Cu and Ag mineralization in the skarn at the contact between a texturally zoned dike and marble. The wollastonite-garnet skarn was originally barren and postdates the dike.

Exploratory fluid inclusion studies suggest a sequential evolution of fluids (Torrey, 1986). Early high T/high salinity (Th = 250°C-520°C and 35-60 wt% NaCl eq.) inclusions occur in crenulate quartz layers, miarolitic cavities and quartz stockworks. Later low-moderate T/low salinity (Th = 200°C-375°C, 2-8 wt% NaCl eq.) inclusions occur as S inclusions in quartz stockworks, and as P inclusions in fluorite of carbonate-quartz-sericite alteration. (From the authors' abstract and text)

TOURAY, J.C., 1987, Gold transport and deposition in fluids from the continental crust: Data from fluid inclusions: Chron. Rech. Min., no. 488, p. 43-53 (in French; English abstract). Author at Univ. d'Orléans, Lab. Métal. & Géoch. Min., 45067 Orléans Cédex 2, France.

First, the possible chemical mechanisms relative to native Au precipitation after destablization of chloride ($AuCl_2$) or bisulfide ($Au(HS)_2$) complexes are discussed. Then the significance of fluid inclusions (F.I.) is discussed with special reference to T-P interpretations; "isotopic" and "geochemical" thermometers are then compared to F.I. data. Third, Au precipitation in present-day geothermal systems and epithermal lode deposits is discussed. In epithermal environments, the characteristics of F.I. are as following: Th scattered in the 150-350°C range, low salinities (with exceptions), low amounts of dissolved gases, and frequent indications of ancient boiling. This last process is discussed as an actual factor for metal precipitation in epithermal environments.

The fourth part is devoted to "deep-seated lodes," especially those located in the "auriferous shear-zones." The general characters of F.I. for such occurrences: existence of early and late inclusions with distinct Th (250 to 350°C for the former and 100 to 250°C for the later); presence amongst early F.I. of heterogeneous groups with three-phase $CO_2$-rich inclusions and water-dominated ones more or less $CO_2$-laden; significant amounts of $CH_4$ and $N_2$ in several instances; low salinity of early inclusions, variable salinity (sometimes high) of later ones. With respect to a general model of auriferous shear-zones, the early stage with volatile-rich fluids is supposed synchronous with native Au deposition in ore-grade shoots. Mechanical mixing involving injections of an excess of gas of deep origin into local aqueous solutions could explain, through destabilization of bisulfide complexes under variable redox conditions, the precipitation of native Au.

Finally possible applications of F.I. studies to gold prospection are sketched. (From the author's abstract)

TOURET, J., 1986, Fluid inclusions in rocks from the lower continental crust, in The nature of the lower continental crust, J.B. Dawson, et. al., eds.: Geol. Soc. Special Pub. no. 24, p. 161-172.

A review. See next item. (E.R.)

TOURET, J.L., 1987a Peak and post-metamorphic P-T conditions in granulites (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 129-130. Author at Inst. voor Aardwetenschappen, Vrije Univ., de Boelelaan 1085, 1081 HV Amsterdam, The Netherlands.

In most granulites, the abundant fluid inclusions show a wide range of composition and densities. $CO_2$ is by far the dominant fluid, but other species ($H_2O$ ± NaCl, $CH_4$, $N_2$) may be present in variable amounts. Only some $CO_2$- and ($H_2O$ + NaCl) inclusions correspond possibly to peak metamorphic conditions, all others must have been trapped or reequilibrated later. If the time sequence of inclusion formation is known, the succession of corresponding isochores constrain, sometimes severely, the post metamorphic P-T evolution (often called "P.T. uplift path" or "trajectory").

Since the pioneering studies of Hollister, Crawford and co-workers, many examples have been published, but some recent findings and the development of micro-Raman analysis ask for a careful reevaluation of most results:

- When only microthermometric measurements were available, melting T at $CO_2$ triple point (-56.6°C) would indicate pure $CO_2$. In fact, $CO_2$-$N_2$ mixtures may show only unnoticeable melting point depression and, if not checked by micro-Raman analysis $CO_2$-$N_2$ mixtures may be mistaken for high density pure $CO_2$. Particularly important is the fact that, in all cases investigated so far, "$CO_2$ ultra-high densities" (Th lower than triple point) turned out to be much lower density $CO_2$-$N_2$ mixtures (A.M. van den Kerkhof, this volume).

- In earlier studies, it has been - often more or less tacitly - assumed that later inclusions tend to be less dense than former ones (model B, see below). So many examples of a different evolution have been found that this "rule" cannot be accepted any longer, even in first approximation. Direct observation of inclusion chronology remains an essential step. If this is not possible, it constitutes the major limitation to this type of study. A detailed example (southern Norway) shows the extent of this reevaluation of earlier data. Many uncertainties remain, but major trends of possible P.T.-paths seem to be relatively well established. They correspond to 3 models, which may partly occur simultaneously in a given area:

Model A (pseudo isochoric): Post metamorphic P = f(T) follows roughly an high-density $CO_2$ isochore. Early inclusions are well preserved in many minerals (quartz, plagioclase, garnet, pyroxene, etc.), late inclusions are rare (or absent). Several examples have been observed in high P granulite terranes: Tanzania, China.

Model B ("Adiabatic uplift") is characterized by a P = f (T) concave towards the P axis (more rapid decrease of P than T; essentially vertical movements). This "main granulitic trend" is found in most subcontinental granulite areas (India, Africa, etc.).

Model C ("Isobaric cooling"): P = f(T) is concave towards the T axis. This trend is typical of thermal domes; it can be caused by slow cooling at depth of synmetamorphic intrusive masses. Best examples occur in low P granulite areas (Finland), but it can also be related to extensive deformation (horizontal shear zones). Several arguments suggest that model A is restricted to very specific and probably uncommon areas, whereas B and C may coexist in most granulites of regional extension. In most cases, real trajectories correspond probably to a complicated interaction between these 2 trends. (Author's abstract)

TOURET, Jacques, 1987b Fluid distribution in the continental lithosphere, in Proterozoic lithospheric evolution, A. Kroner, ed., Geodynamics Series, v. 17, p. 27-33. Author at Earth Sci. Inst., Free Univ., Amsterdam, The Netherlands.

Synmetamorphic fluid inclusions trapped in rock-forming minerals indicate a systematic change in the fluid regime at depth from $H_2O$- to $CO_2$-dominant. The ubiquity of $CO_2$ in the lower crust is explained by selective removal of $H_2O$ in anatectic melts and related to the emplacement, at depth, of magmatic, mantle-derived carbonate phases. (Author's abstract)

TOURET, J.L.R., 1987c Fluid inclusions in skarns: Direct evidence of metasomatic fluids (abst.): Abstracts, NATO Advanced Research Workshop, Fluid movements, element transport, and the composition of the deep crust, Lindås, Norway, 18-24 May, 1987 (unpaginated). Author at Earth Sci. Inst., Free Univ., P.O. Box 7161, 1007 MC Amsterdam, The Netherlands.

A review, including details on studies of Serifos, Greece, and Arendal, Bamble, Norway. Contrary to currently accepted ideas, it is suggested that Bamble skarns did not develop during the peak of metamorphism, but that they represent premetamorphic, contact metamorphism skarns (Serifos type). They have been later isochemically metamorphosed and they have persisted without major modification through the high grade metamorphic events. (From the author's abstract)

TOURET, J.L.R., 1987d, $CO_2$ transport in the lower crust (abst.): Terra Cognita, v. 7, no. 2-3, p. 133. Author at Earth Sci. Inst., Free Univ., Amsterdam, The Netherlands.

See previous entries. (E.R.)

TRULL, T.W. and KURZ, M.D., 1987, Diffusion of $^3$He and $^4$He in basaltic glasses and geochemical implications (abst.): EOS, v. 68, p. 1543.

TRULL, T.W., KURZ, M.D. and PERFIT, M., 1987, Helium isotopes in subduction zone basalts (abst.): Hawaii Symp. on How Volcanoes Work, Abst. Volume, Hilo, Hawaii, Hawaiian Volcano Observatory, p. 256. First author at Woods Hole Ocean. Inst., Woods Hole, MA 02543.

Helium isotope ratios ($^3$He/$^4$He) range from less than 1 to more than 9 times the atmospheric ratio ($R_a$) in glasses, whole rocks, and phenocryst separates of dredged basalts from, the Woodlark Basin, Western Pacific (Woodlark Spreading Center, WSC). Low concentrations and isotopic disequilibrium between He released by crushing and melting in vacuo suggest that addition of He by radiogenic decay and diffusion from seawater has affected some samples. However, for other samples the initial magmatic $^3$He/$^4$He ratio can be recovered. One important result is that Kavachi Volcano, presently active in the Solomon Islands forearc, exhibits ratios of 6.9 ± .2 $R_a$, significantly lower than is observed in WSC basalts (8-9 $R_a$) just 30-50 km away on the downgoing plate.

This difference may be explained as a contribution of radiogenic He from subducted oceanic crust, or as the result of $^4$He ingrowth during long (20,000 yr.) magma transport times. These results will be discussed in light of magma degassing models and new He diffusion measurements. (Authors' abstract)

TU, Dengfeng, 1987, Studies of inclusions in fluorite from the Shuangjiangkuo-Jiangjunmiao fluorite ore deposit in Hunan Province [China]: Diqiu Huaxue, 1987, no. 3, p. 274-279 (in Chinese). Author at Dept. Geol., Lianyungang Chem. Min. Sch., PRC.

The Shuangjiangkuo-Jiangjunmiao fluorite ore deposit occurs in the Early Yenshanian granites in the fold system of south China. The average Th of inclusions in fluorite is 250°. The contents of $CO_2$ and $CH_4$ in the inclusions increase from southeast to northwest as well as in the vertical direction. Liquids in the inclusions are composed mainly of CaO, F, and Cl with minor $SO_4^{2-}$. These phases contributed to the formation and concentration of fluorite as well as to wall-rock alteration. This ore deposit has a mesothermal origin. (C.A. 107: 220718h)

TU, Kan, 1986, Hydrothermal alteration and molybdenum mineralization of the Dawan molybdenum deposit, Laiyuan County, Hebei Province: Mineral Deposits, v. 5, no. 4, p. 49-61 (in Chinese; English abstract). Author at Dept. Geol., Beijing Univ., Beijing, PRC.

The Dawan porphyry molybdenum deposit is located in a rather small rhyolite porphyry body that contains extremely high $K_2O$ and has dolomite as its wall rock. Three types of alteration are well developed within the porphyry, namely potassic alteration, silicification and green alteration.

At the earlier stage, the inclusions in quartz of ore-bearing veinlets had Th of 460-260°C, salinity 50-16 NaCl wt%, $\delta^{18}O(Q)$ 10.7-8.7‰, and $\delta^{18}O(H_2O)$ 5.7-4.6‰, indicating that molybdenite had been precipitated from hydrothermal solution mainly composed of magmatic water. At the late stage, Th was 260-120°C, salinity 11.8-0.3%, $\delta^{18}O(Q)$ 0.8-0.5‰ and $\delta^{18}$ ($H_2O$) under -10.9‰, suggesting that by this stage, meteoric water had probably played a predominant role in the hydrothermal solutions and $\delta^{18}O$ of whole rock had also been more or less reduced. (From the author's abstract)

TURBEVILLE, B.N., WOLFF, J.A., MILLER, D.J. and LEBAS, M.J., 1987, An oceanic nephelinite-phonolite-carbonatite association, Brava, Cape Verde Islands (abst.): EOS, v. 68, p. 1522. First author at Dept. Gesci., Univ. Texas, Austin, TX 78713.

Several of the phonolites are alkali-rich enough to have equilibrated with natrocarbonatite liquid. (From the authors' abstract)

TURNER, G. and KELLEY, S., 1987, Hydrothermal fluids and argon isotopes in cherts (abst.): Terra Cognita, v. 7, no. 2-3, p. 344-345. Authors at Physics Dept., Univ. Sheffield, Sheffield, UK.

In the Gunflint chert one component is present in minute fluid inclusions visible in thin section. Based on the results of crushing experiments the fluids are chlorine-rich hydrothermal brines containing ancient atmospheric argon and parentless or excess $^{40}$Ar. (From the authors' abstract)

TURPAULT, M.-P., FOUILLAC, A.-M., CATHELINEAU, M., LESPINASSE, M., MEUNIER, A., FEYBESE, J.-L. and LEROY, J., 1987, Recent and ancient hydrothermal circulations in Cezallier: Data of solid and fluid phases and stable isotopes: Géologie de la France, no. 4, 1987, p. 81-99 (in French; English abstract). First author at Lab. Pétrol. des Altérations Hydrothermales, U.A. 721 Univ. de Poitiers.

Petrographic studies, fluid inclusions and stable isotope data were used to study hydrothermal alteration in veins and adjacent altered rocks of the Chassole gneiss (Cézallier) drill hole. Crosscutting relationships between several veins allowed the determination of a relative chronology with the following inclusion data: 1) euhedral quartz (type I); 2) quartz-orthose[orthoclase]-sulfides (pyrite, mispickel, blend) ± white micas (phengite, muscovite), veins (T ± 400-300°C); 3) prehnite ± K-feldspar ± euhedral quartz (type II) ± calcite (type A) veins (T <200-180°); 4) chlorite veins; 5) illite veins; 6) illite-smectite mixed layer veins; 7) calcite (type B) veins, siderite veins and siderite breccia (T <80°C).

A stable isotope study was performed on actual and ancient hot spring travertine and also recent hydrothermal alteration secondary minerals from the Chassole drill hole. This confirmed the existence of two families (A and B) of calcite; the association between calcite B and siderite; and the relationships between present fluid and latest secondary minerals, in particular that it is impossible for the random mixed layer illite-smectite to precipitate from the actual fluid under present conditions. We proved the existence of two geothermal systems. We wonder if the most recent secondary minerals are due to one or more fluids. (From the authors' abstract)

TUTTLE, M.L., LOCKWOOD, J.P., KLING, G.W., EVANS, W.C. and DEVINE, J.D., 1987, The catastrophic release of mantle-derived $CO_2$ from Lake Nyos, Cameroon (abst.): GSA Abst. with Programs, v. 19, p. 339. First author at U.S.G.S., MS 916, Box 25046, Denver, CO 80225.

The lake contains dilute (I = 0.016 m) Mg-Fe-$HCO_3$ water with low amounts of Cl and $SO_4$ (<1 ppm); F was <0.1 ppm. As much as 720 mg/l $HCO_3$ is present at pH's as low as 5.2. $\delta^{18}O$ and $\delta D$ for lake-water samples, together with water chemistry, suggest that the lake water has a complex hydrologic origin involving input from both springs and rainwater, but not magmatic waters. Gas samples collected from 220 meters contain 98% $CO_2$ with $\delta^{13}C$ averaging -3.3 per mil and very low $^{14}C$ values. Minor amounts of $CH_4$ (0.29%) and traces of He with a significant primordial component ($R_A$ = 6) were found, but no $H_2S$, $SO_2$, HCN, or CO were detected. The $CO_2$ released from Lake Nyos is from a deep mantle source as supported by the isotopic composition of C and He. Our data suggest that mantle $CO_2$ accumulated in the bottom waters of Lake Nyos until being released on August 21. (From the authors' abstract)

TYBURCZY, J.A., 1987, Upper limits to the water content of the oceanic upper mantle from modeling of electrical conductivity profiles (abst.): EOS, v. 68, p. 1503.

TYUREMNOV, V.A., VINOGRADOV, A.N. and VINOGRADOVA, G.V., 1987, Effect of gas-liquid inclusions in minerals of some rocks on their high-temperature electrical conductivity: Geofiz. Zh., v. 9, no. 4, p. 59-63 (in Russian).

ULMER, G.C. and BARNES, H.L., eds., 1987, Hydrothermal experimental techniques: John Wiley & Sons, New York, 523 pp.

ULMER, G.C. and nine others, 1987, The mantle redox state; an unfinished story?: Geol. Soc. Am. Spec. Paper 215, p. 5-23.

UNDERWOOD, M.B. and HOWELL, D.G., 1987, Thermal maturity of the Cambria slab, an inferred trench-slope basin in central California: Geology, v. 15, p. 216-219. First author at Dept. Geol., Univ. Missouri, Columbia, MO 65211.

Uses vitrinite reflectance. (E.R.)

URABE, Tetsukro, 1987, The effect of pressure on the partitioning ratios of lead and zinc between vapor and rhyolite melts: Econ. Geol., v. 82, p. 1049-1052.

URABE, T. and 15 others, 1987, Hydrothermal sulfides from a submarine caldera in the Shichito-Iwojima Ridge, northwestern Pacific: Marine Geol., v. 74, no. 3-4, p. 295-299.

URUSOV, V.S. and LAPINA, I.V., 1987, Thermodynamic functions of mixing of orthosilicates of magnesium and manganese from the data on the equilibrium: solid solution-chloride melt: Geokhimiya, no. 2, p. 306-311 (in Russian). Authors at Inst. Geochem. & Anal. Chem. of Acad. Sci., Moscow, USSR.

Experiments on equilibrium between crystals $(Mg, Mn)_2SiO_4$ and melt $MgCl_2 + MnCl_2$ at 900-1100°C, time of runs 7-14 days, yielded isotherms (900, 1000 and 1100°C) of Mn partition between crystal phase and melt, and excess energy of mixing of the forsterite-tephroite ss. The paper presents also theoretical analysis of the results obtained. (A.K.)

USTINOV, V.I. and SUSHCHEVSKAYA, T.M., 1987, Evolution of mineral-forming solutions in the process of formation of the cassiterite-silicate ores: Dokl. Akad. Nauk SSSR, v. 293, no. 1, p. 207-209 (in Russian). Authors at Inst. Geochem. & Anal. Chem. of Acad. Sci., Moscow, USSR.

The investigated specimens were collected at the deposit Solnechnoe in the Komsomol'sk tin-ore region. This deposit is typical of the tourmaline type of the cassiterite-silicate formation. From the determinations of $\delta^{18}O$ from tourmaline, quartz, cassiterite and calcite the $\delta^{18}O$ of water of mineral-forming solutions was calculated (from -4.7 to 7.6‰ relative SMOW). The determined Th and Td values of fluid inclusions are in the ranges: quartz-tourmaline association 450-400°C, quartz-cassiterite association 350-300°C and quartz-carbonate association 200-100°C. The calculated admixture of meteoric waters in the parent solutions of the ore mineralization equals ca. 10%. Pre-ore quartz and tourmaline crystallized under the same physico-chemical conditions, quartz and cassiterite of the commercial stage crystallized under near-equilibrium conditions. The $\delta^{18}O$ values of parent fluids decreased from the early stages to the late ones. (Abstract by A.K.)

VALETTE-SILVER, N.J., TERA, F., WATTERS, R.L., Jr., KLEIN, J. and MIDDLETON, R., 1987, $^{10}$Be and trace elements chemistry in the Salton Sea geothermal system (abst.): EOS, v. 68, p. 439. First author at Chem. Dept., Univ. Maryland, College Park, MD 20742.

Water and sediment samples were collected from deep wells drilled in the Salton Sea geothermal field by Republic Geothermal, Inc., and the Salton Sea Drilling Project (SSSDP). Analysis of trace elements included As, Se, Sb, Hg, V, Be in the fluids. A first series of analysis was performed using ICP and AA techniques. The results showed high concentrations of As (≃80 ppm) and Be (≃5 ppb). The other elements were below detection limits which are <0.1 ppm for Se, Sb and Hg and ~0.01 ppm for V. Neutron activation analysis of these elements are currently underway. $^{10}$Be analysis of waters and sediments were performed using a Tandem Van de Graaff accelerator as a mass spectrometer. In waters of superficial environments such as river or aquifers from the Eastern U.S. (where t ≃ 25°C, ph >6, salinity = few g/L) $^{10}$Be concentrations average ≃ $10^3$ atoms/g whereas $^{10}$Be in associated sediments vary from $10^8$ to $10^9$ atoms/g. In the Salton Sea geothermal system, hydrothermal fluids have a t >300°C, a pH ≃ 5.3 and a high salinity with Cl ≃ 180 g/kg; the results show that the $^{10}$Be concentrations in the fluids range from $10^4$ to $10^5$ atoms/g and in the associated sediments from $10^6$ to $10^7$ atoms/g. It appears that due to their low pH, the hydrothermal fluids have leached $^{10}$Be from the sediment pile of the geothermal system. Finally, the results of chemical analysis of samples from the two SSSDP flow tests underline the difference between the two tapped aquifers and may constitute a means for characterization. (Authors' abstract)

VALLEY, J.W., 1987, Granulites and fluids in the deep crust (abst.): Int'l. Union of Geodesy & Geophys., XIX Gen. Assembly, Vancouver, Canada; Aug. 9-22, 1987; Abstracts, v. 1, p. 56. Author at Dept. Geol. & Geophys., Univ., Wisconsin, Madison, WI 53706, USA.

Known examples of granulite facies metamorphism span at least 3.5 by. of Earth history. Mineralogic geobarometry indicates that such metamorphism has occurred in the deep crust, typically at 20-30 km (6-9 kbar). Geothermometry indicates that peak T = 700-1000°C and therefore that T was elevated by at least 200°C over an "anorgenic" geotherm of ~20°C/km. Commonly invoked sources of heat include rising magmas, radioactive decay insulated by continent/continent collision, mantle volatiles, or crustal thinning. Present day crustal thicknesses are normal beneath exposed granulite terranes and the common absence of evidence for post-metamorphic underplating indicates syn-metamorphic thicknesses of 60-80 km. Thus granulites form in tectonically active regions of thickened crust and elevated geotherm. Xenolith suites suggest that granulite facies mineralogy persists in the deepest crust after tectonism in spite of declining temperature to greenschist/amphibolite facies conditions.

Dehydration is a universal characteristic of granulite terranes with quantitative estimates of $H_2O$ activity = 0.1 ± 0.1. Complexity and local variability of fluid conditions has been well documented in some terranes. Proposed explanations of low $\alpha H_2O$ include: 1. melting and selective removal of $H_2O$ in magmas; 2. passage of dry magmas derived at greater depth; 3. metamorphism of already dry rocks (igneous or metamorphic), and 4. streaming of mantle $CO_2$. Controversy surrounds the relative importance of each process. In 1.1. by. granulites from the Adirondack Mountains, N.Y., many rocks were metamorphosed in the absence of any free fluid phase due to processes 1, 2 and 3. Such fluid-absent metamorphism contrasts strongly with evidence from Archaen granulites in S. India indicating large quantities of $CO_2$ streaming and total $CO_2$/rock ratios of 0.1-0.5. High density,

$CO_2$-rich fluid inclusions are cited as evidence for syn-metamorphic $CO_2$-streaming in many terranes, however petrologic results from the Adirondacks show that such inclusions post-date granulite metamorphism. Overpressured $CO_2$ densities in $CO_2$ and $CO_2$-$H_2O$-bearing inclusions indicates that post-metamorphic P-T paths were concave towards T.

Post-metamorphic rehydration is a common feature in many terranes forming retrograde micas and amphiboles. Late-stage veinlets, crack-cements, and fluid inclusions are also evidence of late- or post-orogenic fluids. While large, transient fluid flux is indicated, petrologic evidence does not support the existence of pervasive, steady-state fluid reservoirs in the deep crust, though localized zones of interstitial fluid may occur. (Author's abstract)

van den KERKHOF, F., 1987a, Phase transitions in the $CO_2$-$N_2$ system at constant molar volume (abst.): Terra Cognita, v. 7, p. 23. Author at Inst. v. Aardwetenschappen, Vrije Univ., De Boelelaan 1085, 1081 HV Amsterdam, The Netherlands.

See same author, Fluid Inclusion Research, v. 19, 1986. (E.R.)

van den KERKHOF, A.M., 1987b, The phase behavior and density of $CO_2$-$CH_4$ and $CO_2$-$N_2$-inclusions (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 57-58. Author at Inst. Voor Aardwetenschappen, Vrije Univ., de Boelelaan 1085, 1081 HV Amsterdam, The Netherlands.

The combined application of microthermometry and Raman analysis is a great advance in the study of fluid inclusions. Recent studies indicate that gaseous fluids show a wider compositional range than first assumed. It is therefore essential to take the composition into account for the calculation of fluid densities. It must further be stressed that detailed microthermometric observation should be done as complicated phase behavior is an indication for mixed compositions. Raman analyses show that most gaseous fluid inclusions can be approached as binary systems. Mixtures between $CO_2$-$N_2$ and $CO_2$-$CH_4$ are representative for many natural fluids.

Empirical TX - diagrams could be obtained by studying fluid inclusions of the same generation (e.g., P inclusions) in one sample. The densities within one population of inclusions are supposed to be constant although their composition may vary significantly. In this way theoretical models could be affirmed and further refinement on phase diagrams and equations of state could be achieved.

$CO_2$-$CH_4$-$N_2$-inclusions were classified according to their phase behavior for T >180°C. Two principle types of fluid inclusions could be distinguished based on the last phase transition which can be observed at rising T: 1) homogenization of liquid and vapor (H-type inclusions), and 2) sublimation (S-type inclusions). More phase transitions often precede the "last" homogenization or sublimation. "Earlier" phase transitions comprise LV-homogenization in the presence of solid $CO_2$, incipient melting (forming a liquid or - in some cases - a bubble) and final melting (and combinations between these). A difference in phase behavior reflects a variation in both composition and molar volume, e.g., S-type inclusions are characteristic for higher density and $N_2$-richer inclusions. Better interpretations on fluid densities can be made when the fluid composition is taken into account and when the complete phase behavior is considered. In some cases the implications for the calculated density appeared to be drastic: inclusions showing (metastable) homogenization below the sublimation point have been reported from the Furua Granulite Complex (Tanzania). These inclusions have been interpreted as extreme dense $CO_2$ (up to 1.26 g/cm$^3$). Raman analysis showed, however, that they consist of $CO_2$-$N_2$-mixtures. Densities of these mixtures are much lower (1.1 g/cm$^3$) although their phase behavior is very similar to dense $CO_2$. Many high density $CO_2$-inclusions proved to be lower density mixtures. A number of published data should be reevaluated in this respect. In particular, no pure $CO_2$ homogenizing "metastably" at lower T than melting is really documented and probably does not exist. As earlier findings were not checked by Raman analysis, the maximum density observed in $CO_2$-inclusions is thought not to be higher than that of the triple point (1.178 g/cm$^3$). (From the author's abstract)

van den KERKHOF, A.M., 1987c, The fluid evolution of the Harmsarvet ore deposit, central Sweden: Geol. Föreningens i Stockholm Förhandlingar, v. 109, Pt. 1, p. 1-12. Author at Inst. voor Aardwetenschappen, Vriji Univ., De Boelelaan 1085, 1081 HV Amsterdam, The Netherlands.

A fluid inclusion study of ores from the Harmsarvet deposit, 15 km NW of Falun, Sweden, was made by means of microthermometry and Raman spectroscopy. Two main types of fluid inclusions can be distinguished: gaseous and aqueous inclusions. The gaseous fluids consist of 3 components: $CO_2$, $CH_4$ and $N_2$; aqueous inclusions are essentially complex brines of varying concentration. Most frequent are $CO_2$-rich inclusions with up to 30 mole % $CH_4$ and less $N_2$; $CH_4$ and $N_2$-rich inclusions are free of any $CO_2$. The present data indicate that the first ore minerals formed already during the regional metamorphic conditions estimated at 600 ± 50°C and about 3 kbar. Late phase minerals (e.g., acanthite) formed during retrograde conditions as trails associated with $CO_2$-$CH_4$-bearing inclusions. It is suggested that the gaseous fluid evolved from a $CO_2$-rich fluid to higher $CH_4$-contents by abstraction of $CO_2$ during the formation of carbonates (siderite). Hydrothermal water probably evolved from high saline brines of metamorphic origin of solutions of lower salt contents by mixing with meteoric water. Brines and gaseous fluids remained immiscible during retrograde conditions. (Author's abstract) (See also KERKHOV, 1987, p. 193.)

VANKO, D.A., BODNAR, R.J. and STERNER, S.M., 1987, Phase equilibria in the system sodium chloride-calcium chloride-water: Determination of the halite liquidus (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 876. First author at Dept. Geol., Georgia State Univ., Atlanta, GA 30303.

Solubility relations along part of the vapor-saturated halite liquidus in the system $NaCl$-$CaCl_2$-$H_2O$ have been determined utilizing the synthetic fluid inclusion technique. These data provide a means of estimating the bulk composition of $NaCl$-$CaCl_2$-$H_2O$ fluid inclusions that contain halite daughter crystals at room T. Some fluid inclusions from seafloor and other hydrothermal systems fall into this category.

Synthetic fluid inclusions were produced by loading carefully-measured amounts of solid NaCl and aqueous $CaCl_2$ solutions into Pt capsules, along with fractured quartz cylinders (10 mm long x 4 mm diam.), and running in cold-seal hydrothermal bombs for 10 days. The trapped fluid inclusions contain three phases in equilibrium at room temperature: liquid, vapor and halite. On heating, the disappearance T of halite, Tm(halite), precedes Th of the inclusions, hence Tm(halite) for the known bulk composition provides one datum for the vapor-saturated halite liquidus. Bulk compositions are plotted in the ternary system and Tm(halite) values contoured. The resulting smooth contours are consistent with recently published vapor-saturated halite solubilities in the binary $NaCl$-$H_2O$.

Using the new liquidus data in combination with published low-T phase equilibria, the bulk composition of natural $NaCl$-$CaCl_2$-$H_2O$ fluid inclusions can be determined by measuring (a) Tm(ice) in the presence of a cotectic liquid plus hydrohalite and vapor, and (b) Tm(halite) in the presence of liquid and vapor. Because the vapor bubble has negligible mass, the inclusion's bulk composition lies at the intersection of (a) the Tm(halite) isotherm, and (b) the tie line between hydrohalite and the liquid composition on the ice-hydrohalite cotectic at Tm(ice). (Authors' abstract)

VAN REENEN, D.D. and HOLLISTER, L.S., 1987, Fluid inclusion study across a hydration isograd in granulite facies rocks, southern marginal zone, Limpopo belt, South Africa (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). 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 uplifed and thrust over the low grade granite-greenstone terrane to the south at 2650 Ma. The change in metamorphic conditions during the uplift was from >9.5 kbar, >820°C to 7.2 kbar at about 800°C. During cooling, following this uplift, the granulites were rehydrated in a zone parallel to the contact with the low grade terrane. A sharply defined retrograde isograd at conditions of >6 kbar, 625°-650°C, $X(CO_2) = 0.8$ (Van Reenen, 1986) 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. All inclusions in thin sections of each rock were analyzed. In all four samples, 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 and many $CO_2$ inclusions with lower densities and later aqueous inclusions of variable salinity and containing no detectable $CO_2$. The only apparent correlations of types of fluid inclusions to sample location relative to the hydration isograd is that the ratio of number of $CO_2$ to $H_2O$ inclusions decreases from the unhydrated to the hydrated rocks, and lower density $CO_2$ inclusions are relatively more abundant in the hydrated samples.

Possible explanations for the disparity between the calculated fluid composition of $X(CO_2) = 0.8$ and the observed fluid compositions of pure $CO_2$ or aqueous without $CO_2$ are (1) the hydrating fluid is indeed represented by the $CO_2$ inclusions but the aqueous component, being at most 20 mole %, is not visible; a uniform flushing by such a hydrating fluid through rocks distributed over a T gradient could produce the observed hydration isograd. (2) After development of the hydration isograd, $H_2O$ was preferentially lost from inclusions due to P gradients between inclusions and grain boundaries during the uplift of the southern marginal zone. (3) All inclusions are relics of the long early history of the southern marginal zone, and the hydrating fluid permeated the rocks along grain boundaries rather than in microcracks; permeability of crystalline rocks will be enhanced during cooling due to differential thermal contraction of the minerals. We believe all three explanations apply to our data, which also suggest that fluid densities and compositions appropriate for metamorphic conditions are probably not preserved in high grade terranes with complex histories. (Authors' abstract)

VELASCO, F., PESQUERA, A., ARCE, R. and OLMEDO, F., 1987, A contribution to the ore genesis of the magnesite deposit of Eugui, Navarra (Spain): Mineral. Deposita, v. 22, p. 33-41. First author at Dept. Min., Univ. del Pais Vasco, Apd, 644, Bilbao, Spain.

In the area of the magnesite deposits of Eugui (Navarra, Spain) studies on illite crystallinity, the degree of graphitization of carbonaceous material, measurements of vitrinite reflectivity, and fluid inclusions have been carried out on dolomites, magnesites, schists, and carbonaceous matter. These rocks have suffered metamorphism of very low to low grade.

The magnesite appears generally concordant with the Namurian dolomitic rocks showing a typically banded structure. The genetic model proposed involves an early Mg concentration during sedimenation (syndiagenetic dolomitization), lateral circulation of saline solutions, and formation of diagenetically crystallized rhythmites (DCR), and final compaction. The formation of magnesite took place under the conditions of low P and T close to 150°C, very similar to all strata-bound ore deposits. Deformation and regional metamorphism only caused minor removal, recrystallization, and transformation of the clay minerals and carbonaceous matter. (Authors' abstract)

VETTER, O.J., BENT, M., KANDARPA, V., SALZMAN, D. and WILLIAMS, R., 1987, Three-phase PVT and $CO_2$ partitioning: Proc. 57 Annual Meeting Soc. Petroleum Engineers, SPE 16350, p. 297-310. First author at Vetter Research.

Discusses partitioning between oil, brine, and $CO_2$ vapor phases.(E.R.)

VIBETTI, N.J., 1987, A study of deep fluid circulation in the Troodos ophiolite, Cyprus: PhD dissertation, Univ. Western Ontario, London, ON, Canada.

VIKRE, P.G., 1987a Paleohydrology of Buckskin Mountain, National district, Humboldt County, Nevada: Econ. Geol., v. 82, p. 934-950. Author at ASARCO, Inc., 510 East Plumb Lane, Reno, NV 89502.

Precious metal veins of the National district, Humboldt County, Nevada, occur in strongly altered Miocene volcanic rocks. Hydrothermal assemblages in Buckskin Mountain display a marked zonation from the paleosurface downward that correlates with the elevation and physical properties of enclosing rhyolites. Light stable isotope analyses indicate that meteoric water from two distinct sources comprised the ore fluid. The $\delta D$ values in fluid inclusions from deep-level quartz vein segments, >1,250 ft (>379 m) below the paleosurface, range from -115 to -129 per mil. Fluid inclusion waters from near-surface quartz vein segments, 0 to 1,250 ft (0-379 m) below the paleosurface, have $\delta D$ = -86 to -125 per mil and are generally more depleted than local Miocene ground water whose $\delta D$ is calculated at -85 per mil. The $\delta D$ range in inclusion waters from near-surface quartz veins has resulted from mixing of the fluids present in deep quartz veins with local ground water and condensed steam derived from boiling of both fluids. The fluids present in deep quartz veins probably originated as precipitation on distal highlands with elevations approaching 6,000 ft (1,818 m). Oxygen isotope data from vein and wall-rock minerals record increasing depletion as veins are approached, indicating that quartz veins were the major conduits of fluid flow. The degree of oxygen exchange between hydrothermal fluid and wall rocks, water/rock mass ratios, and the abundance of hydothermal phases increase toward the paleosurface. The progressive influx of local ground water with increasing elevation is also indicated by chloride dilution.

The estimated duration of the Buckskin Mountain hydrothermal system, 50,000 to 200,000 yrs, is limited by the volume of high-T alteration assemblages and the heat budget of a proposed intrusion. Thermal constraints and isotopic data provide an internally consistent range in lifetimes which is several times shorter than that proposed for some active hydrothermal systems. These long-lived modern systems apparently require multiple thermal and/or intrusive events. (From the author's abstract)

VIKRE, P.G., 1987b Fluid-mineral relations in the Comstock Lode, Storey, Washoe, and Lyon Counties, Nevada, U.S.A.: Pacific Rim Congress 87, 26-29 August, 1987, Australasian Inst. Mining & Metallurgy, Victoria, Australia,

p. 603-606. Author at ASARCO Inc., 510 East Plumb Lane, Reno, NV 89502, USA.

Fluid inclusion microthermometry and mineral assemblage paragenesis and textures show that Au and Ag minerals, and most sulfides, were deposited with the earliest and highest T quartz generation. On an ore-stage isothermal projection the highest depositional T approach 300°C beneath Cedar Hill at the north end of the Comstock fault and decrease to <230°C four miles (6.7 km) south at the south end of the Comstock fault. Bonanzas were deposited in the interval >250°C to <275°C, and occur near isothermal reentrants and embayments which mark T reversals. Ore-stage fluid salinities, which range from >6 to <2 wt. % NaCl, are also maximum beneath Cedar Hill and decrease to the south in the Comstock fault. (From the author's text)

VILOR, N.V., BRANDT, S.B., BRANDT, S.S., BOGDANOV, G.V. and MEDVEDEVA, T.I., 1987, The gneiss-dome system; paleotemperature, fluidal hydrogen isotope studies: Sovets. Geolog., v. 9, p. 98-107 (in Russian).

VIVIAN, G., MORTON, R.D., CHANGKAKOTI, A. and GRAY, J., 1987, Blackdome Eocene epithermal Ag-Au deposit, British Columbia, Canada - Nature of ore fluids: Trans. Instn. Min. Metall. (Sect. B: Appl. Earth Sci.), v. 96, p. B9-B14.

The Eocene, epithermal Ag-Au-(Sb-Cu-Fe-Zn-Pb-S-Se-As)-silica deposits of the Blackdome property in southern British Columbia, Canada, have been the subject of fluid inclusion studies and stable isotope analyses. Veins with precious-metal mineralization are hosted by a suite of calc-alkalic volcanic rocks. The deposits were developed when meteoric groundwaters penetrated fissures 0.5-1.1 km below surface into the volcanic pile. A partly vented, boiling geothermal system resulted, and the aqueous fluids effected phyllosilicate plus K-feldspar alteration of the host reservoir rocks. Pervasive propylitization of the host volcanics characterizes this former geothermal field. The geothermal fluids were characterized by low salinities - in the order of 0.21-2.07 wt% NaCl eq.-- densities of 0.720-0.810 g/cm$^3$, $\delta^{18}O$ values of -6.8 to -8.8‰ (SMOW) and $\delta D$ values of -125 to -134‰ (SMOW). Oxygen isotope exchange during hydrative metasomatism caused a positive shift away from the 'meteoric line.' A minor, positive shift in the $\delta D$ values, away from the value of the parent meteoric water, might have been due to loss of hydrogen from the vented system, to selective hydrogen metasomatism of the wallrocks, or both. The Blackdome deposits clearly belong to the adularia-sericite-type group of volcanic-hosted epithermal precious-metal deposits. (Authors' abstract)

VON DAMM, K.L. and BISCHOFF, J.L., 1987, Chemistry of hydrothermal solutions from the southern Juan de Fuca Ridge: J. Geophys. Res., v. 92, no. B11, p. 11,334-11,346. First author at Environ. Sci. Div., Oak Ridge Nat'l. Lab., Oak Ridge, TN.

Fluids from three vent fields on the southern Juan de Fuca Ridge were sampled in September 1984 using the DSRV Alvin. The fluids are uniquely high in both chloride, which ranges up to twice the seawater value, and in metal content. Simple vapor-liquid phase separation could not have produced both the high chlorinity and gas concentrations observed in these fluids. The cause of the elevated chlorinity cannot be uniquely identified but may be the result of either or a combination of two processes: (1) subsurface formation of a degassed brine and subsequent mixing of a small amount of this brine with a hydrothermal seawater which has not undergone a phase separation and (2) dissolution of a chloride-rich phase combined with a possible small loss of gas during sampling procedures. Although measured temperatures were all less than 300°C, quartz geothermometry suggests that the fluids have equilibrated at greater than 340°C. Quartz geobarometry is also in agreement with geophysical estimates of depth to the local magma chamber. (Authors' abstract)

VOVK, I.F., 1987, Radiolytic salt enrichment and brines in the crystalline basement of the East European Platform, in Saline water and gases in crystalline rocks, eds., Fritz, P. and Frape, S.K.: Geol. Assoc. Canada Spec. Paper 33, 1987, p. 197-210. Author at Div. Research & Labs., Int'l. Atomic Energy Agency, A-1400 Vienna, Austria.

Saline waters and brines have been encountered repeatedly in the crystalline basement of the East European Platform, in particular within the Ukrainian and Baltic shields and the Russian Plate. Samples of brines and associated gases were obtained from several dozen mines and boreholes, two of which, in Tatar Dome and Kola Peninsula, pass through shear zones and fractures filled with brine to the depth of 5099 m and 12,000 m, respectively. Highly concentrated brines and gases are also often found as fluid inclusions in minerals and igneous and metamorphic rocks. The concentration of total dissolved solids (TDS) in water sampled from mines and boreholes increases with depth from 0.1 to 100 $g \cdot l^{-1}$ at 2000 to 3000 m and deeper. The brines are of two major chemical types: Na-Cl and Na-Ca-Cl. The Na-Cl brine is found mainly along the Krivoy Rog regional fault crossing the Ukrainian Shield, while the Na-Ca-Cl brine is more widely distributed within the platform. The major component of gas dissolved in Na-Cl waters from iron mines in Krivoy Rog is $CO_2$, accompanied by $H_2$ and He, while Na-Ca-Cl brine from the borehole in Tatar Dome contains mainly $N_2$ and $CH_4$, accompanied by He and $H_2$. Free gases associated with brines and filling the porous media of crystalline rocks are predominantly of $H_2$-$CH_4$ or $CH_4$-$H_2$ composition with smaller amounts of $N_2$ and He. The chemical and isotopic data, as well as geological position suggest that saline waters of Na-Cl type from the Krivoy Rog region may be diluted Paleozoic sea brine. The source of the Na-Ca-Cl brines and major gases, particularly $H_2$, is not well understood but could be residual metamorphic fluids originated from Precambrian sea water highly modified radiolytically and/or in some other way. Radiolytic salt enrichment through the decomposition of water molecules owing to the natural irradiation of water-rock systems during spans of geological time is discussed on the basis of experimental data and geochemical evidence. (Author's abstract)

VROLIJK, Peter, 1987a Using fluid inclusions to unravel structural and tectonic processes - Evidence from the Kodiak accretionary complex, Alaska (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Author at Earth Sci. Board, Univ. California, Santa cruz, CA 95064.

Methane-rich and water-rich fluid inclusions in syn-tectonic quartz veins of the Kodiak accretionary complex, Alaska, provide clues for two tectonic processes: (1) the opening and growth of fault and fracture systems, and (2) the migration and escape of fluids from deep to shallow levels in the subduction zone. Fluid inclusions preserve a record of transient phenomena in the deforming rock mass not found in any other feature of ancient rocks and may therefore be extremely useful in more clearly understanding structural and tectonic processes.

Syn-tectonic quartz veins in sandstone boudins of melanges from the Ghost Rocks Fm., Kodiak Fm., and Uyak Complex preserve cogenetic single-phase methane inclusions and two-phase liquid-water + methane-vapor inclusions. Interestingly, methane density decreases within individual veins in the direction of crystal growth; the highest densities (.385 $g/cm^3$) occur along the vein wall where crystal growth initiated and the lowest densities (.310 g/cm$^3$) are found near the center of the vein. Because Th (= Tt) remain constant throughout the vein (260-290°C), the decrease in methane densities must result from dropping fluid P (310-330 MPa to 175-265 MPa). The highest fluid P are interpreted as near-lithostatic pressures present during opening of the vein (hydrofracture). Later lower fluid P record growth of a hydrologic conduit, probably an interconnected fault system, toward shallower levels, resulting in fluid escape and fluid P release. Using these same samples as paleothermometers/barometers, I find that the measured P-T conditions define a thermal gradient of 20°C/km for fluids flowing through active faults. This gradient is much higher than a gradient of 7-10°C/km predicted by conductive heat flow models of subduction zones.

Methane + water fluid inclusions may be vitally important in unraveling tectonic processes in "low-grade" rocks in accretionary complexes throughout the world. They offer precise P-T conditions where other techniques are lacking; T measured by carbon isotope fractionation between methane fluid inclusions and calcite vein material agree exactly with fluid inclusion T. Sediments deposited in subduction zones often contain terrigenous organic matter, so methane and water will be common fluid constituents. Finally, methane is generated under conditions where the rock deforms brittlely and quartz is easily deposited by small changes in P-T; quartz veins will be ubiquitous. In summary, fluid inclusions hold vital information concerning the interactions of fluid and rock in actively deforming environments. (From the author's abstract)

VROLIJK, Peter, 1987b, Tectonically driven fluid flow in the Kodiak accretionary complex, Alaska: Geology, v. 15, p. 466-469. Author at Earth Sci. Board, Univ. California, Santa Cruz, CA 95064.

Full paper for previous abstract. (E.R.)

VRY, J.K. and BROWN, P.E., 1987, Fluid inclusions across the Pikwitonei granulite domain, Manitoba (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Authors at Dept. Geol. & Geophys., Univ. Wisconsin, Madison, WI 53706, USA.

Fluid inclusions in a variety of quartz-bearing rock types sampled along Cauchon Lake and Natawahunan Lake in the Archean Pikwitonei granulite domain (PGD) were examined by petrographic and microthermometric methods. The PGD, located in central Manitoba at the northwest margin of the Superior Province, is regarded as a structurally and metamorphically contiguous, high-grade, deep crustal level of the Superior Province. Cauchon Lake lies along the mapped orthopyroxene isograd on the SE margin of the PGD; Natawahunan Lake is located some 50 km NW of Cauchon Lake in the granulite facies.

Saline aqueous inclusions are found in small quantities throughout the region, and are often associated with massive quartz segregations. Aqueous inclusions are most common, however, in the transitional amphibolite-granulite facies rocks at Cauchon Lake. In several of these Cauchon Lake samples, virtually all of the inclusions are aqueous and contain one or more dxls. Traditional microthermometry of these inclusions is hampered by severe metastability; even the largest inclusions rarely can be frozen.

Different quartz segregations from a single outcrop area may contain distinct populations of fluid inclusions. In small, concordant quartz-rich seams, the inclusions generally resemble those in adjacent wall rocks. Massive quartz, on the other hand, often contains low-density $CO_2$ inclusions, ± aqueous inclusions, but without associated high-density $CO_2$.

Abundant, texturally S inclusions in a few samples from Natawahunan

Lake contain a black solid, identified as highly ordered graphite by laser Raman spectroscopy. These samples give consistently low triple point values (-59°C), suggesting the presence of methane or another component.

$CO_2$-rich inclusions predominate in rocks from Natawahunan Lake, but occur, with similar low- and high-density $CO_2$ inclusion distributions, throughout the study region. The transition from aqueous to carbonic fluid inclusions does not appear to correspond to the location of the orthopyroxene isograd. Measured $CO_2$ triple points cluster around -56.6°C. High-density, texturally P or PS $CO_2$-rich inclusions with Th between -37.2 and +5°C were observed in several samples. If these high-density (1.11 to 0.9 $g/cm^3$) inclusions preserve peak metamorphic fluids, then for inferred average metamorphic T of 630-750°C (Mezger et al., 1986), isochores give P estimates of 4 to 7.8 kbars. These results are similar to the P estimates (6.1-7.8 kbars) of Mezger et al., and could be interpreted to support massive $CO_2$ infiltration as has been done in other granulite terrains. However, partial melting and fluid absent metamorphism are often viable alternatives (Lamb et al., 1985). (Authors' abstract)

VRY, J., BROWN, P.E. and BEAUCHAINE, J., 1987, Application of micro-FTIR spectroscopy to the study of fluid inclusions (abst.): EOS, v. 68, p. 1538. First author at Dept. Geol. & Geopys., Univ. Wisconsin-Madison, Madison, WI 53706, USA.

The combination of optical and infrared microscopy with analytical Fourier transform infrared spectroscopic (micro-FTIR) techniques shows promise for the rapid, nondestructive analysis of $H_2O$, $CO_2$, other gases such as methane, and some daughter salts in individual fluid inclusions. The improved sensitivity of micro-FTIR for $H_2O$, especially when compared to other techniques such as micro-Raman spectroscopy, offers the potential for calibration of molar $H_2O/CO_2$ ratios in fluid inclusions. The method also makes possible the detection of small amounts of $H_2O$ ($\leq$10-20 mole %) otherwise invisible in $CO_2$-rich inclusions; this is important in both fluid inclusion geobarometry and petrologically-related fluid composition studies.

The Nicolet 5SCXCFT-IR is interfaced to a Nicolet IR Plan microscope; a unique redundant aperture system permits isolation of individual fluid inclusions for infrared spectroscopic analysis. Infrared spectra have been obtained from small (7 to 30 µ), natural and synthetic fluid inclusions in standard doubly-polished thick sections of quartz, often with excellent sensitivity for $H_2O$ and $CO_2$. Figure 1 shows the clear signals obtained from water and $CO_2$, and the excellent reproducibility of analyses of a single inclusion at different depths well within the quartz matrix (sample scanned from opposite sides). Typical measurements using 128 to 512 co-added scans at 8 to 16 wave number resolution require only 140 to 400 seconds per inclusion analysis.

Micro-FTIR analyses of 3 high-density $CO_2$-rich fluid inclusions from granulite-facies occurrences in the Adirondack Mountains, N.Y., and the Pikwitonei domain, Manitoba, detected no $H_2O$ or other fluid species. Phase equilibria studies (Lamb, et al., 1987, in press) indicate that such inclusions cannot represent the peak metamorphic fluid; however the inclusions may provide information of post-metamorphic uplift paths. (Authors' abstract)

VYSOTSKAYA, V.A., 1987, Typomorphism of quartz from tantalum-bearing granites (eastern Transbaikalia): Zap. Vses. Mineral. O-va, v. 116, no. 1, p. 93-99 (in Russian).

WALDER, I.F. and SEGALSTAD, T.V., 1987, Hydrothermal vein molybdenite deposits associated with the Drammen biotite granite in the Permian Oslo rift, Norway (abst.): American Current Research on Fluid Inclusions, Jan. 5-7, 1987, Socorro, N. Mex., Program and Abstracts (unpaginated). Authors at Mineral.-Geol. Museum, Sars gate 1, N-0562 Oslo 5, Norway.

The Drammen biotite granite occupies about 7000 $km^2$ and is situated in the central part of the Permian Oslo rift. It intrudes Precambrian gneisses and Lower Paleozoic sedimentary rocks. Numerous small contact-metasomatic ore deposits are found along the northern and northwestern contacts of the granite batholith. The granite batholith is petrographically divided into eight intrusions, which are divided into two main groups by the help of whole rock chemistry. One of the groups contains intrusions which all carry Mo deposits. All the deposits are small and carry molybdenite along thin (0.5-5 cm) quartz veins in one or two meter wide linear fracture zones. These veins may contain feldspar and fluorite.

Fluid inclusion studies of the vein quartz show that the P inclusions are water-dominated and may carry both $CO_2$ and frequent crystals of halite at room T. Tt is between 250°C and 400°C.

The vein quartz has been separated, and thermally decrepitated in vacuum system for gas analyses, and in an open system for radiogenic isotope analyses on the salts. The latter analyses show that the aqueous solutions which carried Mo were probably primary magmatic solutions, but at places where there was precipitation of molybdenite (and quartz) the solutions were mixed with crustal water. This is confirmed by oxygen isotope analyses of the same vein quartz ($^{18}O$(SMOW) = 8 to 10 per mil).

Sulphur isotope analyses of the molybdenite indicate that the sulfur is primary magmatic ($S^{34}$(PDB) = -.5 to 3 per mil). The gas analyses yield 99 mole % water, less than 1 mole % $CO_2$, some sulphur mainly as $SO_2$, and trace amounts of other gases. There may have been too little sulphur in the molybdenum carrying aqueous solutions to produce large Mo deposits and other intramagmatic sulfide deposits. Different gas geothermometers give fluid T of 300-450°C for the Mo deposits, in good consistency with fluid inclusion Tt. (Authors' abstract)

WALKER, G.P.L., 1987, Pipe vesicles in Hawaiian basaltic lavas: Their origin and potential as paleoslope indicators: Geol., v. 15, p. 84-87. Author at Hawaii Inst. Geopys., Honolulu, HI 96822.

Study of several Hawaiian tholeiitic volcanoes shows that pipe vesicles form only in thin pahoehoe flow units standing on a ground slope of less than about 4°. The vesicles thus have potential as paleoslope indicators. Two examples are given of their use to deduce that the steep dip of certain intracaldera lavas is due to tilting. Pipe vesicles are attributed to gas bubbles rising through lava at a stage in its cooling history when it had acquired a yield strength of a few tens of $N{\cdot}m^2$ sufficient to prevent closure of lava behind the bubbles. (Author's abstract)

WALKER, J.S. and VAUSE, C.A., 1987, Reappearing phase: Sci. Amer., v. 256, p. 98-105.

A discussion of the occurrence of immiscibility, and its occasional disappearance with decrease in T. (E.R.)

WALLACE, P.J., CHRISTIE, D.M. and CARMICHAEL, I.S.E., 1987, Sulfur content in mid-ocean ridge basalt glasses (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 879-880. First author at Dept. Geol. & Geophys., Univ. California, Berkeley, CA 94720.

Analyses of sulfur, ferrous and total iron for 51 fresh, mid-ocean ridge (MOR) basalt glasses constrain the strong dependence of the sulfur solubility on the iron content of these magmas and the systematics of this relationship with respect to geography and chemistry. Our sample set includes glasses from seven areas in the Atlantic, Pacific and Southern oceans ranging in chemistry from high $Al_2O_3$, low FeO basalt to MORB to FeTi enriched basalt. The sulfur concentrations in these glasses varies linearly as a function of the ferrous iron content from 750 ppm S and 6.77 wt.% FeO to 2500 pm S and 14.65 wt.% FeO, in good agreement with the total iron data of Mathez (1980) and Perfit et al. (1983). All analyses fall along this trend regardless of geographic location or chemical type. Many of the outer pillow margins from which these glasses were taken contain immiscible sulfide globules indicating that the majority of these magmas were at or near saturation with respect to sulfide prior to eruption, and that these globules are one of the earliest phases to appear in cooling MOR basalt liquids. Minimum T of extrusion for phenocryst-free glasses estimated using the solution model of Ghiorso et al. (1983) at 500 bars P and oxygen fugacity below FMQ decrease from 1240°C in low FeO basalts to 1120°C in FeTi basalts. Due to the strong positive influence which T exerts on the solubility of sulfur in silicate melts, this decrease has an effect opposite to that of Fe enrichment in these liquids. Therefore, we suggest that the equilibrium between silicate melt and Fe-S-O liquid, present as immiscible sulfide globules, constrain MOR basalt magmas along this trend by buffering the ratio of oxygen to sulfur fugacity. (Authors' abstract)

WALTERS, I.J., 1986, Fluid inclusion studies of gold bearing quartz veins, Wales: Undergraduate thesis, Southampton Univ., 79 pp.

Fluid inclusions from one barren and one Au-bearing quartz sample of the Gwynfynydd mine, Wales, were studied. Both samples were found to be of relatively low salinity. (<10 wt.% NaCl eq.); Th values differed, and it is thought that the Au-bearing quartz may have formed between 310° and 355°C. (From the author's abstract)

WALTHER, J.V. and WOOD, B.J., eds., Fluid-rock interactions during metamorphism, Advances in physical geochemistry, Vol. 5: Springer-Verlag, New York, 218 pp.

WALTON, L.A., 1987, Geology and geochemistry of the Venus Au-Ag-Pb-Zn vein deposit, Yukon Territory: MS thesis, The University of Alberta.

The Venus Au-Ag-Pb-Zn vein is hosted in Late Cretaceous, intermediate volcanic rocks of the Mount Nansen Group. The vein consists of quartz, arsenopyrite and pyrite, with lesser amounts of sphalerite and galena. The andesitic to felsic wall rocks are hydrothermally altered to a sericite-carbonate-quartz-pyrite assemblage, with local pods of intense clay alteration.

The paragenesis can be divided into two mineralogically distinct stages: Stage I - early quartz, arsenopyrite and pyrite, and Stage II - later quartz, sphalerite, galena, and Au. Au and galena occur together as fracture fillings or replacements in earlier deposited arsenopyrite and pyrite. Steeply plunging ore shoots, which are not visually apparent, comprise 20% of the vein and typically contain both Stage I and Stage II mineralization.

Stage I fluid inclusions are characterized by Th >290°C, moderate $CO_2$ (17 mole %), and low salinities (3 to 4 wt% NaCl eq.). Relative to Stage I, Stage II fluid inclusions are cooler (260°C), $CO_2$ depleted and may have been more saline (up to 7.5 wt% NaCl eq.). Variable $H_2O$-$CO_2$ ratios indicate that sporadic effervescence occurred during Stage II. Influx of Stage II fluid and subsequent base metal-Au precipitation was restricted to open parts of the vein.

Sulphide precipitation and loss of $H_2S$ from sporadic effervescence generated a sulphide deficiency in the fluid, and subsequent breakdown of $Au(HS)_2^-$ complexes. Au precipitated with galena in the last stages of mineral deposition. Preferential precipitation of Au and galena near preexisting arsenopyrite and pyrite may be due to electrochemical interaction between sulphide grain surfaces and the hydrothermal ore fluid.

An enrichment of $^{18}O$ in the Venus quartz depositing fluid (+10 to +14‰), and preliminary δD data (-159‰) suggest a meteoric-hydrothermal origin for the fluid. P estimates from fluid inclusions average between 1000 to 1300 bars, indicating a depth of formation of at least 3 km. The high $\delta^{18}O$ values are probably a function of extensive water-rock interaction at high T and depths. (Author's abstract)

WAN, Faning, 1987, Tungsten deposits related to regional metamorphism and ore-controlling factors: Geol. Review, v. 33, no. 5, p. 417-425 (in Chinese; English abstract). Author at Jiangxi Inst. Sci., Jiangxi.

May involve fluid inclusion data. (E.R.)

WANAMAKER, B.J., EVANS, B. and WONG, T.-F., 1987, Fluid inclusion decrepitation (cracking) in San Carlos olivine (abst.): EOS, v. 68, p. 1527. First author at LLNL, Livermore, CA 94550.

The minerals in many igneous and metamorphic rocks contain fluid inclusions which may have fractured during uplift. Similar fracturing (decrepitation) events occur during microthermometry experiments on microscope heating stages. Roedder (1984) has pointed out that the diameter of a fluid inclusion and the maximum P difference which it will support, appear to be inversely related. Once formed, the annular crack around the fluid inclusion will extend until the external and internal P are nearly equal.

Using linear elastic fracture mechanics and assuming that fluid inclusions contain small initial flaws which scale with their diameter, the maximum P difference is predicted to depend directly on the critical stress intensity factor and indirectly on the square root of the inclusion radius, in qualitative agreement with decrepitation experiments done on San Carlos olivine. Once formed, the annular crack around the fluid inclusion will extend until the internal (gas) and external (mineral) P are nearly equal. The final radius of the annular crack is a function of the radius of the original fluid inclusion, and the internal and external P.

Some naturally decrepitated fluid inclusions in San Carlos olivine have partially healed and others have not. Using the relations suggested above, and an estimated rate for crack healing, it may be possible to estimate roughly the ascent rate of the nodules. (Authors' abstract)

WANAMAKER, B.J., KOHLSTEDT, D.L. and EVANS, B., 1987, Reequilibration of fluid inclusions in San Carlos olivine by point defect diffusion (abst.): EOS, v. 68, p. 417. First author at Dept. Materials Sci. & Engrg., Cornell Univ., Ithaca, NY 14853.

The ratio of CO-to-$CO_2$ in high density fluid inclusions in single crystals of San Carlos olivine ($Fo_{90}$) has been systematically changed by annealing samples in the temperature range 1000 to 1400°C at $pO_2$s within the stability field of this olivine. The CO:$CO_2$ ratio in the inclusions, as measured by the melting point depression of the fluid, increases as the external $pO_2$ decreases. The $fO_2$ calculated from the CO:$CO_2$ ratio in the fluid inclusions is the same as that imposed by the external buffering gas, independent of the gas mixture (i.e., $CO_2/H_2$ or $CO_2/CO$). There is no evidence for the presence of water or methane in the inclusions annealed in a $CO_2/H_2$ atmosphere, thus hydrogen is not directly involved in the reequilibration process. The absolute rate and activation energy for reequilibration indicate that this process is rate limited by diffusion of metal vacancies and not by the direct transport of oxygen between the external surface and the fluid inclusions. These experiments suggest that fluid inclusions in mantle olivines can reequilibrate rapidly to natural changes in their chemical environment. (Authors' abstract)

WAND, U. and STRAUCH, G., eds., 1987, Isotopes in nature (Proc. Fourth Working Meeting, Leipzig, Sept. 1986): Berlin, Akademie-Verlag, 688 pp.

WANG, Kuiyuan, 1987, The mineralization of Xiaoyingpan gold deposit in Hebei: Earth Sci., Mar., v. 12, no. 2, p. 179-184 (in Chinese; English abstract). Author at Tianjin Inst. Geol. & Min. Resources, PRC.

The Na/K ratio of inclusion in the Xiaoyingpan Au deposit is 1.43. This ratio indicates that a certain amount of sylvite should yet be produced[sic]. It is calculated that the KCl is about 8% and NaCl 9.9%, so that the total salinity reaches 17-18%. Using the Na/K/Ca geothermometer the author calculates the equilibrium T to be 540°C. The total P of the ore-bearing hydrothermal fluid is $4.19 \times 10^7$ Pa. The above mentioned data suggest that this Au deposit may be explained [by a] circulating model. (Author's abstract)

WANG, Shiqi, ZHENG, Shuhui, ZHENG, Sicheng and CHEN, Chengjie, 1987, Hydrogen, oxygen and carbon isotope studies on the genesis of the Tianpishan pegmatite in Inner Mongolia: Mineral Deposits, v. 6, no. 3, p. 85-90 (in Chinese; English abstract). Authors at Dept. Geol., Peking Univ., Beijing, China.

The H, O and C isotopes of fluid inclusions and minerals from this well known muscovite mine were studied.

$\delta^{18}O$ values of quartz ranges from 12‰ to 14.4‰, avg. 13.8‰, while $\delta^{18}O$ values of muscovite ranges 11.5‰ to 12.2‰, avg. 11.9‰. These values are somewhat higher than the values for pegmatites reported in the foreign literature, but are consistent with those of the wall rocks in the ore district, suggesting that the material of the pegmatite might have come from the metamorphic rocks of this area.

$\delta D$ of muscovite range -30.3‰ - -59.4‰, avg. -48.9‰, and $\delta D$ of water in fluid inclusions of quartz extend from -32‰ to -73.4‰, avg. -59.1‰, quite in conformity with the values reported abroad. The $\delta^{18}O_{H2O}$ - $\delta D_{H2O}$ range implies that the waters in pegmatite of this area were predominantly from magmatic water and partly from surface water.

Two groups of $\delta^{13}C$ value are recognized for $CO_2$ in fluid inclusions of quartz, i.e., -5.5‰ and -19.6‰. The heavy C might have derived from the primary C in the deep crust and the light C from the organic C in the wall rocks. (Authors' abstract)

WANG, Yurong, CHOU, I.-M., 1987, Characteristics of hydrolysis of the complex $Na_2SnF_6$ in hydrothermal solutions - An experimental study: Geochemistry, v. 6, no. 4, p. 372-381 (in English).

WARK, D.A., Plagioclase-rich inclusions in carbonaceous chondrite meteorites: Liquid condensates?: Geochimica Cosmo. Acta, v. 51, p. 221-242.

WATSON, E.B. and BRENAN, J.M., 1987a Wetting characteristics of C-O-H fluids in polycrystalline quartz and olivine at elevated P-T conditions (abst.): EOS, v. 68, p. 465. Authors at Dept. Geol., Rensselaer Polytech. Inst., Troy, NY 12180.

An important but as yet uncharacterized aspect of lithospheric fluids is their distribution among the grains of rocks with which they are in chemical and mechanical equilibrium. The dihedral angle (θ; i.e., the angle formed by the intersecting walls of a fluid-filled pore at a junction with two solid grains) uniquely defines the fluid distribution in the following way: For $0° < \theta < 60°$ the fluid will form a 3-dimensionally interconnected network of channels along grain edges; for θ>60°, the fluid will pinch out to form isolated pockets at grain corners. We have measured θ for a variety of C-O-H fluids (some containing dissolved salts) in equilibrium with synthetic dunite and quartzite at 1 GPa and 950-1150°C. For $CO_2$-$H_2O$ fluids in equilibrium with polycrystalline $SiO_2$, θ varies systematically from -57° for pure $H_2O$ to -90° at $X(CO_2)$ -0.9. Similarly, for olivine, θ varies from -65° for pure $H_2O$ to -90° at $X(CO_2)$ -0.9. The addition of solutes (NaCl, KCl, $CaF_2$, $Na_2CO_3$) to pure $H_2O$ causes a major decrease in θ in the $SiO_2$/fluid system, but has no effect on fluid wetting characteristics in dunite. The implications of these results are that: 1) in crustal rocks at elevated P-T conditions, aqueous fluids (especially saline ones) are likely to form a grain-edge network that is continuous in 3-dimensions, thus greatly affecting chemical transport rates and physical properties such as electrical conductivity; and 2) in the mantle, the high wetting angles for most fluids inhibit 3-D connectivity, and imply that the mechanism of fluid transport is not porous flow or infiltration on the scale of individual grains but rather hydraulic fracturing or crack propagation. (Authors' abstract)

WATSON, E.B. and BRENAN, J.M., 1987b, Fluids in the lithosphere, 1. Experimentally-determined wetting characteristics of $CO_2$-$H_2O$ fluids and their implications for fluid transport, host-rock physical properties, and fluid inclusion formation: Earth & Planet. Sci. Ltrs., v. 85, p. 497-515.
Full paper for previous abstract. (E.R.)

WATSON, E.B. and ZINDLER, Alan, 1987, Preliminary experimental results on the metasomatic transport potential of fluids produced by devolatilization of metabasalts (abst.): EOS, v. 68, p. 1543.

WEBSTER, J.D. and HOLLOWAY, J.R., 1987, Partitioning of halogens between topaz rhyolite melt and aqueous and aqueous-carbonic fluids (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 884. First author at Dept. Geol., Arizona State Univ., Tempe, AZ 85287.

Superliquidus melts of topaz rhyolite composition have been equilibrated with fluids which consist of $H_2O$ and $H_2O + CO_2$ at P of 1/2 to 5 kb and T of 750° to 1000°C (with $fO_2$ controlled near NNO). The starting material is naturally enriched in lithophile trace elements, F (1.25 wt%) and Cl (0.15 wt%). The major element, Cl and F contents of the starting material and the run product glasses are determined by electron microprobe. The distribution coefficients, $D_{Cl}$ and $D_F$, are calculated as (ppm halogen in fluid/ppm halogen in melt). The halogen content of the fluid is calculated by mass balance.

F partitions in favor of the melt and $D_F$ ranges from 0.19 to 0.35. F partitioning is dependent on T and fluid composition. Increasing the $(CO_2/CO_2 + H_2O)$ of the fluid and decreasing T cause F to partition more strongly in favor of the melt.

Cl partitions in favor of the fluid for all experimental run conditions. For natural abundances of Cl in the magmatic system (up to 7 g Cl/Kg fluid) $D_{Cl}$ ranges from 2 to 10. These values are much lower than have been reported in the literature. $D_{Cl}$ increases as the Cl content of the melt increases, as T and P increase, as the peraluminousity of the melt increases and as the $(H_2O/H_2O + CO_2)$ of the fluid increases. Peraluminous granitic melts in equilibrium with aqueous fluids at 800° and 2 kb achieve saturation in Cl with 2650±200 ppm Cl. In experiments with Cl ranging from 7 to 300 g Cl/Kg fluid $D_{Cl}$ ranges from 10 to 130 and is consistent with literature values.

For granitic melts which are saturated in $H_2O$, the fractionation of Cl from the melt to the fluid also partitions trace elements, potential ore metals and the major elements Na, K, Fe ± Ca into the fluid. (Authors' abstract)

WEI, W., DONG, X., ZENG, H. and GAO, J., 1987, The geological characters and genesis of ultrabasic rock mass and chromite deposit in Sartokay of Xingjiang, China: Bull. of Xi'an Inst. Geol. & Min. Resources, no. 16, 1987, p. 57-145 (in Chinese; English abstract).

The chromite deposit in Sartokay of Xinjiang is one of the larger chromite deposits in China. The ultrabasic rock massif is situated in the eastern part of the Darbut ophiolite belt and belongs to an Alpine-type rock mass occurring in the West Junggar Variscan foldbelt. Inclusions of silicate melt, crystal-fluid and solids have been found in the ore minerals. The daughter minerals are chiefly forsterite (Fo95-96), enstatite (En93-94), clinopyroxene, chrome spinel and hornblende, etc. The regressive colored rocks are obviously rich in volatile components such as Cl, B, S and so on; the highest, up to 6800 ppm and 799 ppm in Cl and B respectively. According to results of temperature measurement of primary inclusions in olivine, pyroxene and chrome spinel from ore, the crystallization temperature of ultrabasic rock, and chromite is 1300-700°C. No cumulative characters are present in the distribution of the different ore types in the ore body, or between the mutual relationship of various ore bodies and ore texture. So, we conclude that the chromite was formed by liquid differentiation from a residual magma during the late magmatic stage. (From the authors' abstract)

WEIDNER, J.R. and MARTIN, R.F., 1987, Phase equilibria of a fluorine-rich leucogranite from the St. Austell pluton, Cornwall: Geochimica Cosmo. Acta, v. 51, p. 1591-1597. First author at Dept. Geol. Sci., McGill Univ., 3450 University Street, Montreal, Quebec, Canada H3A 2A7.

Highly evolved leucogranitic rocks in the St. Austell pluton, Cornwall, of Hercynian age, contain accessory muscovite, topaz and fluorite. We have studied the $H_2O$-saturated melting behavior of one representative sample. Its solidus and liquidus pass through the points 663 and 725°C, respectively, at 1 kbar, 640 and 665°C at 2 kbar, 610 and 717°C at 4 kbar, and 608 and 700+°C at 8 kbar. Plagioclase is on the liquidus at low P, and topaz is on the liquidus at 4 kbar. The fluorite is consumed in the formation of the first-formed liquid. Ca can partition into an evolved granitic melt if complexed by F. The fluorite appears to be largely primary in fresh fluorite granite at St. Austell, and not to reflect the albitization of oligoclase in the surrounding biotite granite. Such F-rich leucogranites can be expected to be of subsolvus character. (Authors' abstract)

WEIMER, B.A. and MANWARING, M.S., 1987, Evaluation of and new completion recommendations for a fractured, crystalline, igneous reservoir, Texas Panhandle: AAPG Bull., v. 71, no. 2, p. 245.

WEIR, R.H., Jr. and KERRICK, D.M., 1987, Mineralogic, fluid inclusion, and stable isotope studies of several gold mines in the Mother Lode, Tuolumne and Mariposa Counties, California: Econ. Geol., v. 82, p. 328-344. First author at Dames & Moore, 4620 Street Road, Trevose, PA 19047.

Gold-bearing quartz veins in the southern part of the Mother Lode, California, formed from fluids which contained Si, K, $CO_2$, Ca, S, and metals and which were focused into permeable fault zones. In the Coulterville district of the Mother Lode, these fluids altered serpentinite to a talc-chlorite-magnesite-quartz assemblage which is crosscut by veins containing quartz, dolomite, sericite, sulfides, tellurides, and gold.

These deposits were subjected to deformation during and after their formation. Fluid inclusions in the milky vein quartz exhibit only a narrow range in Tm ice but a large range in Th which probably reflects posttrapping deformation. Microthermometry of fluid inclusions from vug-filling quartz in the Alleghany district, in the northern portion of the Mother Lode, reveals low-salinity (<2 equiv wt % NaCl), $CO_2$-$H_2O$ fluids with Tm $CO_2$ = -56.7°C, Tm clathrate = 9.5°C, and Th total = 150° to 200°C. Visual estimates of $CO_2$ content indicate a maximum of 10 mole % $CO_2$. In contrast, inclusions from vug-filling quartz in the Coulterville district are filled with low-salinity, low Th (110°-140°C), $H_2O$-rich fluids which were probably later than, and unrelated to, the gold-mineralizing fluids. Data suggest either a single or well-mixed source of oxidized carbon for the fluids.

The chemistry of the Mother Lode ore-forming fluids is characterized by several approaches. With an $X(CO_2)$ estimate of 0.1 from fluid inclusions, quartz-magnesite assemblages in the Coulterville serpentinite alteration zones limit the T of formation to below 325°C for P <2 kb. Microthermometric evidence of one-phase trapping of the $CO_2$-$H_2O$ fluid, coupled with the assumption of Tt of 300°C, suggests minimum Pt of 1,000 to 2,000 bars. Assuming equilibrium, the assemblage of dms described by Coveney (1981) indicates neutral pH conditions of 5.5 to 6.0 at the prevailing P-T conditions. Sulfide mineral stabilities imply that $H_2S$ was the dominant sulfur species and that $\alpha(O_2)$ of the mineralizing fluids was in the range $10^{-32}$ to $10^{-35}$.

Our preferred model for the formation of the Mother Lode vein system involves magmatic activity associated with a subducting slab. In this model, generation of ore-forming fluids is possible by a variety of mechanisms including metamorphic devolatilization reactions in rocks adjacent to the plutons, direct magmatic input, and deep circulation of meteoric water. Any of these mechanisms is possible given the available data on the Mother Lode deposits. (From the authors' abstract)

WEISBROD, Alain and LEROY, Jacques, 1987, Metastable behavior of homogeneous fluid inclusions in rock-forming minerals. Application: C.R. Acad. Sci. Paris, v. 305, Ser. II, p. 455-459 (in French; English abstract).

The study of the microthermometric behavior of homogeneous fluid inclusions demonstrates the metastable status of the fluid. The process of return to the equilibrium state is analyzed. It gives clear indications that, in most cases, fluids have been entrapped at T above at least 150°C. (Authors' abstract)

WEISBROD, Alain and MARIGNAC, Christian, 1987, General features and mechanisms of Sn-W quartz veins formation in peri-batholitic enviornment, from fluid inclusion data (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 131-132. First author at C.R.P.G. (C.N.R.S.), Rue N.D. des Pauvres, 54500 Vandoeuvre, France.

Fluid inclusion studies performed on deposits from the South-Western Hercynian belt, yield the following generalizations:

1. - Peribatholitic quartz veins were the site of long duration hydrothermal circulations of high to medium T (600 to 300°C), representative of deep geothermal systems more or less evolving from the thermal metamorphism of the related intrusion. Good examples of such situations are the Serre-courte-Drobie little W and Sn deposits in S.E. French Massif Central, and the Walmes cassiterite deposit in the Central Meseta of Morocco.

2. - Early fluids involved in those circulations are low density $CO_2$-$CH_4$-$N_2$ bearing aqueous fluids derived from the metamorphic environment. In the studied deposits, the surrounding rocks are characterized by the presence of carbon-rich shales. According to the metamorphic grade of these

rocks prior to the intrusion(s), two classes of early fluids are distinguished: a) $N_2$-rich fluids, with variable relative amounts of $CO_2$ and $CH_4$ in anchizonal rocks (i.e., Walmes district); b) $N_2$-poor or absent and $CO_2$-dominated fluids in epi- to meso-zonal rocks (i.e., French Cévennes). It is worth noticing that the Cornish deposits (such as in Cligga Head) are located within Devonian series poor in carbon-rich shales.

3. - Sn or W deposition usually appears as a catastrophic event corresponding to a restricted stage of the circulation. Most often, this event is related to the involvement in the system of non-carbonic aqueous fluids of lower T. The Cévennes and Central Morocco Sn and/or W deposits provide good examples of such processes. Although it is less common, another type of blunt disturbance results from fluid unmixing ("boiling").

4. - As a rule, actual fluid T and P are difficult to obtain. Usually, P is roughly and often empirically estimated, and T are deduced from the isochores. When they occur, boiling phenomena give a better constraint: a good example is the Echassières district, where secondary boiling in late granites yields an estimate of the confining P at the time of intrusion. In the same district, the ore body is overprinted by a granitic intrusion, and this situation provides a way of estimating the minimum confining P of the ore deposition.

5. - Finally it must be kept in mind that fluid inclusions do not provide all the necessary information concerning the evolution of a paleogeothermal system. Careful mineralogical and paragenetic studies are always necessary, for instance, to recognize if the mineralizing fluids were either saturated or undersaturated with respect to quartz, a feature which is of basic interest. Stable light isotope geochemistry also brings significant specific constraints, very useful in determining the sources and the fluid/rocks ratios; these studies are most useful when they are directly performed on fluid inclusions, as well as on primary and alteration minerals. (Authors' abstract)

WEISSBROD, T., LANG, B. and BOGOCH, R., 1986, Barite-fluorite-calcite veins in the Precambrian Roded block, southern Israel (abst.): The Israeli Assoc. Advan. of Mineral Engrg., 8th Conf., p. 94. Authors at Geol. Survey of Israel.

Two mineralized veins of barite (~90%), fluorite, calcite and minor copper minerals, occurring in the Roded block of the northern extension of the Precambrian Arabo-Nubian Massif, were examined. Host rocks are mainly linear to massive quartz diorites. The veins are each approximately 800 m in length, occur over topographic differences of ~100 m, and average 50 cm in width. Based on their field occurrence, petrography and fluid inclusion homogenization temperatures, a possible paragenetic model (Fig. 1) envisages the initial deposition of barite, followed by calcite and fluorite. The copper minerals probably formed at higher temperatures with the early barite (<300°C). Assuming a subsurface depth of 25 m, the total potential amount of raw material in the veins (mainly barite) exceeds 250,000 tons. Further research is required both to examine other barite-bearing veins in the Precambrian of southern Israel, and to determine the genesis of the veins by a comprehensive-isotopic study. (Authors' abstract)

WELHAN, J.A., 1987, Characteristics of abiotic methane in rocks, <u>in</u> Saline water and gases in crystalline rocks, eds., Fritz, P. and Frape, S.K.: Geol. Assoc. Canada Special Paper 33, 1987, p. 225-233. Author at Dept. Earth Sci., Memorial Univ. Newfoundland, St. John's, Newfoundland, Canada A1B 3X5.

Methane in mid-ocean ridge (MOR) hydrothermal fluids can be shown to be derived abiotically from MOR basalts, together with carbon dioxide and helium of mantle origin, by the leaching action of fluids circulating in the crust. Carbon isotope ratios in this methane are distinctive (-15 to -18‰ vs PDB), and, in light of experimental evidence for high-T C isotope exchange between $CO_2$ and $CH_4$, very likely reflect isotope equilibrium with mantle $CO_2$ ($\delta^{13}$ = -5 to -7‰ vs PDB) at 500-800°C within the basalt. Lower T equilibration appears not to affect the $CH_4$ isotope ratios significantly due to the sluggishness of C isotope exchange at T <500°C. Available data on igneous rocks which are rich in $^{13}C$-enriched $CH_4$, suggest that high-T, abiotically-synthesized $CH_4$ preserves its unusual isotopic signature at low T for very long times. It is postulated that the $^{13}C$-enriched character of such high-T $CH_4$, and the characteristic C isotope compositions of co-existing light hydrocarbon gases, could be a distinctive tracer for abiotically-synthesized $CH_4$, and that the high $^{13}C/^{12}C$ ratios of $CH_4$ found in deep brines of the Canadian Shield may reflect an abiotic origin within these rocks. (Author's abstract)

WELHAN, J.A. and CRAIG, Harmon, 1987, Origins of methane in hydrothermal systems (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 885. First author at Earth Sci., Memorial Univ., St. John's, NF A1B 3X5.
See previous item.

WESOLOWSKI, D. and PALMER, D.A., 1987, Solubility of gibbsite in NaCl-NaOH and NaCl-HCl brines from 6.4 to 80.0°C and ionic strengths of 0.001 to 5.0 m (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 887.

WHELAN, J.F. and SHAW, C.A., 1987, Reliability of delta D and delta 18 O values of inclusion fluids from sulfides: U.S. Geol. Survey Open-File Rept. OF 87-0138, 10 pp.

WICKHAM, S.M. and TAYLOR, H.P., Jr., 1987, Stable isotope constraints on the origin and depth of penetration of hydrothermal fluids associated with Hercynian regional metamorphism and crustal anatexis in the Pyrenees: Contrib. Mineral. Petrol., v. 95, p. 255-268.

WIEDEMANN, Rainer, 1987, Facies and thermobarometric investigations in metamorphics of the western Erzgebirge anticlinorium: Freiberger Forsch. C415, p. 41-64 (in German; English abstract). Author at Tech. Univ. Schwerindustrie Miskole, East Germany.

According to the results of the investigations of fluid inclusions, tectonites of the Niederschlag-series crystallized at 550-600°C, tectonites of Schwarzburg-series at 350-400°C. (From the author's Summary)

WIENS, R.C. and PEPIN, R.O., 1987, Where in the glass is the gas? Siting studies on shergottite EETA 79001 and laboratory shocked analogues (abst.): Meteoritics, v. 22, p. 527-528. Authors at Sch. Physics & Astron., Univ. Minnesota, Minneapolis, MN 55455.

The trapped gas component in shergottite EETA 79001 similar in composition to the martian atmosphere was apparently emplaced by shock.

Glass inclusions in EETA 79001 vary in the number and size distribution of vesicles. Microvesicles of 10-100 θm[μm?] dia. were found in the inclusion used for most of the trapped gas analyses, and have been suggested as possible sites for the trapped gases. Evidence for siting in vesicles also comes from release of gases predominantly at the melting point of EETA 79001 glass. To address this possibility we have conducted in-vacuum crushing experiments on EETA 79001 glass and a laboratory shocked sample. The latter released 40-50% of its noble gases upon crushing, while EETA 79001 release was <20% of the total, and appeared to be a mixture of martian atmospheric gases and ~60% fractionated air. (From the authors' abstract)

WILBURN, D.L., BANKSTON, B.A. and MONGER, T.G., 1987, An experimental investigation into the effect of chemical type on $CO_2$/heavy-hydrocarbon phase behavior: 1987 Int'l. Symp. on Oilfield Chem., Proc. [Soc. Petroleum Engineers], p. 307-318. First author at Shell California Production Inc.

This paper provides PVT and compositional data for seven $CO_2$/synthetic-oil systems. The oils were composed of light paraffins plus heavy hydrocarbons selected from one or two of the three main chemical types; namely, paraffins, naphthenes, and aromatics. (From the authors' abstract)

WILCOX, W.R., 1987, Influence of convection on the growth of crystals from solution (abst.): Ann. Meeting Am. Crystallographic Assoc., Univ. Texas, Austin, Texas, March 15-20, 1987, Program and Abstracts, Series 2, v. 15, p. 25. Author at Dept. Chem. Engrg., Center for Adv. Materials Processing, Clarkson Univ., Potsdam, NY 13676, USA.

This is a review of the influence of convection on the growth of crystals from solution. The growth rate is increased by convection up to the point where interface kinetics becomes rate controlling. Compositional inhomogeneity and morphological instability (inclusion formation) are probably worse for gentle convection than for either no convection or for vigorous stirring. Stirring, particularly of crystal suspensions, can cause an order of magnitude increase in the rate of formation of new crystals. This is called secondary nucleation.

Under the direction of Ravendra Lal at A&M University of Alabama, triglycine sulfate crystals were grown on Spacelab 3. Although the growth rate was almost entirely diffusion-controlled, crystal facets formed. Unlike crystals grown on earth, the boundary between the seed and the space-grown layer could not be seen; no microinclusions were present. On one crystal a sheet grew out from one side to cover much of the surface. (Author's abstract)

WILKINSON, W.H., WENDT, C.J. and DENNIS, M.D., 1987, Gold mineralization along the Riverside Mountains detachment fault, Riverside County, California (abst.): Program with Abstracts, Symp.: Bulk Mineable Precious Metal Deposits of the Western United States, April 6-8, 1987, Geol. Soc. Nevada, p. 53. Authors at Westmont Mining, Inc.

Mineralization is characterized as a gold system with very low base metal, arsenic, and antimony geochem values. Preliminary fluid inclusion data suggest silica, which is spatially associated with Au mineralization, formed at shallow levels between 165 and 225°C. Tm of the fluid inclusions are in the range 0 to -9°C (0 to 13.5 wt. % NaCl eq.). (From the authors' abstract)

WILLIAMS, A.E., 1987, Chemical and isotopic variations and the distribution of brines across the Salton Sea Geothermal Field, California (abst.): EOS, v. 68, p. 438-439. Author at Inst. Geophys. & Planet. Physics, Univ. California, Riverside, CA 92521.

Recent and published fluid chemical analyses from forty (40) production intervals in wells located in the Niland, Buttes and Westmoreland areas of the Salton Sea Geothermal Field (SSGF) indicate several distinctive features of brine distribution across the field. In particular, a bimodality is observed in the total dissolved solids (TDS) of SSGF brines with distinct hypersaline (19 to 26 wt% TDS) and low salinity (less than 10% TDS) clusters. A rather sharp interface between these fluid types is implied by the close vertical proximity of production zones in five areas where both fluids have been sampled. The cooler (<260°C) low salinity fluids overlie the hot (>260°C) hypersaline brines with their interface roughly following the northeast-southwest elongated domal shape of the SSGF thermal distribution.

In areas where there is adequate well log information on structural and stratigraphic features it is apparent that there is little or no stratigraphic control on thermal and salinity distributions. Structures such as faults, however, may influence fluid migration and therefore control the shape of the thermal and salinity dome, at least locally.

Evidence for brine mixing along the salinity interface is provided by measurements of intermediate salinity fluid inclusions, stable isotopic compositions of fluids and the development of possible mixing trends on chemical ratio plots.

The development and evolution of the SSGF may be intimately linked to extensive dissolution and precipitation reactions expected near such an interface as fluid mixing or flow between areas of dissimilar chemistry occurs. (Author's abstract)

WILLIAMS, A.E. and McKIBBEN, M.A., 1987, A brine interface in the Salton Sea geothermal system, California: Mechanism for active ore formation (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 890. Authors at Inst. Geophys. & Planet. Physics & Dept. Earth Sci., Univ. California, Riverside, CA 92521.

Brine samples from recent drilling and production in the Salton Sea geothermal field (SSGF), in addition to published analyses, provide a three-dimensional picture of brine stratification in this hot (up to 360°C), saline (up to 26 wt % TDS) system. Data from more than 45 individual production intervals from this field indicate a distinct bimodality in total dissolved solids (TDS) with deep, hot, hypersaline (19 to 26 wt % TDS) and cooler intermediate salinity (less than 10% TDS) end members. A sharp, density controlled interface between these fluid types is indicated by their close vertical proximity in areas of the SSGF where both have been sampled.

Evidence for occasional mixing across this interface is provided by measurements of intermediate salinity fluid inclusions which are observed in fractures mineralized with ore phases such as pyrite, chalcopyrite, sphalerite, galena, hematite and pyrrhotite. Intensely mineralized zones are often observed in rock samples near to the inferred brine interface.

Abrupt and significant changes in overall brine chemistry are observed in production intervals very near to the fluid interface. In particular, Mn, Zn and Pb abundances decrease slightly while Fe concentrations in hypersaline brines drop from > 1,500 ppm to < 600 ppm as the interface is approached. Active precipitation of ore phases may occur when mixing across this brine interface drastically decreases chloride complexing of transition metals or causes oxidation of dissolved species. Although mixing across such a density stabilized interface is not simple, the hydrothermal circulation and active tectonics of the SSGF area provide ample opportunity for transient mixing events. (Authors' abstract)

WILLIAMS, S.N., SANO, Yuji and WAKITA, Hiroshi, 1987, Helium-3 emission from Nevado del Ruiz volcano, Colombia: Geophys. Res. Letters, v. 14, no. 10, p. 1035-1038. First author at Dept. Geol. & Geophys., Louisiana State Univ.

High helium-3/helium-4 ratios, up to 6.6 $R_{atm}$ (6.6 times the atmospheric ratio of $1.40 \times 10^{-6}$) were observed in nine samples of gases and hot waters from seven sites located around the volcano Nevado del Ruiz, Colombia. The values of the ratio decrease with distance from the crater. Such a tendency coincides well with the pattern first reported from the volcano Ontake, central Japan, and suggests a general signature of helium isotope ratios around individual volcanoes. The corrected helium-3/helium-4 ratios at one gas vent sampled twice over six months increased. This is interpreted to mean that the mantle contribution of helium may have increased with time. (Authors' abstract)

WILMART, Edith and DUCHESNE, J.C., 1987, Geothermobarometry of igneous and metamorphic rocks around the Aana-Sira anorthosite massif: Implications for the depth of emplacement of the South Norwegian anorthosites: Nor. Geol. Tidsskr., v. 67, no. 3, p. 185-196 (in English).

Compares many different geothermometers and geobarometers. (E.R.)

WILSHIRE, H.G. and KIRBY, S.H., 1987, Brittle fracturing and related phenomena in the lower lithosphere (abst.): Geol. Soc. Am. Abst. with Programs, v. 19, p. 464. Authors at U.S. Geol. Survey, Menlo Park, CA.

WILTSCHKO, D.V. and BUDA, J.M., 1987, Water/rock interaction during deformation of the Absaroka thrust sheet Idaho-Wyoming-Utah thrust belt: The control of structural position (abst.): EOS, v. 68, p. 1527.

WINTERS, M.B., 1987, An investigation of fluid inclusions and geochemistry of ore formation in the Cedar Creek breccia pipe, North Santiam mining district, Oregon (abst.): Oregon Geol., v. 49, no. 5, p. 61.

See abstract from G.S.A., in Fluid Inclusion Research, v. 19, 1986. (E.R.)

WITTRUP, M.B., KYSER, T.K. and DANYLUK, T., 1987, The use of stable isotopes and brine chemistry to determine the source and origin of brines in Saskatchewan potash mines (abst.): GAC-MAC, AGC-AMC Joint Ann. Mtg., Program with Absts., v. 12, p. 102. First author at Dept. Geol., Univ. Saskatchewan, Saskatoon, Saskatchewan, S7N OWO.

Recent mine level floods at Saskatchewan potash mines have shown the need to accurately identify the source of the water to undertake proper preventative or remedial action. Chemical compositions of waters are inadequate in constraining the source of the brines because it is erroneously assumed that the concentrations of at least some of the elements do not change during fluid migration. Chemical compositions, however, may be valuable in making an initial diagnosis of the source of the fluid such as to differentiate between basinal waters and connate waters.

Stable isotopes of oxygen and hydrogen are normally conservative elements of waters so that within a basin the $\delta D$ and $\delta^{18}O$ values of the pore waters typically increase with depth because of the mixing of connate and meteoric waters. Thus, by comparison of the isotopic composition of the mine level waters with those of waters from the stratigraphic profile it is possible to assign an origin to the flood waters. The stable isotope method allows for an accurate assessment of the brine source irrespective of the changes in the chemical composition of the brine during migration of the fluid. (Authors' abstract)

WOAKES, M., 1987, [Gold at Bin Yauri and Okalom, Nigeria], Newsletter, Int'l. Liaison Group on Gold Mineralization, no. 4, April 1987, p. 5.

Reports work by S.O. Akande, et al., on these veins, showing two Th peaks at 170° and 240°C, with maximum at 320°C. Salinity average = 1.5% NaCl eq. Metamorphic dewatering of the enclosing sediments and volcanics is the probable fluid source. (E.R.)

WODZICKI, Antoni, 1987, Origin of the Cracovian-Silesian Zn-Pb deposits: Ann. Soc. Geol. Polon., v. 57, p. 3-36. Author at Geol. Dept., Western Washington Univ., Bellingham, WA 98225, USA.

Previous work has shown that most of the mineralization occurs as metasomatic replacement of hydrothermal dolomite, and as cavity-filling in hydrothermal karst breccias. It was emplaced along a paleoaquifer within the Muschelkalk mainly during Early Cimmerian movements. Available geological and geochemical data suggest that the hydrothermal fluids were episodically expelled from the Upper Silesian coal basin as a result of fluid overpressure generated during burial and diagenesis. Initially the fluids were buffered by quartz-illite-K feldspar, and aqueous carbonate-methane equilibria. During hydrothermal karst formation and ore deposition they became more oxidizing and acid, probably as a result of mixing with near surface waters and the generation of hydrogen ions by oxidation of methane. The zinc and lead could not have been transported as chloride or bisulphide complexes, but may have been transported as organometallic complexes. (Author's abstract)

WOOD, P.C., BURROWS, D.R., THOMAS, A.V. and SPOONER, E.T.C., 1986, The Hollinger-McIntyre Au-quartz vein system, Timmins, Ontario, Canada; geologic characteristics, fluid properties and light stable isotope geochemistry: Proc. of Gold '86 Symp., Toronto, 1986, p. 56-80. Authors at Dept. Geol., Univ. Toronto, Toronto, Ontario M5S 1A1, Canada.

See Wood, Burrows, and Spooner, 1986, in Fluid Inclusion Research, v. 19, p. 478. (E.R.)

WOOD, S.A., 1987a Application of a multiphase ore mineral solubility experiment to the separation of base metal and gold mineralization in Archean greenstone terrains: Econ. Geol., v. 82, p. 1044-1048. Author at Dept. Geol. Sci., McGill Univ., Montreal, Quebec, Canada H3A 2A7.

Uses literature data on fluid inclusions. (E.R.)

WOOD, S.A., 1987b Thermodynamic calculations of the volatility of the platinum group elements (PGE): The PGE content of fluids at magmatic temperatures: Geochim. Cosmo. Acta, v. 51, p. 3041-3050.

WOOD, S.A., CRERAR, D.A. and BORCSIK, M.P., 1987, Solubility of the assemblage pyrite-pyrrhotite-magnetite-sphalerite-galena-gold-stibnite-bismuthinite-argentite-molybdenite in $H_2O$-NaCl-$CO_2$ solutions from 200° to 350°C: Econ. Geol., v. 82, p. 1864-1887.

WOOD, S.A. and MOUNTAIN, B.W., 1987, Thermodynamic calculation of the solubility and transport of PGE in hydrothermal fluids at 300°C: Application to hydrothermal PGE deposits in shear zones in mafic and ultramafic rocks (abst.): Terra Cognita, v. 7, no. 2-3, p. 318.

WOODLAND, A.B. and WALTHER, J.V., 1987, Experimental determination of the solubility of the assemblage paragonite, albite, and quartz in supercritical $H_2O$: Geochimica Cosmo. Acta, v. 51, p. 365-372. Authors at Dept. Geol. Sci., Northwestern Univ., Evanston, IL 60201, USA.

The results indicate Al can be readily transported in pure $H_2O$ solutions at temperatures and pressures as low as 350°C and 1 kbar. (From the authors' abstract)

WOODS, T.L. and GARRELS, R.M., 1987, Thermodynamic values at low temperature for natural inorganic materials: An uncritical summary: Oxford Univ. Press, New York.

WOPENKA, Brigitte and PASTERIS, J.D., 1987, Raman intensities and detection limits of geochemically relevant gas mixtures for a laser Raman microprobe: Anal. Chem., v. 59, p. 2165-2170. Authors at Dept. Earth & Planet. Sci. & McDonnell Center for Space Sci., Box 1169, Washington Univ., St. Louis, MO 63130.

We describe Raman experiments on gas mixtures of known composition containing $N_2$ plus two or more of the following species: $SO_2$, $CO_2$, $O_2$, CO,

$H_2S$, $CH_4$, and $H_2$. The mixtures were used to calibrate a RAMANOR U-1000 with the goal of increasing the accuracy of compositional analyses of fluid inclusions in geological samples. We derived instrument-specific "Raman quantification factors" that incorporate both relative (to $N_2$) Raman scattering cross sections and instrumental efficiencies. The experiments were done on gases in thin-walled, silica glass capillaries at <15 atm pressure. The application of these quantification factors eliminates the need to choose among the widely differing literature values for Raman scattering cross sections and permits better correction for specific optical and geometric effects than does the use of a calibration lamp. Detection limits for analysis of fluid inclusions exceeding about 10 µm in diameter range from about 0.3 to 1.6 atm partial pressure. (Authors' abstract)

WRIGHT, J.H., WALLACE, A.R. and KARLSON, R.C., 1985, New studies at the Schwartzwalder mine, Jefferson County, Colorado (abst.): The Canadian Inst. Mining & Metal. Spec. Volume 32, Geology of uranium deposits, Sibbald, T.I.I. and Petruk, W., eds., p. 262.

The deposit was formed from ascending hydrothermal fluids. Wallrock alteration produced carbonatization of mafic minerals, strong K enrichment and Na depletion. Th of fluid inclusions in late-stage amethyst and calcite are ~120°C and 150°C, respectively, and probably are minimum T estimates for vein formation. Freezing studies indicate salinities of about 10 wt.% NaCl eq. Probably, ore was deposited from an ascending carbonate-dominated hydrothermal fluid. (From the authors' abstract)

WU, Houze, LIU, Yuexing, CHI, Shangrong and TIAN, Yingqiu, 1987, Experimental study on synthetic primary inclusion of minerals: Jour. of Geol. of Guanqxi, no. 1, 1987, p. 21-28 (in Chinese; English abstract). Authors at Res. Inst. Geol. for Min. Resources, China Nat'l. Nonferrous Metals Industry Corp.

A series of experimental data have been made through synthesis of primary inclusion of minerals about forming mechanism, application of data measured from inclusions. This is the first time to synthetize the mineral inclusion by analogising geologically the mineralization, with a lot of important data obtained. It is known from experiment that T has an obvious impact on the development, number, size and gas ratio of the inclusion. When P is low, the even-T of the inclusion approaches the T at which it was formed. Under the condition of high-T and low-P, salinity-low medium changed into salinity-high inclusion. It is believed that the magmatic hot liquid turned into an uneven system with a salinity-high liquid phase and a salinity-low gas phase under the critical conditions, thus explaining the origin of medium-high-salinity inclusions of porphyry deposits. (Quoted verbatim, as I am not certain of the meaning. E.R.)

WU, Xiangbin, 1987, The hydrolytic weakening of quartz grains in the Chijiang fault zone: Geol. & Prospecting, v. 23, no. 9, p. 24-26 (in Chinese; English summary).

WYLLIE, P.J., 1987a Discussion of recent papers on carbonated peridotite, bearing on mantle metasomatism and magmatism: Earth & Planet. Sci. Letters, v. 82, p. 391-397.

WYLLIE, P.J., 1987b, Metasomatism and fluid generation in mantle xenoliths, in Mantle Xenoliths, P.H. Nixon, ed.: John Wiley & Sons, p. 609-621.

Includes a discussion of the differences in composition, and phase relations, of the two types of fluid, silicate melt and volatile-rich. (E.R.)

WYLLIE, P.J., 1987, Transfer of subcratonic carbon into kimberlites and rare earth carbonatites, in B.O. Mysen, ed., Magmatic Processes: Physicochemical Principles: Geochem. Soc. Spec. Pub. 1, p. 107-119.

XAVIER, R.P., 1987, Fluid inclusion studies in the Fazenda Brasileiro gold deposit, Rio Itapicuru Greenstone Belt, Bahia State, Brazil: MS thesis, Univ. of Campinas, Sao Paulo, Brazil, 142 pp. (in Portuguese; English abstract). Modified from report in Newsletter Int'l. Liaison Group on Gold Mineralization, 1987, no. 4, p. 41-42. Author at Dept. de Metalogênese, IG - UNICAMP - CEP 13100, Campinas, SP, Brazil.

Microthermometric and Raman studies on $CO_2$ and $H_2O-CO_2$ inclusions in quartz showed that the mineralizing fluids were dense (0.85-0.95 g/cm$^3$) and hot (>400°C) solutions composed essentially of $CO_2$ (89.7-85.4 mol%) and minor amounts of $CH_4$ and $N_2$, which gradually evolved to more aqueous fluids (40 to 62.5 mol% $H_2O$) of low salinity (<10 wt% NaCl) at lower T (250-300°C) and higher crustal levels.

The isochores of the carbonic and $H_2O-CO_2$ fluids, the T of total homogenization and mineral equilibrium in the ore paragenesis, point to at least two periods of gold deposition: (1) 380-491°C and 2.2-3.2 kb in the quartz-ofelspathic and arsenopyrite-pyrite quartz veins and; (2) 270-300°C and 1.2-1.4 kb in the massive quartz vein.

The predominance of the $H_2O$ regime over the $CO_2$ regime at higher crustal levels might have been the cause of $CO_2$ dilution, decrease in pH and oxidation and, as consequence, the precipitation of gold.

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, as has been deduced for other gold deposits in similar granite-greenstone terrains. (From the author's abstract)

XIA, Linqi, 1987, Significance of the study of magmatic inclusions in the petrology of volcanic rocks: Acta Petrol. Sinica, no. 2, p. 52-63 (in Chinese; English abstract). Author at Xian Res. Inst. of Geol. & Min. Resources.

A review of the uses of magmatic inclusions. (E.R.)

XIA, Linqi and CLOCCHIATTI, R., 1986, Magmatic inclusions in phenocrystals from andesitic lavas, Krakatau volcano, Indonesia: Geochemistry, v. 5, no. 4, p. 331-346.

See Fluid Inclusion Research, v. 19, p. 480, for abstract. (H.E.B.)

XIA, Weihua and FENG, Zhiwen, 1987, Rock-forming analysis of carbonatites and their metallogenic prognosis in central Shandong (China): Diqiu Kexue, v. 12, no. 3, p. 285-292 (in Chinese).

XU, Guofeng, 1987, Source of ore-forming material of gold-silver deposits from volcanic rock area in Zhejiang, China: Earth Sci., Jul., v. 12, no. 4, p. 389-396 (in Chinese; English abstract). Author at Wuhan College of Geol., Wuhan 430074, PRC.

The results of investigation of stable isotope and geological characteristics indicate that the source of ore-forming material in these deposits is of polyphyletic[sic] origin, and the metals and volatiles come from the deep lithosphere (lower crust or upper mantle) and upper crust. Ore-forming fluid is a mixed solution, which is composed of a large [amount] of atmospheric water and a small [amount] of magmatic water. Au-Ag mineralization is related to plate movement and the convection system of geothermal fluid. (Author's abstract)

YANG, Tingdong, 1987, The study of complex mineralization and metallogenic series of Xiayingfang gold deposit, Hebei Province: Earth Sci., Jul., v. 12, no. 4, p. 405-413 (in Chinese; English abstract). Author at Wuhan College of Geol., Wuhan 430074, PRC.

The author [believes] that this deposit is related to granitic magma, from the anatexis of sialic crust (including parts of greenstone belt). The deposit formed by the mobilization and migration of Au, Ag and Fe, etc., from greenstone belt during magmatic mixing and latter volcanic-subvolcanic hydrothermal activity. The study suggests that the various genetic types and distinctive geological characteristics of the deposit are closely related to the multi-period and multistage mineralization. (Author's abstract)

YIBAO, Dong, BOTH, R.A., BARNES, R.G. and SUN, S.S., 1987, Regional stable isotope and fluid inclusion study of vein-type mineralization in the Broken Hill Block, New South Wales, Australia: Trans. Instn. Min. Metall. (Sec. B: Appl. Earth Sci.), v. 96, p. B15-B30.

The stable isotope and fluid inclusion data that were obtained in the present study, when combined with field relationships and previous lead isotope studies, suggest that the strata-bound and vein-type deposits were derived by remobilization or leaching of components from the metasediments and metavolcanics of the Willyama Supergroup.

The various vein deposits are closely associated with retrograde schist zones or areas of pervasive regional retrogression, which suggests that the mineralization may have resulted from fluid movement during retrograde metamorphism.

Estimated $\delta^{18}O$ values for the mineralizing fluids are consistent with the interpretation that the water was derived from the surface (meteoric and/or sea water) and that differing degrees of water-rock interaction were part of the processes that led to the formation of the various types of vein deposits. (From the authors' abstract)

YIE, Zhongji, 1987, The study on the origin of Zhongjia tungsten deposit with its mineral[sic, fluid?] inclusions: Geol. of Fujian, v. 6, no. 2, p. 128-142 (in Chinese; English abstract). Author at Fujian Inst. Geol. Sci.

Fluid inclusions of Zhongjia W deposit show three T ranges, 600-540°C, 420-380°C and 330-180°C. [W mineralization occurred] from 280°C to 350°C, and the T of the pneumatogenic stage is 380-420°C. The total salinity was 34-44 wt%. There are high-T, high-salinity and supercritical boiling inclusions in quartz of coarse-grained granite and granite-porphyry as well as in other intrusive rocks; the T and salinity are 660-540°C and 39.3-78 wt% (avg. 50.5 wt%). The characteristics of inclusions in the diagenetic stage are similar to those of the metallogenic stage, but salinity and T are higher than in the latter. The approximate P in the metallogenic stage is $650 \times 10^5 - 275 \times 10^5$ Pa (eq. to the depth of 2.36-2.90 km). Therefore, the diagenetic and metallogenic conditions are hypabyssal and near-surface. The writer thinks that Zhongjia W deposit is a porphyritic W-type deposit. (From the author's abstract)

YIH, C.-S., 1987, Convection instability of a spherical fluid inclusion: The Physics of Fluids, v. 30, no. 1., p. 36-44.

YIU, Bin and DUAN, Guangxian, 1987, The density and isochoric formulae for $NaCl-H_2O$ fluid inclusions (salinity 25 wt %) and their applications: Acta Mineral. Sinica, v. 7, no. 4, p. 345-352 (in Chinese: English abstract). Author at Dept. Geotech. Engrg., Shanghai Tongji Univ.

Considering the state equations available are not applicable to salt-bearing fluid inclusions, the authors have established the density and isochoric formulae for $NaCl-H_2O$-bearing fluid inclusions (salinity <25 wt %) using the least squares method in conjunction with the experimental data.

Only by substituting the measured homogenization Th and salinities into the density formula can one calculate the fluid density. And based on this the formation T and P of fluid inclusions can be worked out by using the isochoric formula for density and salinity.

Three typical examples are given in this paper. (Authors' abstract)

YONEDA, Tetsuro, 1987, Barite ores and compositional variations in tetrahedrite-tennantite of the Minamishiraoi mine, Hokkaido, Japan: Mining Geol., v. 37, no. 5, p. 323-336 (in Japanese; English abstract). Author at Dept. Resources Dev. Engrg., Hokkaido Univ., Sapporo 060, Japan.

Presents Th data for barite and related sphalerite. (E.R.)

YU, Dagan and RAO, Minghui, 1987, Discussion on effect of carbon dioxides in mineralization process of hydrothermal uranium deposit (abst.): Geol. Soc. Am. Abstracts with Programs, v. 19, p. 903. Authors at East China Geol. Inst., Fuzhou, Jiangxi, PRC.

In hydrothermal (vein-type) U deposits of China, pitchblendes are widely in paragenesis with colloidal pyrite. There are no reducing agents on both sides of vein. Basing on composition study of gaseous-liquid inclusion in typical vein-type U deposits in south China, U-bearing solution has a value of Eh of 400 MV. This explains that U is transported in stronger reducing solution, [and] then precipitated. In these deposits of granites, volcanic rocks, and carbonate-siliceous-pelitic rocks, stable isotope data interpret that hydrothermal water is of meteoric origin. The range of values of $^{13}C‰$ are between 6-8. These indicate that the carbon dioxide [was] derived from the deep crust. Because [of the] role of carbon dioxide, U was mobilized from the U-rich host rocks, so that they are dissolved and U-bearing fluids are formed. Because carbon dioxide has a high partial pressure, $U^{6+}$ is transported as uranyl carbonate complexes but does not precipitate in reducing fluids. Complexes are decomposed as carbon dioxide is evolved and partial pressure decreases. $U^{6+}$ change into $U^{4+}$ and precipitate automatically [from] U-bearing solution by reduction. Pyrite occurs in paragenesis with pitchblende.

As mentioned above, occurrence of carbon dioxide coming from deep crust is a necessary condition to form deposits, so $^{13}C‰$ can be regarded as a regional criterion for the evaluation of U deposits. (Modified by E.R. from the authors' abstract)

YU, Huilong, 1987a An antimony deposit of the megacrystalline calcite vein-type: Kexue Tongbao (Science Bulletin), v. 32, no. 21, p. 1481-1485 (in English). Author at Jianghan Petroleum College, Jingzhou, Hubei.

Temperatures [Td?] reported for calcite (136-174°C), barite (142-168°C), and stibnite (178°C). Fluid salinities (wt%) were: calcite 12.9, barite 14.8, and stibnite 15.2. Delta D, C, and O data are given. Delta D values of inclusion water [calc.?] for calcite, barite and stibnite range from -82 to -85%. (E.R.)

YU, Huilong, 1987b, Material source of and the properties of ore-forming solutions responsible for stratabound antimony deposits in carbonate rocks at Xujiashan, Hubei Province (China): Diqiu Huaxue, 1987, no. 2, p. 167-175 (in Chinese).

YU, Yunmei and WANG, Yurong, 1987, Experimental study on biotite in the Na-, F- and Li-rich pneumatolytic-hydrothermal processes: Geol. Review, v. 33, no. 3, p. 258-266 (in Chinese; English abstract). Authors at Inst. Geochem., Acad. Sinica.

This paper describes the experimental method and results from a study of the changes of biotite taking place in the Na-, F- and Li-rich pneumatolitic-hydrothermal processes by using two buffers (NNO and CFG). (From the authors' abstract)

YUAN, Zhongxi, BAI, Ge and YANG, Yueqing, 1987, A discussion on petrogenesis of rare metal granites: Mineral Deposits, v. 6, no. 1, p. 88-96 (in Chinese; English abstract). Authors at Inst. Mineral Deposits, Chinese Acad. Geol. Sci., Beijing, PRC.

Based on several geological phenomena, the authors hold that most of the rare metal granites must have been formed by autometasomatism whereas only a very few are products of magmatic crystallization. Inclusions in two rock bodies suggest that the formation T of quartz can be divided into two groups, i.e., >500°C and <500°C (Table 1, 2), with the first group probably denoting T of magmatic crystallization and the second group those of metasomatism (the T of formation of microlite and manganotantalite, i.e., 315-320°C, are consistent with those of the second group). (From the authors' abstract)

ZADNIK, M.G., SMITH, C.B., OTT, U. and BEGEMANN, F., 1987, Crushing of a terrestrial diamond: $^3He/^4He$ higher than solar (abst.): Meteoritics, v. 22, p. 540-541. Authors at Max-Planck-Inst. Chemie, 6500 Mainz, FRG.

It is very unlikely that this stone contains a previously unknown trapped helium component. The only variable [viable?] alternatives seem to be in situ production of $^3He$ from cosmic ray spallation or neutron capture by $^6Li$ or $^{10}B$. Based on the production rate of $^3He$ from cosmic rays (Kurz, 1986) and the e-fold attenuation length of ~0.5 m spallation can be ruled out.

Since the gases are released upon crushing they appear not to have been residing in the diamond proper but rather in inclusions so that the $^3He$ must have been produced in mineral inclusions (mass <1% total). It is only with Li contributing to the production of $^3He$ via $^6Li$ (n, α) that the observed high $^3He/^4He$ ratios can be explained. (From the authors' abstract)

ZAIKOWSKI, Anthony, KOSANKE, B.J. and HUBBARD, Norman, 1987, Noble gas composition of deep brines from the Palo Duro Basin, Texas: Geochimica Cosmo. Acta, v. 51, p. 73-84. First author at Bendix Field Engrg. Corp., P.O. Box 1569, Grand Junction, CO 81502, USA.

Deep groundwaters in sedimentary basins can be sufficiently old (>10 m.y.) to have accumulated both radiogenic $^4He$ and $^{40}Ar^*$. Differences in the ratio of (U + Th)/K for aquifer lithologies lead to variations for $^4He/^{40}Ar^*$ in the groundwater. These variations can be used to resolve chronologically significant noble gas components. Application of a binary model to brine samples from the Palo Duro Basin, Texas, yields (U, Th)-$^4He$ residence times of 100 to 300 m.y. Concentrations of two non-radiogenic noble gases ($^{20}Ne$ and $^{36}Ar$) provide information on the salinities of the water that recharged these aquifers. (Authors' abstract)

ZAYKIN, I.D. and MOISEENKO, V.G., 1987, Kinetics of gas release from gas-liquid inclusions in native metals: Dokl. Akad. Nauk SSSR, v. 292, no. 3, p. 713-715 (in Russian). Authors at Amur Complex Sci.-Research Inst. of Far-East Sci. Center of Acad. Sci. USSR, Blagoveshchensk, USSR.

Gradual heating (with T increase) of native gold, silver and platinoids indicated that for complete release of volatiles from GL inclusions in these metals at 300°C the time of heating 10 min. is sufficient. However, at 500 and 700°C gases and water release much slower[sic]. The kinetics of gas release ($CO_2$, CO and $N_2$) from two samples of gold and one sample of osmiridiuim from the deposits in Priamur'ye, USSR, was investigated by gas chromatography. The specimens were cleaned with HF, HCl and $HNO_3$ and handpicked under a binocular [microscope]. It was found that volatiles from fluid inclusions release at T 100-700°C. The samples were first heated up to 300°C till the complete gas release at this temperature. Next in 2 minutes T increased to 500°C and the amount of the gas released was determined every 10 minutes till the complete gas release and the same operation was repeated at 700°C. The authors write that the gas release from fluid inclusions at high T has an activation energy and present an equation describing the kinetics of this process and calculated or estimated constants to these equations. (Abstract by A.K.)

ZEITLER, P.K., HERCZEG, A.L., McDOUGALL, I. and HONDA, M., 1987, U-Th-He dating of apatite: A potential thermochronometer: Geochimica Cosmo. Acta, v. 51, p. 2865-2868.

ZENG, Yishan, AI, Ruiying and CHEN, Yuetuan, 1986, Determination of solubility of $Fe_2O_3$ in dilute aqueous solutions at 300°C and 10 MPa - Appending a discussion about the transporting form of iron in hydrothermal solutions: Scientia Sinica, Ser. B, v. 29, no. 11, p. 1221-1232 (in English).

ZENG, Yishan, WANG, Fengzhen, HE, Zongli, LIU, Guoping, WANG, Chengqiang and HAO, Jicheng, 1986, Study on composition of inclusions in minerals and simulation experiment on hydrothermal metasomatic process of the Bayan Obo iron deposit: Acta Geol. Sinica, v. 60, no. 4, p. 352-364 (in Chinese; English abstract). Authors at Dept. Geol., Beijing Univ.

In order to study the genetic relationship between different minerals in the Bayan Obo iron deposit, the compositions ($K^+$, $Na^+$, $Ca^+$, $Mg^+$, $F^+$, $Cl^+$[sic], $\Sigma CO_2$, $SO_4^{2-}$ and pH) of inclusions in fluorite (23), hematite (13), magnetite (3), sodic pyroxene (2) and dolomite (5) from the main mine and the eastern mine were determined by using the vacuum decrepitation and leaching methods, and cluster analyses of the data on the compositions were made. The Q-mode cluster analysis indicates that some iron oxide minerals in the deposit are related to dolomite of sedimentary origin, while others are related to fluorite and sodic pyroxene-products of hydrothermal activity. The R-mode cluster analysis shows that the components of the leaching solution may be divided into two groups: one includes $\Sigma CO_2$, $Mg^{2+}$ and $H^+$ (pH), which are obviously associated with dolomite; the other comprises $Na^+$, $K^+$, $Ca^+$, $F^+$[sic], $Cl^-$ and $SO_4^{2-}$, which may possibly represent the composition of hydrothermal solutions,.

The reaction of a Na-F-Cl solution (pH 4.72) with hematite-dolomite at 300°C and $5 \times 10^7$ Pa and under alternately "static" and "dynamic" conditions produced large amounts of hematite and fluorite and small amounts of smectite and Na(Fe)-silicates, and the hematite-fluorite assemblage accords with the actual geological conditions in the deposit. From a comparison between the compositions of "static" and "dynamic" solution samples, it may be known that the flow reaction facilitates the migration of Fe, F, Ca and other components as well as Na-metasomatism (Na and Si are fixed in a solid phase).

The study of the compositions of mineral inclusions and simulation experiments on hydrothermal metasomatism have provided new evidence for the hypothesis of metamorphosed-sedimentary and hydrothermal-remoulding origin of the Bayan Obo deposit, and pointed out emphatically that hydrothermal metasomatism plays an important role in the formation of the minerals deposit, particularly in the main and the eastern mine. (Authors' abstract)

ZENG, Y., WEI, J. and XIONG, D., 1987, Experimental study of hydrothermal alteration of carbonate rocks by Na-F solutions under flow conditions: Applied Geochem., v. 2, p. 181-191.

ZHANG, Dehui, 1987, A further discussion on the property of ore-forming fluid of the quartz-vein type wolframite deposit: Earth Sci., Mar., v. 12, no. 2, p. 185-192 (in Chinese; English abstract). Author at Wuhan College of Geol., Wuhan 430074, PRC.

The author contrasts the [microscopic features of] quartz-vein type wolframite deposits with the pegmatitic deposits. It is believed that both deposits [have similar] ore-forming fluids. It is characterized by residual magma during the late period of magma evolution. Considering that there is the appearance of hydrothermal activity, the ore-forming fluid is called a magmatic-hydrothermal solution intermediate type fluid. (Author's abstract)

ZHANG, Enshi, ZHANG, Wenhuai and LIU, Wei, 1987, On formation mechanism of Keketuohai pegmatite, Xinjiang, China: Earth Sci., Jul., v. 12, no. 4, p. 381-388 (in Chinese; English abstract). Authors at Wuhan College of Geol., Wuhan 430074, PRC.

From a study of fluid inclusions, the physicochemical conditions of pegmatite formation are discussed. Some melt and melt-solution inclusions are found for the first time from No. 3 pegmatite vein in this district. Some principal problems about the characteristics and evolution of rock-forming and ore-forming fluids and the formation mechanism of pegmatite have been studied deeply and some new knowledge of them has been suggested. (Authors' abstract)

ZHANG, Jianzhong, FENG, Binghuan, JIN, Haojia, LIU, Bin, LUO, Yupeng, JIN, Zhiming, ZHU, Meizhu and CHEN, Shuzhang, 1987, The genetic relationship between marine volcanic rocks and iron deposits at Abagong-Mengku area, Altay district, Xinjiang and ore-forming geological features: Bull. Xi'an Inst. Geol. & Min. Resources, Chinese Acad. Geol. Sci., no. 20, 1987, p. 89-176.

The iron ore belt occurs in a series of metamorphic spilite-quartz keratophyres and is controlled by ocean floor volcanism. To sum up, manifold metallogenesis such as ore magma eruption-injection, eruption-sedimentation and volcanic hydrophreatic replacement can be found, and those are not all identical in different iron deposits and occurrences. The later metallogenesis is the most important in Mengku iron deposit and the surrounding. The iron ore bodies and their country rocks show distinct "skarnization," the products of mixing of volcanic hydrophreatic liquid and submarine Ca-rich brines. Inclusion thermometry and barometry data indicate 194-530°C and 200-1900 bar. The large amount of ferruginous crystal grains exist in melt inclusions and the appearance of $CO_3$, $Cl^-$ and salt dms in fluid inclusions reveals that the iron in Abagong deposit stems directly from the ore magma, and the majority of iron in Mengku and the surrounding ore deposits stems mainly from an ore-bearing hydrophreatic [fluid] fractionated from the volcanic magma. (From the authors' abstract)

ZHANG, Xiaomao, 1986, Fluid inclusion and stable isotope studies of the gold deposits in Okanagan Valley, British, Columbia: MS thesis, The University of Alberta.

Two kinds of Au mineralization, epithermal and mesothermal, occur in the Okanagan Valley, southern British Columbia. Fluid inclusion and stable isotope studies indicate that two distinctive hydrothermal fluids were responsible for the mineralization events. At Dusty Mac, the epithermal fluid had T ~240°C, a low salinity of ~0.5 wt% NaCl eq. and a low value for $\delta^{18}O(SMOW) = -7$ to -9 per mil. The mineralization process probably occurred at a depth of more than 380 meters. At Oro Fino and Fairview, the mesothermal fluids had a high $CO_2$ content, T of 280°-330°C, salinities of 4-6 wt% NaCl eq. and $\delta^{18}O$(SMOW) of +4 to +6 per mil. The mineralization occurred at a depth of 3-4 km. The data indicate that fluids involved in both mineralization processes originated from meteoric water, with shallow circulation responsible for the epithermal deposit (Dusty Mac) and deep circulation for the mesothermal ones (Oro Fino and Fairview). (Author's abstract)

ZHANG, Y.-G. and FRANTZ, J.D., 1987a Determination of the compositional limits of immiscibility in $H_2O$-$CO_2$-$CaCl_2$ fluids at 600°C and 2.0 kbar using synthetic fluid inclusions (abst.): EOS, v. 68, p. 1539. Authors at Geopys. Lab., 2801 Upton St., N.W., Washington, DC 20008.

The conditions under which high-T, high-P fluids of different compositions exist as immiscible liquids have an important bearing on metasomatic reaction paths occurring in the Earth's crust. In an effort to determine the effect on liquid immiscibility of adding 2-1 electrolytes to $H_2O$-$CO_2$ fluids, the system $H_2O$-$CO_2$-$CaCl_2$ was studied using synthetic fluid inclusions. Prisms cut from synthetically-grown quartz were hydrothermally equilibrated with fluids of varying compositions at 500 and 600°C at 1.0, 1.5, and 2.0 kbar. Silver oxalate was used as the source material for $CO_2$. The appearance of coexisting vapor-rich and liquid-rich inclusions, measurements of the relative volumes of the vapor and liquid phases within single inclusions, and Th of liquid-gaseous $CO_2$ were used to define the limits of immiscibility and the tie lines within the immiscibility field.

A significant immiscibility range was found under all these run conditions. At 600°C, 1.0 kbar, fluids containing 0.5 molal $CaCl_2$ and as little as 10 wt % $CO_2$ show immiscibility. The same is true for fluids containing 2.0 molal $CaCl_2$ and as little as 25 wt % $CO_2$ at 600°C and 2.0 kbar. The P effect on the compositional range of the immiscibility was found to be much larger than the T.

These results suggest that the addition of a small amount of a 2-1 electrolyte to an $H_2O$-$CO_2$ fluid can extend the $H_2O$-$CO_2$ immiscibility gap to well above 600°C. Also, the results are consistent with the observations of Sisson et al. (1981) in which natural inclusions containing immiscible fluids were found in rocks formed at 600°C and 6.5 kbar. These inclusions contained 23 to 25% salt. (Authors' abstract)

ZHANG, Yi-gang and FRANTZ, J.D., 1987b Determination of the homogenization temperatures and densities of supercritical fluids in the system NaCl-KCl-$CaCl_2$-$H_2O$ using synthetic fluid inclusions (abst.): ECRFI, European Current Research on Fluid Inclusions, IX Symp., Oporto, 4-6 May, 1987, Abstracts, p. 161. First author at Centre de Recherches Pétrogr. & Gépchim., B.P. 20, 54501 Vandoeuvre-lès-Nancy Cedex, France.

Abstract same as given by Zhang and Frantz, 1986 (Fluid Inclusion Research, v. 19, 1986) except for a change in the definition of $A_2$ in the mathematical function (the last term changed to "$(a_3 + a_4\ Th^2)m$") and the substitution of the following for the last sentence: A function is also given which permits calculation of isochores for fluids containing more than one solute. The results of these experiments compare favorably to those of Burnham et al. (1969) and Hilbert (1979). (E.R.)

Note - This abstract was a late addition and hence is not in the bound volume of abstracts. (E.R.)

ZHANG, Y.-G. and FRANTZ, J.D., 1987c, Determination of the homogenization temperatures and densities of supercritical fluids in the system NaCl-KCl-$CaCl_2$-$H_2O$ using synthetic fluid inclusions: Chem. Geol., v. 64, P. 335-350. First author at Centre de Recherches Pétrogr. & Géochim., Centre Nat'l.

Recherche Sci., F-54501 Vandoeuvre-lès-Nancy Cédex, France.

Similar to previous item but last term in definition of $A_2$ is now "$(a_3 + a_4\ Th)m$." (E.R.)

ZHATNUEV, N.S., 1987, Models of the vapor-dominated hydrothermal systems under subcritical conditions: Dokl. Akad. Nauk SSSR, v. 293, no. 1, p. 203-206 (in Russian). Author at Inst. of the Earth's Crust of Siberian Div. Acad. Sci. USSR, Irkutsk, USSR.

The supposed depth of formation of hydrothermal ore deposits is 1-3 km, the source of heat and part of the water are shallow magmatic chambers, which cause T gradients exceeding usual geothermal gradient. P of hydrothermal solutions down to 1 km is close to hydrostatic P and from 1 to 3 km it exceeds hydrostatic P. Under approximate PT conditions reservoirs of vapor may form. Although the natural hydrotherms are composed of fluids, in the presented model the pure water system will be considered for simplicity, based on the PT plot of water shown in the Figs. 1 and 2, where it is drawn together with hypothetical curves of distribution of T in hydrothermal system above the shallow magmatic chamber. P equals hydrostatic P, $t_G$ - curve of the normal geothermal gradient, $t_1$-$t_5$ - distribution of temperature in the hydrothermal system above a magmatic chamber from the center towards periphery after a certain time since magma intrusion. In the right parts of the drawings there are the cross-sections through the thermal field of the considered zone, where the curves $t_1$-$t_5$ are shown as the lines 1-5, as isotherms of every 50°C. The evolution of the heat anomaly goes from $t_G$ to $t_1$-$t_5$, at first progressive and next regressive. The first model (Fig. 1) shows the formation of a closed vapor reservoir at the depth of $<2.2$ km, where hydrostatic P of the hydrothermal solution does not exceed P critical. The curves $t_1$ and $t_2$ twice cross the monovariant equilibrium line vapor-liquid and their central section occurs in the vapor area. Projection of the monovariant line in the right part of the drawing forms a closed curve with vapor area within and liquid area-outside. This scheme is pertinent to the vapor-dominated system: gas-type supercritical fluid from zone A, when it reaches the critical isotherm, condenses to form liquid solution under supercritical pressure (zone B). Next, during uplift and decrease of the hydrostatic P below the critical value, the liquid boils forming the reservoir C, closed from the upside by decreasing T, that causes the condensation of vapor in zone D. If the rate of vapor formation is higher than the rate of condensation, the excess pressure will occur periodically leading to the eruption of vapor through the zone D to the surface.

Some thermal springs (e.g., Sulfur Bank) boil (with separation of the gas phase enriched in $CO_2$) at 80-185°C; seemingly this may be explained by the model shown in Fig. 2. Here the temperature distribution lines $t_1$-$t_2$ cross the monovariant vapor-liquid line coming from the vapor area to the liquid area and again to the vapor one (left part of the Fig. 2). Projection of the monovariant line on the cross-section of the hydrothermal system (right part of the Fig. 2) gives two vapor areas A and C separated by zone of liquid B. Here the gas fluid A condenses during uplift to liquid B and later, on decrease of hydrostatic P, again boils to form vapor C. This scheme needs especially low thermal gradients in the upper parts of the considered hydrothermal zone. Evolution of the models 1 and 2 is presented in the Fig. 3. During T increase, the line $t_1$ may occur completely in the vapor area, i.e., a vapor "channel" linking the magmatic chamber directly with the Earth's surface may form. These models may be pertinent to the location of the geochemical threshold connected with the boundary liquid-vapor, being effective, however, only under $P<P$ critical, when at this

boundary the structure and density of the water solutions change distinctly, and this may cause the precipitation of ores. (Summary by A.K.)

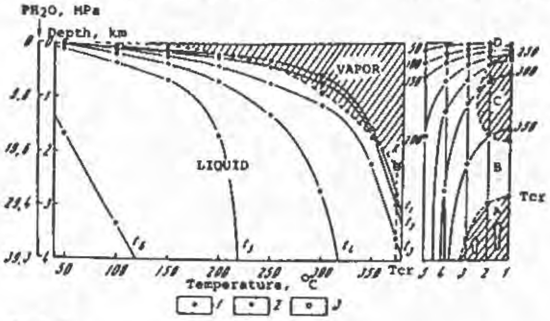


FIG. 1

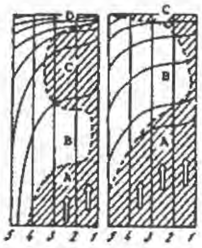


FIG. 3

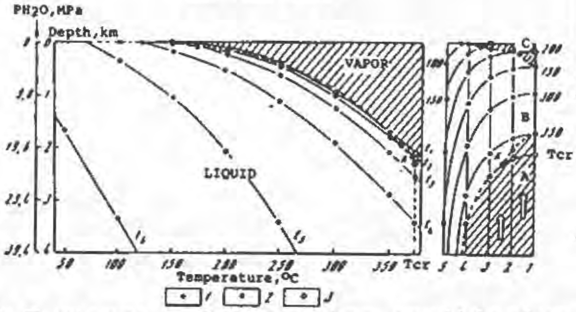


FIG. 2

Fig. 1. P-T diagram of the water equilibrium liquid-vapor plotted together with curves of the T distribution in a hydrothermal system with a vapor reservoir (left) and cross-section through a hydrothermal system (right). K - critical point of water, 50-350-isotherms, Tcr - critical isotherm, A - reservoir of supercritical fluid adjacent to the magma chamber, B,D - zones of liquid hydrotherms, C - vapor reservoir. Dash line - boundary liquid/vapor, arrows indicate the heat flow; points of the crossing of lines of the temperature distribution (polytherms) with isotherms in the liquid are (1), with the monovariant liquid/vapor line (2) and with isotherms in the vapor area (3).

Fig. 2. Same as in Fig. 1, but with the near-surface zone of vapor formation. A - area of the gas-type fluid adjacent to the magmatic chamber, B - liquid solution, C - subsurface zone of vapor.

Fig. 3. Scheme of progressive heat evolution of hydrothermal systems with vapor pertinent to the first (left) and to the second (right) model.

ZHENG, Haifei and FENG, Jialing, 1987, Glass microlites in the inclusions of the Hannouba basalt and their significance: Geol. Review, v. 33, p. 12-21 (in Chinese; English abstract). Authors at Hebei College of Geol., Xuanhua.

Experiments show that the inclusions in spinel lherzolites and garnet pyroxenites occurring in basanite contain glass microlites formed from partial melting. X-ray analysis proves that the glass microlites are in fact microlite aggregates composed of pyroxene, spinel and plagioclase and the result of crystallization of the inclusions at over 10 x $10^5$ kPa on the way of their ascent. Due to the shift of the invariant point of the Ol-Di-Gt system to garnet caused by the pressure release in the mantle environment, the chemical composition of the glass microlites are similar to that of garnet. At the P-T conditions that can cause melting, garnet can melt directly, while the formation of the same melts in spinel lherzolites invokes reaction at the boundaries of minerals. The melts can evolve into tholeiite through crystallization differentiation. At higher pressures, the invariant point of the system lies between clinopyroxene and garnet; thus primary alkaline basalt magmas may form directly. (Authors' abstract)

ZHENG, Minhua and LIU, Jianming, 1987, Physico-chemical conditions and ore-forming process of the Zhilingtou Au-Ag deposit, Zhejiang, China: Acta Geologica Sinica, v. 61, p. 251-266 (in Chinese, English abstract). Authors at Chengdu College of Geol., PRC.

The Zhilingtou Au-Ag deposit occurs as massive Au-bearing quartz veins in Precambrian metamorphic rocks. The deposit was formed as a result of mobilization of Au and Ag in the country rocks by the circulation of heated infiltrating meteoric water and its migration into tenso-shear fractures.

Studies of fluid inclusions in minerals indicate that the deposit formed from 350° to 160°C and a depth of nearly 2 km. The average T of the early mineralization stage was 320°C and that of the main mineralization stage, 270°C. In the ore-forming process, the decrease of the P was quite conspicuous, and the ore fluids boiled several times.

The ore-forming solutions were acidic, relatively strongly oxidized and poor in sulfur, with intermediate $Cl^-$ activity and salinity. The Au and Ag in the metamorphic rock series were mobilized and got into the solutions in the form of $AuCl_2^-$ and $AgCl_2^-$.

After the ore-forming fluids gathered in a low-P zone (tenso-shear fractures), the P lowered dramatically and consequently the fluids boiled, thus causing the salinity and pH value of the fluids to increase and the $Cl^-$ activity to decrease. With decreasing T, the ore-forming substances in the ore fluids precipitated, and finally the ore deposit was formed. (Authors' abstract)

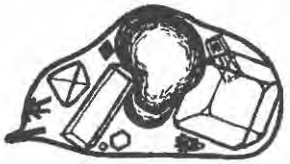
ZHU, Qijun et al., 1987, To realize a new temperature reference point at 800°C - NaCl freezing point: Acta Metrol. Sin., v. 8, no. 3, p. 180-186 (in Chinese; English abstract in Chinese Sci. Abstracts, v. 6, no. 5, p. 58 (1987).

This paper describes the method by which the freezing point of NaCl was realized with a sealed cell. Experiments show that the reproducibility of the NaCl freezing pont is within ±6 mK; the duration of T plateau is 2 to 3 hours; and the overcooling degree is 1°C. This reference point, that is t(68.NaCl) (802.12 ± 0.034)°C, can be used as the secondary T reference point of IPTS. It is now applied in the research of non-uniqueness of IPTS and calibration of high T Pt resistance thermometers. (Chinese Sci. Abst. No. 87A2706)

ZIMMERMANN, J.L., CHEMINÉE, J.L. and DELORME, H., 1987, Chemical analyses and diffusion studies of gases in andesitic lavas: Arenal Volcano (Costa Rica): Chem. Geol., v. 61, no. 1/4, p. 299-308.

Full paper for abstract in Fluid Inclusion Research, v. 18, p. 477-478, 1985. (E.R.)

ZUKIN, J.G., HAMMOND, D.E., KU, T.-L. and ELDERS, W.A., 1987, Uranium-thorium series radionuclides in brines and reservoir rocks from two deep geothermal boreholes in the Salton Sea Geothermal Field, southeastern California: Geochimica Cosmo. Acta, v. 51, p. 2719-2731.



## 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.

CHINESE SOC. OF MIN., PETR., AND GEOCHEM., 1987, Studies of Fluid Inclusions in Minerals: Papers from Chinese Second National Conf. on Fluid Inclusion Studies and Experimental Geochemistry, Guiling, Guangxi Province, 16-22 Nov. 1987. (in Chinese).

The following titles from the fluid inclusion part have been translated by H.-Z. Lu.

LI, Zhaolin, Preliminary study of the mechanism of forming fluid inclusions, p.1-2.
LIU, Bin, Equation of density, isotherms and isobars for brine fluid inclusions, and their application to determination of temperature and pressure, p.3-4.
LU, Huan-Zhang, Fluid-melt inclusions, p.5.
MAO, Dongqing, LU, Huan-Zhang, and FANG, Genbao, Melt inclusions in basalt and granite, Ross Island, Antarctica. p.6.
XIA, Linqui, The significance of magmatic inclusion research on volcanic rocks, p.7-8.
FANG, Genbao, WANG, Liankui, and LU, Huan-Zhang, The characteristics and homogenization temperatures of melt and fluid inclusions in two series of granites of south China, p.9-10.
JIN, Shichang and ZHUANG, Fengliang, Melt inclusions of granites in Longling-Luxi area, Yunan Province, p.11-12.
LIU, Jixian, Studies on melt inclusions and their homogenization temperatures for basalts in Wudalianchi area, Heilongjiang Province, p.13-16.
ZHOU, Shili, Melt inclusion studies of olivine nephelinite, p.17-19.
LI, Binglun, Melt inclusions in pyrite, Ningwu region, p.20.
LIU, Fan, Temperature determination of melt inclusions in Echeng pluton, p.21-22.
ZHOU, Guanyong, The characteristics of silicate melt inclusions of basalts, northeast Hubei Province, and their geological significance, p.23-24.
ZHOU, Guanyong, Melt inclusion studies on Yangxi complex and the relationship between magma and mineralization, p.25-27.
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ZHANG, Zixian and SHI, Lida, Inclusion studies on granitoid rocks, Zhaoyuan, Shandong Province, p.30-31.

LI, Zhaolin, et al., The temperatures of formation of magmatic rocks, Ningzhen area, p.32-34.

LI, Zhaolin, et al., Inclusion studies on magmatic rocks and hydrothermal quartz veins in the Antarctic, p.35-37.

GUA, Fan, et al., Melt inclusion studies of Hao County meteorite, p.38-41.

WANG, Bixiang, et al., Melt inclusion studies on volcanic rocks, Great Wall Station, George Island, Antarctica, p.42-43.

CHU, Tongqing, et al., Research on inclusions in tektites, p.44-47.

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WEI, Jiaxiu, Using the composition of melt inclusions to estimate the evolution of magma, p.50-51.

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XIA, Linqui, Some basic consideration of chemical composition of magmatic inclusions, p.60-61.

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XU, Shuying, The characteristics of melt inclusions in granites of Jiangxi Province, p.69-71.

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YE, Zhongji, Preliminary discussion of fluid inclusion features and genesis in Zhongjia tungsten deposit, Longyan, Fujian Province, p.82-83.

LIU, Jiaqi, Fluid inclusion studies on Xihuashan and Dongping tungsten deposits, p.84-85.

LIU, Jiaqi and CHANG, Hailiang, Geothermometry and geobarometry of wolframite-quartz vein deposits, Nanling, p.86-87.

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LI, Zhaolin and YANG, Zhongfang, Ore-forming mechanism of Lianhuashan tungsten deposit, p.104-105.

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DU, Xinjun, Fluid inclusion geochemistry of Jiaojie-type gold deposit, Shandong Province, p.141-142.

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CHEN, Qinyan, YANG, Guozeng, and ZHOU, Peikun, Fluid inclusion characteristics of Carlin-type gold deposits, Guizhou Province, p.145-146

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HE, Zhili and YANG, Zhenlin, The physical and chemical conditions of formation of the Jingchangyu gold deposit, p.178-179.

LI, Zhaolin, FAN, Hongrui, and DING, Ru, The physical and chemical conditions of formation of the Jinshan stratabound gold deposit, p.180-181.

LI, Paizheng, Fluid inclusion studies on Huangshan gold area, Zheijiang Province, p.182-183.

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TU, Dengfeng, Fluid inclusion and genetic studies on quartz crystal deposits, Donghai County, Jiangsu Province, p.233-234.

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SHI, Jixi, et al., Mechanism, type, and characteristics of organic fluid inclusions and their application to exploration for oil and gas, p.279-280.

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ZHOU, Shili, Discussion on several problems of the decrepitation method, p.330-331.

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*XIA, Guilan, et al., Fluid inclusion features of Songshujiao tin deposit.

*ZHENG, Yaopeng, Application of the PC-1500 model computer to fluid inclusion studies.

*JIANG, Haoshen, LGHC-1 model quench instrument.

*WU, Kaihua, et al., Fluid inclusion studies on Jiumao tin deposit, North Guangxi Province.

*LU, Huan-Zhang, The first conference of American current research on fluid inclusions: An introduction.

*The last 5 papers were presented at the meeting but were not in the abstract volume.

SKEWES, M.A. and CAMUS, F., 1987, Fluid inclusions in El Bronce de Petorca, Chile: Implications for genesis of a gold epithermal deposit associated with Upper Cretaceous volcanism in the Andes: Acta Del Decimo Congreso Geol. Argentino, v. 4, p. 290-291 (in Spanish; translated by G. Landis).

El Bronce de Petorca is a epithermal deposit of Au and Ag, rich in base metals. Mineralization in the El Bronce district occurred in a geologic environment marked by volcanic rocks, principally pyroclastics, of Middle to Upper Cretaceous age, associated with a volcanic caldera, Morro Hediondo. The caldera structure has been important in controlling Au mineralization in the district. K-Ar age determinations of the alteration associated with El Bronce mineralization are 82 ± 7 m.a., coincident with intrusive phases of the caldera (Camus, et al., 1987).

The El Bronce de Petorca deposit consists of quartz-adularia veins with very little sulfide minerals. Mineralization is in large veins, dominated by quartz, that formed as open space filling. The paragenesis indicates that quartz deposition continued throughout the evolution of the deposit. Five principal vein parageneses are recognized at El Bronce (Fig. 1), all associated with quartz: 1) pyrite, the earliest sulfide, is replaced and cross-cut by most later sulfide minerals, 2) chalcopyrite, replaces pyrite and is intimately associated with dark sphalerite, 3) sulfosalts (tetrahedrite) and galena, commonly associated with native Au, 4) sulfates (barite most abundant) found in the upper zones of the deposit, and 5) carbonates (siderite and ankerite) and sphalerite that represent the final hydrothermal deposition in the El Bronce deposit. Au mineralization occurs from the second through the third stage of the paragenesis, commonly associated with sulfosalts and frequently, for the most part, found in fractures cutting pyrite.

Fluid inclusions were studied in quartz, from both Au-rich and Au-poor zones. Only two-phase inclusions were observed; no dms or liquid $CO_2$. The range of salinities measured for both P and S fluid inclusions is 1 to 10 eq. wt.% NaCl. Th range from 150°C to 350°C (Fig. 1, Skewes, 1986). Fluid inclusion and other evidence indicates boiling of fluids at very shallow levels, with boiling initially extending to a zone ~350 meters below the paleo-surface. P fluid inclusion data from this very shallow portion of the system indicate Th of 215°C to 286°C with salinities between 1.8 to 6.8 eq. wt.% NaCl.

Precious metal mineralization formed in a zone ~400 to 1200 meters below the paleo-surface, under hydrostatic conditions. At intermediate depths, Th of P fluid inclusions range from 301°C to 336°C, with indicated salinities between 4.4 and 8.0 eq. wt.% NaCl. In the deepest levels studied, the P fluid inclusions indicate that hydrothermal fluids were 327°C to 344°C and between 6.1 to 10.0 eq. wt.% NaCl. Throughout these deeper levels, no evidence for fluid boiling was observed.

El Bronce differs from other epithermal deposits (e.g., Indio, Chile, Jannas and Araneda, 1985), in various aspects. First, the level of mineralization occurs below the level of boiling at El Bronce. Au coexists, especially below the level of boiling, with base metal sulfides (Fig. 1). Salinities indicated for ore fluids at El Bronce are much higher than that typical for Au-Ag epithermal deposits. The fluid salinities at shallow depths in El Bronce are similar to other epithermal Au deposits (Buchanan, 1981), but these shallow zones at El Bronce do not host Au.

A mechanism of mixing fluids of different origins could explan the large range of observed salinities, the paragenetic sequence of mineral deposition and their distribution, and the position of the zone of fluid boiling above the zone of Au mineralization. The hydrothermal solutions responsible for Au deposition were initially high in salinity, and low in sulfur. The low sulfur content of the fluids reflects a primary characteristic of the magmatic activity during the late Cretaceous in this portion of the Andean mountains. These ascending fluids mixed with solutions of much lower salinity, probably meteoric water. This fluid mixing produced the large range in salinities and paragenetic sequence observed at El Bronce. The mixed fluids were diluted and of diminished capacity to transport sulfides as chloride complexes. Sulfides were initially deposited as pyrite, chalcopyrite, and sphalerite, reducing further the sulfur content of solutions initially poor in sulfur. Au in solution at the indicated T existed largely as bisulfide complexes. Au was precipitated with the lowering of sulfur molality in solution, and the destabilizing of bisulfide complexes. By this fact, Au follows and is closely associated with the sulfides paragenetically. As hydrothermal fluids encountered dilute solutions near the surface, boiling commenced.

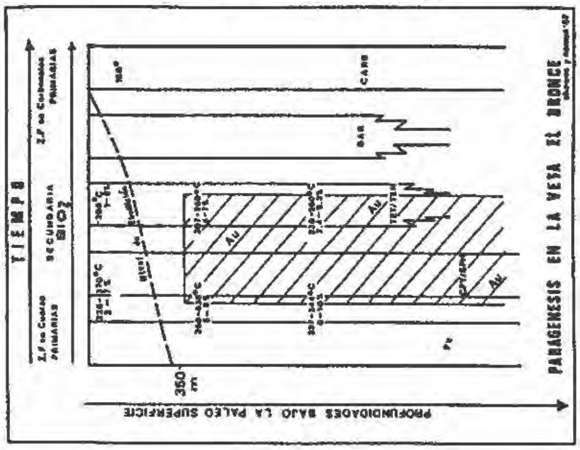
## References

Buchanan, L., 1981. Precious metal deposits associated with volcanic environment in the southwest. Arizona Geol. Soc. Digest. Vol. XIV, p. 237-262.

Camus, F., Skewes, M.A. and R. Borić, 1987. Geología del yacimiento de oro El Bronce de Petorca. (en Prensa). Revista Geol. de Chile.

Jannas, R. and R. Araneda, 1985. Geología de la veta Indio Sur 3500: una estructura tipo bonanza del yacimiento El Indio. Revista Geol. de Chile, No. 4, p. 49-62.

Skewes, M.A., 1986. Inclusiones fluídas en el sistema El Bronce. Informe inédito la Cía. Minera El Bronce, 20 pp.



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KALYUZHNYI, V.A., 1982, Principles of knowledge about mineral-forming fluids: "Naukova Dumka" Publ. House, Kiev, 240 pp. (in Russian). Author at Inst. Geol. & Geochem. of Mineral Fuels, Acad. Sci. Ukr. SSR, L'vov, Naukova str. 3A, Ukrainian SSR.

Note: Translation of Part I of this book, pages 1-77, and the entire table of contents, is in Fluid Inclusion Research, v. 15, 1982, p. 289-333, and Part II, pages 78-100, is in v. 16, 1983, p.306-320. The remainder of the book is translated below. Pages 101-208 were translated by D.A. Brown and pages 209-225 by A. Kozłowski, references 1-90 by I. Kulikov, and 91-210 by S. Jaireth. The original Russian text page numbers are given in brackets. There are some ambiguities as to the relative rank of headings in the original that could not be clarified. (E.R.)

[100] Analysis of soluble components (aqueous-extraction method). Inclusions consist mainly of soluble material, readily removable in water after sample crushing. Aqueous extraction has been used for some time for determining the composition of inclusions [46, 47, 77, 103, 179, 257]. It is one of the most important procedures for determining the components of mineral-forming solutions. Without dwelling on its advantages, including its simplicity and suitability for examining the aqueous extract by macro- and microchemical methods, we may note its main deficiencies: a) water, in addition to dissolving the components of the inclusions, may dissolve the mineral hosts or foreign impurities present in the crushed samples (including material from the pulverizer); b) owing to the removal of [p. 101] gas from the inclusions and contact with the atmosphere, the redox and pH equilibria are disturbed, so that solid and poorly-soluble materials may be precipitated from the solution; c) the composition of the extract reflects the mean bulk content of all the inclusions, differing in genetic type, age, and composition; d) [only] the quantitative ratio of the components of the inclusions is determined, and less frequently (in the case of analysis of the water content), their concentration in the solution of the inclusions; and e) phenomena of selective adsorption by crushed material are not taken into account.

In order to eliminate these deficiences, we proceeded as follows: two- or three-fold extraction of one and the same sample [190]; differential extraction of the inclusions, disrupted at lower or higher temperatures [77]; quantitative determination of the water in the inclusions in the analyzed samples [195]; and removal of impurities and extraction with the aid of electrodialysis [240].

Starting with the differing solubility of the components in the inclusions, on the one hand, and in the materials of the mineral-host or mineral impurities, on the other, it has been suggested that contamination of the aqueous extract by components of solid minerals may be excluded by comparing the analytical data for portions of the filtrate, taken in succession. Khitarov [190] has proposed a method of triple extraction, amounting to the three-fold successive elutriation of the soluble components from a particular rock. Taking the solubility of the impurities as constant, and using the analytical data for the third portion of the solution, he deducts the results for the first and second portions[sic]; the difference obtained is summed and equated with the composition of the inclusions[10].

A comparison of the methods for obtaining extracts from mechanically and thermally disrupted inclusions, and also a study of the [effects of] sorption phenomena on the analytical results, have been given by Khitarov and Uchameishvili [192]. Authors, such as Roedder [240], have concluded that the thermal method does not permit extraction of material from all inclusions, in which respect, the results obtained, as compared with those obtained by the method of triple extaction, are underestimated and give a different ratio of components. The effect of sorption on crushed quartz, calcite, and fluorite, is insignificant and is excluded during triple extraction with deduction of the components of the impurities.

Sushchevskaya [179] has given attention to the uncertainty in interpreting the results obtained by the method of aqueous extracts. First, such components as Fe, Si, and Al, under conditions of diluted extracts, are readily hydrolyzed and are removed from the solution in the form of hydroxides. Second, silica cannot occur in extracts and solutions of in-

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[10] In publication [191], however, a more precise calculation of the concentrations is suggested, according to which the result of the third is deducted from that for the first portion; the second extract is disregarded.

clusions in the ionic form ($HSiO_3^-$ and $SiO_2^{2-}$) owing to the low pH value; the same also applies to the $CO_3^{2-}$ anion. Sushchevskaya [p. 102] recommends that, when extrapolating these extracts to the composition of the natural mineral-forming fluid, account be taken of the instability of sulfur compounds and the processes of complex-formation during changes in P-T conditions.

In our studies, the method of aqueous extraction, allowing for the above listed factors, was carried out as follows:

1. In this method, as in the bulk gas analysis of inclusions, there is great significance in the correspondence between the saturation [i.e., volume %] of the sample in inclusions (and consequently, the size of its weighed sample) and the sensitivity of the analytical methods employed; in this case, we must start with the fact that an increase in the degree of sample crushing contributes to the passage of the mineral and structural impurities into the solution of the extract; an increase in the size of the sample does not necessarily cause a concentration of foreign contaminants, but at the same time, it will lead to a singificant quantitative preponderance of the readily-soluble components of the inclusions over the impurities indicated, which increases the accuracy of the determinations. The weighed samples are usually 200-500 g, and less commonly, 700-1000 g.
2. Electrodialysis is used to purify the previously crushed material.
3. Extraction of the finely-crushed sample undertaken in the normal way or in a specialized filter column, which has enabled us to obtain several successively selected portions of solution from a single sample.

The column is a hollow cylinder 1, made of stainless steel (Fig. 40). The cylinder is 1 m long, with an internal diameter of 1.7 cm. A sleeve 2, with openings for draining the solution, is screwed onto the lower part of the cylinder. Between the sleeve and the cylinder are 3-5 layers of membrane filters 3. The upper part of the column is connected by a coupling 4 to a manometer 5. Gas (nitrogen) comes from a cylinder, and its supply and discharge are [p. 103] regulated by two taps. The gas pressure is maintained at 2.5-3.0 MPa. The crushed sample, weighing 200-300 g, is placed in the lower part of the column. Doubly-distilled water (DDW) is admitted above the sample, and occupies approximately one-third of the column. Under pressure, the DDW passes steadily through the crushed material, extracting the soluble components. After passage of the filtrate, the solution is collected in a vessel. The elutriation process takes 2-3 hours. The volume of the successively collected solution, available for evaporation and analysis, is 160-250 ml.

The column, currently being used, has a metallic reservoir (1.5 L), giving a supplementary capacity for distillate and nitrogen; the filter tubes (2-4 pieces) are screwed directly to the reservoir; the weight of the sample treated may be increased to 500 g. The column employed significantly accelerates (by 5-6 times) and simplifies the preparation of the aqueous extracts and makes it possible to allow for foreign components in the solutions, brought in by leaching of the mineral-host or xenogenic solid inclusions.

4. Normally, three portions of filtrate are taken for each sample, and each portion is analyzed separately. Prior to analysis, each portion is evaporated to 20 ml, as a result of which the concentration of the solution is brought close[r] to that in the original inclusions. Corrections are made to the analytical data for the first portion, using a comparison of the analyses of all three portions. Microchemical methods of analysis, described earlier [47] have been used. The results are controlled by spectrographic and X-ray analysis of the dry residues from the extract solutions.

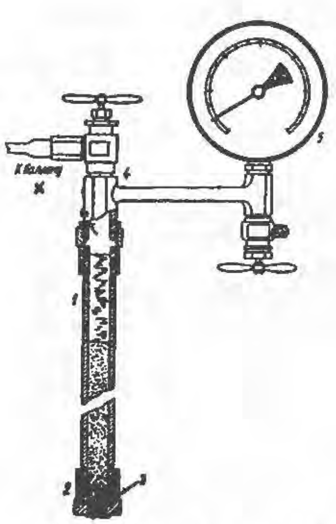


Fig. 40 [p. 102]. Sketch of filter column for aqueous extracts (explanation in text).

x=To gas cylinder

5. The data obtained have mainly been used for comparing the composition of inclusions from zones of different age in individual large crystals in the Volyn' pegmatites. The column has been employed to study the influence of extracts of such minerals as quartz, albite, and K-feldspar on the results. A sample (250 g) of very pure quartz (with a minimum of inclusions) was treated with DDW and artificially-prepared solutions with acid (pH 6.6; NaCl, $K_2SO_4$, $CaCl_2$) and alkaline (pH 7.8; NaCl, $K_2SO_4$, $NaHCO_3$) reactions. In this case, 20 ml of the acid and alkaline solutions were injected and maintained under pressure for 30 minutes, after which DDW was admitted, and samples of the extracts were selected. The results are shown in Table 8.

Table 8 [p. 103]. Leaching of Quartz by DDW, and Acid and Alkaline Solutions (per 80 ml solution, in mg)

| Sample No. of Solution | Extracting medium | | |
|---|---|---|---|
| | DDW | Solution pH 6.6 | Solution pH 7.8 |
| 1 | 0.4 | 0.1 | 0.7 |
| 2 | 0.5 | 0.5 | 0.6 |
| 3 | 0.5 | 0.5 | 0.6 |
| 4 | 0.5 | 0.6 | 0.5 |

Data on the leaching of quartz show that, beginning with the second samples, a constant concentration of $SiO_2$ is established, on [p. 104] average equal to 0.5 mg per 80 ml of solution. As expected, the solubility of quartz in the acid solutions decreases (0.1 mg), and in the alkaline solutions, increases (0.7 mg per sample). Consequently, under the given conditions of the experiment, the optimum corrections are as follows (per volume of sample (160 ml), selected for chemical analysis): ca 0.9 mg in the case of a neutral solution, ca 0.6 mg with acid reaction, and ca 1.3 mg in an alkaline medium. The results given are approximate, and further studies are needed to obtain more precise and generally-applicable corrections.

Owing to the ready hydrolysis of the feldspars, contamination of the extracts of the minerals with alkalies is possible. With the object of checking and obtaining quantitative values for the solubility, relatively pure, crushed samples of albite and K-feldspar, and also of quartz with small traces of one of these feldspars, were treated with DDW in the filter column. The samples weighed 250 g, and the additions of feldspars to the pure quartz, 5 g. Results are shown in Table 9.

Table 9 [p. 143]. Amount of Alkalies (per 80 ml of solution, in mg) After Interaction Between DDW and Feldspar

| Mineral examined | Ion | Sample No. of Solution | | | |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 |
| Albite | $Na^+$ | 5.40 | 2.56 | 2.72 | 2.56 |
| | $K^+$ | 0.04 | 0.02 | 0.01 | -- |
| K-feldspar | $Na^+$ | 4.0 | 1.9 | 1.9 | -- |
| | $K^+$ | 5.3 | 2.4 | 2.5 | -- |
| Quartz with trace of albite | $Na^+$ | 1.72 | 0.30 | 0.30 | -- |
| | $K^+$ | 0.30 | -- | -- | -- |
| Quartz with trace of K-feldspar | $Na^+$ | 1.30 | 0.67 | 0.33 | 0.14 |
| | $K^+$ | 1.2 | 0.6 | 0.5 | 0.5 |

The following observations may be made:

1. The feldspars used in the experiments were insufficiently pure (in the albite, there was an insignificant trace of K-feldspar, and the K-feldspar contained an increased amount of albite component (evidently resulting from perthitic intergrowths).

2. In the first samples of the solutions, the concentration of alkalies was approximately twice that in the later samples, which may have been due to gas-liquid inclusions.

3. In the samples of solutions 2-4, the amounts of alkalies became constant, with the exception of those obtained from the mineral with an extremely small quantity of the second component (K in albite, and Na in the K-feldspar, additive to quartz); this is evidently connected with the complete leaching of the indicated additive. The constant concentration of alkalies in Samples 2 an 3 may serve as a correction to the analyses of these extracts.

[p. 105] 4. The overall content of K and Na in the samples of the solution, obtained during treatment of monomineralic material, is significantly greater (by about three times) than in those passed through quartz with additives of albite and K-feldspar. This has resulted from the unequal degree of approximation to complete equilibrium between the mineral and the solution.

Thus, equalizing of alkali concentrations obtained in the final samples 2 and 3, up to constant values, emphasizes the validity of the idea of the rational nature of successive selection of the filtate for excluding additive components, present in the extracts.

In essence, it is impossible to study inclusions of a definite age category by the method of aqueous extraction. Only in exceptional cases, when the material will enable the selection of samples with a volume necessary for analysis, with uniform inclusions, similar in origin, does it seem possible to provide the composition of the mineral-forming fluid close to its real value. The use of the method of aqueous extracts is especially valuable for the comparative description of the composition of the fluids, captured in the form of inclusions by the minerals of the various age-zones or different generations of a particular deposit.

An example of a good result from the method may be the systematic

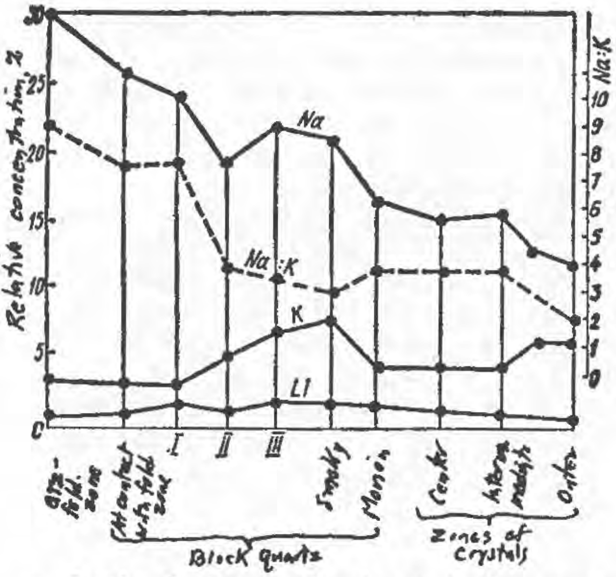


Fig. 41 [p. 105]. Content of $Na^+$, $K^+$, and $Li^+$ and Na/K ratio in solutions of inclusions in quartz from the Volyn' pegmatites (based on averaged data for aqueous extacts).

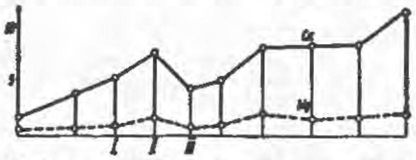


Fig. 42 [p. 106]. Content of $Ca^{2+}$ and $Mg^{2+}$ in solutions of inclusions in quartz of pegmatites (based on averaged data for extracts). (Same samples)

analytical data, obtained during a study of the "zanorysh" pegmatites of Volyn'. Samples for analysis were selected in the mine workings or from drill-core in downward succession from the [p. 106] graphic zone to the zanorysh pegmatite. The accepted order was taken as that corresponding to the sequence of changes in the quartz-forming solutions. In this case, it has been suggested that between the formations of the earliest graphic zone and the latest zanorysh region, there must be intermediate mineral deposits, arranged in the general sequence. In the case where solutions, coming from the direction of the underlying rocks, have been involved, the later were manifested significantly more intensely in the late formations of the zanorysh region. The analytical results for the extracts have shown a definite pattern of change in the composition of the solutions. Thus, the rational nature of the method has been confirmed, and the method of sampling is justified.

The results of microchemical analyses of extracts, based on analyses for five ions, have been recalculated as percentage amounts of the total sum of the salts, which has shown a change in each component in relative terms and in this way has unified the results into a convenient form for comparing different objects. The averaged data for the content of ions of Na, K, Li, Ca, and Mg in the extracts, based on 33 analyses, and also the ratios of alkalies, are shown in the form of graphs (Figs. 41 and 42).

## A study of individual inclusions

Only micro- and ultramicro-methods may be used in studying individual inclusions. This results from the very small volumes of the inclusions. On average, their volumes range from 0.000001 to 0.001 $mm^3$. Inclusions with a volume of a few cubic millimeters are extremely rare, and [occur] only in certain deposits; vacuoles of 1 $cm^3$ volume are regarded as unique. In very many deposits, there are no inclusions greater than 0.1-0.3-mm in length.

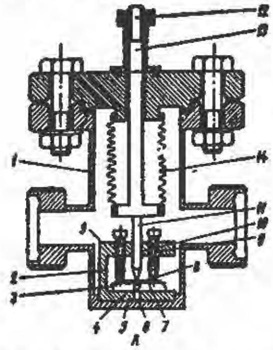
[p. 107] The study of individual inclusions of definite genetic type (especially of large size) has enabled us to obtain the most accurate quantitative and qualitative data. There is also the possibility of studying certain insoluble mineral-hosts, passed over when using the method of aqueous extracts.

However, the technique of opening and micromanipulation of the inclusions, and the relatively low sensitivity of the methods of chemical microanalysis, prevent our making a complete examination of all the components in an individual micro-inclusion. As a consequence, the contents of individual, specially selected inclusions are examined separately, according to the predominance of one of the phases in them (gas, liquid, or solid). Thus, studies of the composition of the gas phase, liquid aqueous solution, and solid components of the inclusions are distinguished.

Study of the composition of the gaseous phase of inclusions. Methods of opening gas bubbles in glasses and procedures for their analysis are given in publications [208] and [17]. The first attempts to measure the volumes of gas in opened inclusions and to determine the composition by the absorption method, were made by us [88]. More accurate analyses were made by Slavyansky [169] and Maslova [141]. In detail, the method of volumetric analysis of inclusions in minerals has been developed and widely used in many deposits by Dolgov and Shugurova [54]. It is distinguished by the relatively high accuracy of the determinations, the uncomplicated nature of the apparatus, and the simplicity of analytical operations. However, separate and accurate determination of such principal components as $CO_2$, $H_2S$ and other 'acid' gases, cannot be regarded as satisfactory. A substantial obstacle to this is the incomplete inertness of the material of the barrier liquid (castor oil and anhydrous glycerine) with respect to the 'acid' gases being analyzed.

As already noted, the analysis of individual inclusions is carried out with chemical mass-spectrometers of the MX-1303 and MCX-3A type. They possess an extremely wide range of analyzable masses (respectively 1-600 and 1-400) and good sensitivity $1.10^{-17}$-$1.10^{-18}$ A[sic]). In order to study individual inclusions with a volume of 0.00001-0.000005 $mm^3$, the MCX-3A instrument is the more suitable, although its resolving capacity is much lower than that of the MX-1303. The latter, however, gives more complete and precise results for inclusions with a volume from 0.5 to 1.0 $mm^3$.

Opening of inclusions has been carried out under high-vacuum conditions in a cylindrical attachment A(1) to the mass-spectrometer (Fig. 43). The inclusion preparation is fixed in the holder B(2), set in the cylindrical attachment. Mounting of the preparation is achieved as follows. First of all, the mineral slice 3 is polished so that one of its planes is located at a distance of 0.005-0.01 mm from the selected inclusion 4. Then the preparation is set, with the aid of a microscope at the base of holder 5 so that the inclusion lies approximately in the center of the opening 6. The preparation is fixed to the holder by melting crystals of Rochelle salt, set beneath the plate, at 70-80°C. A metallic sheet-stencil 7 [p. 108] is placed on the preparation. Openings 8 of definite diameter (depending on the size of the inclusion) are precisely set over the inclusion or a portion of it most convenient for exposing it. In this position, the stencil is clamped by two screws 9, and in the opening in the L-shaped cross-piece 10 is placed the striker 11, with a sharp pobedit point [W-Co-C-(Ti) alloy]. Its position above the inclusion is fixed by the aperture



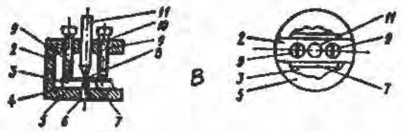


Fig. 43 [p. 108]. Vacuum attachment A (section) with preparation-holder B (section and view from above) for MCX-3A mass-spectrometer for opening individual microinclusions (explanation in text).

in the sheet-stencil. The holder with the preparation is placed at the base of the cylindrical attachment. When the necessary vacuum has been achieved, the inclusion is opened by exerting pressure on the top 12 of the movable rod 13, assisted with the aid of sylphon bellows 14.

A series of experimental determinations of the composition of uniform syngenetic inclusions, occurring in individual sealed fissures, were carried out on the MCX-3A instrument. Each analysis was accompanied by the determination of the composition of a portion of standard gas, approximately equal in volume to the inclusion. The standard gas ($CO_2$ 82.0%; $N_2$ 5.8; $CH_4$ 10.6; and $H_2$ 1.6%) was passed into the analytical chamber of the instrument through a special measuring valve. The analytical results of the standard mixture are marked by accuracy of the measurements. The average amount of $CO_2$, based on 18 measurements, is 83.2%, which deviates from the standard by 1.2%; the absolute error for individual measurements is ±10%; it decreases for a series of measurements, and for 18, should not exceed ±1.2%; the relative error of a single measurement is ±12, and for 18, not more than ±1.5%. The absolute error in measuring the amount of nitrogen is ±0.5% for eighteen; for methane, the respective values are ±11.0 and ±1.0%.

Analyses of inclusions of average size (0.1-0.5 mm) give values of errors close to those calculated above. During analysis [p. 109] of inclusions of smaller size (<ca 0.1 mm), the values of the errors increase, so that in order to increase accuracy, we must analyze not one, but several inclusions from a series of uniform syngenetic items.

Study of aqueous solutions of inclusions. The aqueous solution in individual microscopic inclusions may be studied by direct chemical methods but only with great difficulties. In fact, relatively complete data on the composition of solutions have been obtained only for inclusions measuring more than 1 $mm^3$. Incomplete data based on individual characteristics of the chemical composition are known for inclusions with a volume greater than 0.001 $mm^3$.

The study of microscopic inclusions began after the development of methods of extraction and preservation of their liquid component. Opening microscopic inclusions under normal conditions leads to rapid, and almost instantaneous evaporation of the solution. A portion of it is absorbed by the powdered mineral material formed during drilling. Earlier, no appropriate attention had been paid to such simple reasons for the disappearance of the solution. For a long time, therefore, there were no appropriate means for counteracting this phenomenon, in order to preserve the solution. The use of a damp chamber [88] made possible the wide application of microchemical and ultra-microchemical methods.

During further investigation into the possibility of applying microchemical analysis, yet another factor was identified, which greatly facilitated the study of microchemical amounts of solutions in inclusions. It has turned out that the internal pressure in most inclusions significantly exceeds that of the external atmosphere. In this respect, quite insignificant cracking of the mineral will allow the solution from the inclusions to be squeezed out onto the surface of the lamina. Thus, inclusions of this type, under conditions of a space saturated with water vapor, abandon the narrow chamber of the vacuole and create an access for microchemical instruments and reactants. These two factors must play a special role in the evolution of studies of inclusions by the ultramicro-method of chemical analysis.

Principally in the aqueous solution of individual microscopic inclusions, we may determine: a) the pH, b) the quantitative and qualitative amounts of individual ions, and c) the ratio of certain chlorides by the electronographic method.

The micro-colorimetric method of measuring the pH of solutions from inclusions. The index of hydrogen ions (pH) in a medium under the conditions of formation of mineral deposits is of special significance. Depending on the pH value, particular mineral products are dissolved, transported, and precipitated. A study of inclusions in minerals as relicts of parent solutions may provide direct factual information about this important parameter.

The pH depends on the composition and concentration of the solution with respect to its salt and gas components. Disturbance of the ratio of the latter during opening of inclusions for measuring the pH by the colorimetric method, has in most cases little influence. Hence, the pH, measured under normal conditions, is a definite physicochemical [p. 110] characteristic of the state of the solution in the inclusion; it may serve as a basis for comparing the fluids studied and for extrapolating the data obtained into the field of high thermodynamic parameters.

The micro-colorimetric buffer method, which we have developed, enables us measure the pH of solutions with a volume of up to 0.001 $mm^3$ with an accuracy of ±0.1 [88]. The main obstacle in colorimetry of ultra-small volumes (the imperceptible change in color of the solution in a thin layer of liquid) has been overcome by using special film, saturated with acid-alkali indicators. Of the many experimental absorbant materials for preparing indicator films, the following have proved suitable: cellophane, keratin (horny matter), natural silk fibers, and the inner-eggshell membrane (albumen film). Each of these absorbants has its own peculiarities and may be used most effectively in defined pH ranges and during saturation with definite indicators.

Of all of the experimental materials, the albumen film, saturated with the universal indicator ZIV-1, gives the best results in the pH range from 5 to 8. The main advantages of the film are: 1) evenness of color, 2) excellent color identification in reflected light, 3) independence of color density from the thickness of its section, 4) ease of obtaining sections from macro- to micro-dimensions, and 5) the extraordinary capacity to retain the indicator and not to fade (e.g., one and the same segment may serve as a good indicator for several samples of solution with different pH). The deficiencies of this absorbant include: 1) the low efficiency of measurements at a pH <3.0; 2) deterioration of color visibility in very small segments of the film (owing to limitations on the optics of the MBS microscope); 3) lowering of the accuracy of measurements in weakly-buffered solutions; and 4) the impossibility of measuring pH values in the range of 9.5-10.0, owing to breakdown of the film material.

In practice, the pH in solutions from inclusions is measured using the albumen indicator film. Other materials, such as keratin, natural silk, and cellophane, are more often used for control only, especially at those pH values where the capacities of the first indicator are inadequate.

Immediately prior to measuring the pH, it is essential to prepare the following: a) the indicator film; b) standard buffer solutions; c) the preparation with the inclusion; d) a humid chamber with the preparation.

As an absorbant, we may use both albuminous inner-shell membranes, although the inner one yields much better results, especially when a finely-fibrous surface immediately adjoining the albuminous material is chosen for the observations. The film, after separation from the raw egg shell, is well rinsed in cold distilled water and then boiled for 6-8 hours in doubly-distilled water (continuously changed). The film is immersed for 1-2 days in a solution of universal indicator, rinsed in water, and dried. The concentration of solution of [p. 111] acid-alkaline indicator should be 5-10 times greater than that recommended for macro-measurements. After drying, the film is cut into small portions, using a [razor] blade under a binocular microscope.

Buffer solutions are prepared in the normal manner. A set of citrate-phosphate solutions with pH of 2.2-8.0 at 0.2 intervals, may be used.

The inclusion, selected for measurement, is brought to within <10-20 μm of the surface of the plate by sectioning. This is one of the most complicated operations: it is carried out under constant control with a microscope (as is well-known, the actual thickness of the preparation is determined by multiplying the reading on the micometer scale of the microscope by the refractive index of the mineral).

The moist chamber, prepared from translucent organic sheet, consists of a frame and cover (Fig. 44). The frame has a base 1 and a cylindrical portion 2. The rectangular aperture in the cover is closed by two sliding screens 3. The preparation 4 is set in the center of the chamber on an elevated disc 5. The internal space of the chamber is sealed off by placing distilled water in the slot. Water is also used to moisten the lumps of wadding 6 or filter paper, set along the rim of the cylindrical frame.

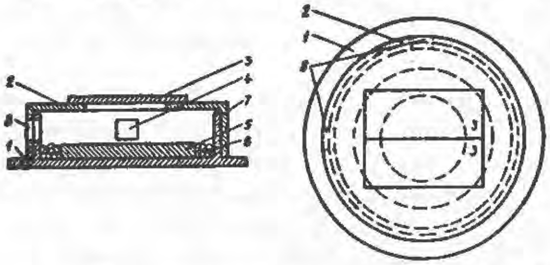


Fig. 44 [p. 111]. Moist micro-chamber for opening inclusions and ultra-microchemical analysis of contents of vacuole (explanation in text).

The pH measurements are carried out in such a sequence. The preparation, carefully rinsed in water and cleaned in alcohol, is fixed with plasticine in the center of the moist chamber. The chamber is maintained for 10-15 min with the screens closed in order to saturate the space above the preparation with water vapor. Having slightly opened the screens, the inclusion is pierced with a pobedit needle. Under pressure from the ribbed portions of the needle, very fine capillary cracks appear in the mineral, through which the solution, in the form of drops, is squeezed out under the influence of internal pressure from the inclusion onto the surface of the preparation plate. A segment of the indicator film is placed in a drop of the solution. Separate segments of the film are also placed in drops of standard buffer solutions, previously placed alongside the inclusion. By comparing the color of the films, the pH of the solution from the inclusion is determined.

[p. 112] It is recommended that the pH be determined after identifying the color of the indicator in 15-30, and sometimes 60 seconds following opening of the inclusion. Allowing for the possible effect of evaporation or condensation of water, it is necessary to trace the dimensions of a squeezed-out drop of solution, the volume of which should not substantially deviate from the initial volume of the liquid phase in the inclusion.

In regard to the change in conditions of the solution in the inclusion and after its extraction from the vacuole, the question arises as to the degree of correspondence between the measurement of the pH and the value of this index for the solutions that occur under the conditions of the closed vacuole, and also as to the reproducibility of the results. We have in mind mainly the effect of the variation of $CO_2$ concentration in the solution.

It is well known that an increase in the $CO_2$ concentration in water, with constant temperature, will lead to a decrease in the pH, that is, to a rise in the acidity of the solution. For example, at 25°C, the pH may fall to 5.5, if the $CO_2$ content in the water reaches 8.8% [152]. But to create such a concentration, a $CO_2$ pressure of approximately 60 MPa is necessary [176, p. 358]. In most inclusions at normal temperature, the indicated pressure is 2 or 1-1/2 times below that. In the presence of liquid $CO_2$ only, it is equal to 5-6 MPa. Moreover, the solutions in inclusions, according to the concentration of salts in them, differ substantially from pure water; therefore, in taking account of the lower solubility of $CO_2$ in salt solutions and the relatively low internal pressure in the inclusions, we should not expect low pH values in closed vacuoles because of $CO_2$. It is likely, if we use the data in [137], that the pH of weakly-concentrated solutions is reduced as compared with its neutral value, but it is not lower than 5.8-6.0, and for a 10% solution of NaCl, not lower than 6.2. Measurement of pH immediately after opening of the inclusion under conditions of incomplete removal of $CO_2$, additionally decreases the disparity of its determination under different conditions. Consequently, taking account of the measurement data presented, the pH in most cases corresponds to or exceeds its value in a closed inclusion by not more than a single unit. The practice of measuring the pH of solutions in numerous inclusions confirms this conclusion; the data obtained also point to the good reproducibility of the analytical results.

For example, the pH values for inclusions of the principal types (see Table 3) have been obtained at different times and by different investigators, but their values do not differ by more than 0.1-0.2. It is true that the effect of solutions from inclusions of definite type on the index is quite specific. Thus, under the influence of concentrated solutions from inclusions with daughter minerals in quartz (Type 5), the color of the indicator film is established immediately following opening of the inclusion and is maintained without alteration for many hours (for the pegmatite body under consideration, the pH is 5.2-5.4). The pH value of Type 4 inclusions (60G + 40L) is steady, varying for different pegmatites from 7.8 to 8.2. Multiphase inclusions in topaz and fluorite [p. 113] behave in such a manner, and also the gas-liquid inclusions without solid phases in various minerals from many other deposits [12, 32, 78].

The solutions from inclusions with a low concentration of salts or saturated with $CO_2$ display a gradual pattern of change in pH with time. Liquid-gas inclusions in topaz, with a composition of 60G + 40L [146] have, at the moment of opening, a pH of 5.2, and after 1 minute, 5.5; the latter value is then preserved without change for a long time. Great deviation has been noted in the complex inclusions of $CO_2$ in topaz, where the pH increases from 6.0 at the moment of opening to 7.0 after 5-10 mins; then it remains unchanged for many hours. Inclusions with liquid $CO_2$ in morion (Types 6 and 8) are also marked by a substantial change in pH. After 20-30 seconds following their opening, the pH is 7.2-7.4, and after 2-3 mins, 8.2; inclusions of this kind in quartz from another pegmatite body have a value of 8.2 after 20-30 secs and 9.2, after 2-3 mins.

Consequently, judging from the data presented, the state of the solution from inclusions, with respect to the pH, determined by the microcolorimetric method, is an important index for classifying the inclusions and their relative comparable characteristics.

When estimating the pH of a solution from an inclusion, measurable under normal conditions, the question also arises, as to whether it is possible to reconstruct the acid-alkaline conditions of natural mineral-formation on the basis of the analytical data obtained? It is quite likely that the measured index may not correspond under surface conditions to its value at the high P-T parameter of mineral development, in the same way as the P-T-X parameters, determined from inclusions under normal conditions, deviate from the natural conditions to a greater or lesser degree. Temperature increase in varying degree influences the degree of dissociation of the various components of the solution; the hydrolytic constants of the acids and bases are altered. As a result, the dependence of the acid-alkaline equilibrium on temperature has no direct regular change. It has been established from experimental and theoretical studies that the change in pH with rise in temperature has an extreme value in the field of low pH values. According to Naumov [152], the turning point of the curve for pH change may appear in accordance with the composition of the solution at a low temperature (about 60°C for essentially $CO_2$ solutions) or at a relatively high temperature (250-300°C for chloride solutions). The presence of a turning point for pH-temperature dependence does not allow us completely to use the pH values, measured under normal conditions, for reconstructing the evolution of the acid-alkaline state of the fluid in relative pH units. However, it is clear that in some narrow (for chloride solutions) or broader (for $CO_2$ solutions) limits, allowing for the unidirectional deviation of pH, such a restoration is possible.

The measurable pH value in individual inclusions reflects the reaction of a solution, saturated in volatiles ($CO_2$, etc.), at [p. 114] normal atmospheric pressure immediately after opening of the vacuole. This value, like the indirectly determined characteristics of the mineral-forming fluid (e.g., the total concentration, determined by cryometry or refractometry, and the temperature regime, obtained with the aid of homogenization of the inclusions), may be used (with a certain amount of caution) for judging the relative (and sometimes actual) change in the pH of the fluid mineral-forming medium. This has been confirmed by the results of a detailed study of the conditions of origin of actual deposits.

Several types of inclusions have been identified in the crystals of quartz and other minerals of different generations in the zanorysh pegmatites of Volyn'. The genetic type and relative age of the formation of the inclusions have been determined from their distribution with respect to the growth zones in the crystal, phenomena of refilling during transection of asynchronous systems of [p. 115] joints or zones, the phase and material composition, and other features. The measured pH values of ten types of inclusions are plotted on the diagram (Fig. 45, Line E).

Curve E has four extremes: two with minimum pH values and two with maxima; a jump in the pH values has been noted at the end of the process of formation of the pegmatite, and the possible existence of a third pH minimum. The question arises as to the causes of such changes in pH and the degree of their connection with the paragenetic associations of the pegmatites, which have been relatively well studied in the deposit [113, 146]. Detailed investigations have established a direct link between the corresponding extreme values of pH and the mineral associations, typical of particular conditions of the acid-alkaline regime. Five intervals have been recognized on the basis of pH changes in the post-inversion phase of the pegmatite process: three acid and two alkaline (see Fig. 30 [p. 73 of book]).

Triple repetition of the pH minima is well correlated with the index properties of such minerals as topaz, fluorite, and quartz.

Topaz, which crystallizes only from fluoride solutions with low pH [174] has been found in all the paragenetic associations of the recognized acid intervals [146]. It has been encountered in the form of a mineral-satellite [i.e., inclusions] in bands of 'honeycomb' inclusions (acid-interval I). In the zanorysh and metasomatically transformed rocks of certain pegmatites, topaz is one of the main minerals: in the leaching cavities of quartz of an albitized apographic rock[sic], which had developed

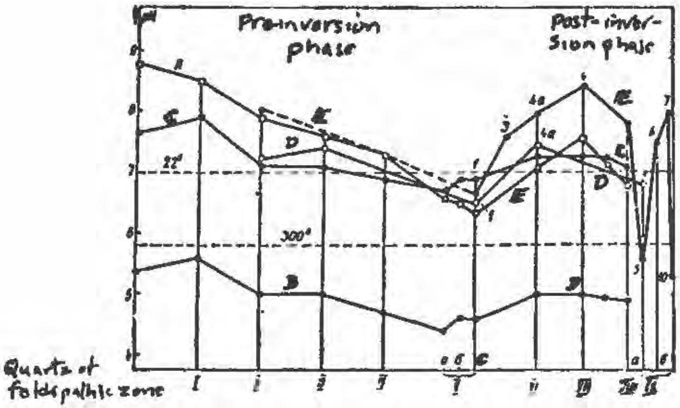


Fig. 45 [p. 114]. Diagram showing pH of aqueous extracts and solutions of defined age types of inclusions in quartz from the zanorysh pegmatites A) mean pH of aqueous extracts from samples of quartz from three pegmatite bodies measured at 25°C; B) pH values of same extracts, calculated by B.N. Ryzhenko's method for a temperature of 25°C; C) the same for 300°C; D) pH values of aqueous extracts from samples, containing only inclusions of definite type, calculated for 300°C; E) pH of solutions from inclusions of definite age type, measured during opening of individual vacuoles; 1-10) types of inclusions; I-V) sequentially located varieties of quartz in section of block zone (a, b, c - respectively smoky quartz, morion, and 'honeycomb' quartz); zones of quartz crystals: VI) central (ice-translucent), VII) intermediate, VIII) outer (morion); IX) regeneration quartz (a - smoky and patchy), b - colorless translucent). Dashed lines show pH values of central medium at 25 and 300°C.

in the previous alkaline-interval I, well-facetted topaz crystals, formed by free growth, have been observed; sometimes, very coarse grained topaz after coarse-blocky microcline is developed in association with quartz and muscovite (acid-interval II). In translucent regeneration quartz there are microcrystals of topaz in conjugate growth with the mineral-host or facetted crystals in the bands of the latest inclusoins in rock crystal (acid-interval III).

The alkaline intervals have been established in the mineral associations by repeated late K-feldspathization, noted by many investigators of pegmatites and metasomatically-altered granites, and also by breakdown and pseudomorphous replacement of minerals of earlier acid-intervals (topaz, beryl, etc.). In the leaching and recrystallization bands of the quartz-feldspar graphic zone, there are microcline brushes of free growth, the individual crystals of which sometimes overgrow epitaxially on the earlier thick-columnar albite; induction overgrowths of microcline and morion crystals in the cavities of this one indicate their synchronous growth during the concluding stage of this process; monomineralic rocks (microclinites of alkaline-interval I) are formed in certain pegmatite bodies. A later low-temperature generation of milky-white microcline, distinguished by crystals of typical oblique-prismatic habit, and montmorillonite-muscovite pseudomorphs after topaz and beryl mark the increase in alkalinity of the fluids during the concluding stage of the post-inversion phase (alkaline-interval II) [146].

[p. 116] The established association between the kind of color centers in quartz and the chemistry of the pH changes in the parent medium [7] corresponds to the conditions of crystallization of morion (increased alkalinity) and colorless quartz (a weakly-acid or weakly-alkaline medium), based on pH measurements in the inclusions. The close coincidence in the pH of solutions, measured under normal conditions in autoclaves prior to the artificial growth of quartz and in inclusions after the experiments, has been obtained experimentally [187].

An analysis of the association between pH measured directly in the inclusions and the index features of the minerals (see Fig. 30) demonstrates that the change in pH with falling temperature confirms the established patterns of pH evolution in the post-magmatic fluids, according to Korshinsky [109] and Naumov [152]; complication of the directional process of changes by the repeated pH minimum (acid-interval II) emphasizes the effect of contractional-tectonic factors on the process of formation of pegmatites.

We have attempted, so far as the original data permit, to compare the nature of the change in acid-alkaline conditions, determined by measuring the pH of individual inclusions (also extracts in part) and that according to calculations using B.N. Ryzhenko's method (see Fig. 45).

The points on Line A show the pHs of the aqueous extracts, prepared from quartz samples. The samples were collected through zones of block quartz and individual crystals from earlier to later formations. The extracts were prepared from mineral samples of 0.5-1.0-kg mass; their volume was reduced to 20 ml by evaporation; in such a way, the concentration, pH, and other properties of the extracts, approximate to some degree the properties of the solutions in the inclusions. Curve D corresponds to extracts from specially selected samples with inclusions of a definite kind only. The diagram also shows pH values calculated by Ryzhenko's method [167] for 25° (Line B) and 300°C (Line C), using analyses of the chemical composition of the aqueous extracts.

Without dwelling on certain problematical questions as to this method of construction, it may be stated that the curves for pH values, measured and calculated, are similar, although the contrasting nature of the changes is more distinct for the former.

A periodicity of change in the activity of the hydrogen ions has been established not only for the zanorysh pegmatites of Volyn'. Studies of inclusions in minerals from pegmatites of the Korsun'-Novomirgorod pluton [12] and from Kazakhstan [209], and also from greisen formations amongst the granites of Kamennye Mogil in the Azov region [78], confirm such a periodicity (Fig. 46).

Thus, the factual data presented demonstrate the advisability of measuring the pH of the inclusions, not only for the purpose of their correct classification, but also for reconstructing the conditions of endogenic mineralization. The latter must be done very carefully, allowing for the peculiarities of the chronological succession of crystallization of the mineral associations, and their index features. Interpretation (let alone extrapolation) of any measurements, in contrast to account taken of data obtained with the aid of precise methods, [and] [p. 118] verified in practice, may be achieved provisionally within defined limits and in accordance with the erudition and conscientiousness of the investigator's being more or less objective.

<u>Qualitative and quantitative ultramicrochemical analysis of individual inclusions.</u> At present, there are quite well-developed methods for chemically analyzing substances of mass <u>n</u> ($10^{-6}$ - $10^{-12}$)g and solutions of volume <u>n</u> ($10^{-3}$ - $10^{-6}$)ml [1]. Studies of such microscopic objects are achieved with the aid of speical methods for conductng analytical reactions under the microscope, special equipment, and unusual devices for micromanipulation and experiments. These methods are completely applicable to the analysis of the contents of inclusions of medium size (0.001-0.0001 mm$^3$).

In practice, the two most productive methods for carrying out ultramicroscopic analyses are: 1) qualitative and semiquantitative analysis on adsorption indicator films; and 2) qualitative and quantitative analysis

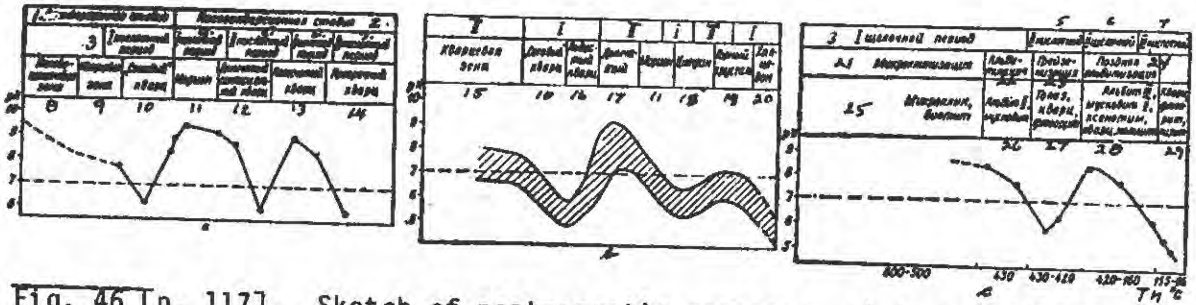


Fig. 46 [p. 117]. Sketch of postmagmatic process: a) in pegmatites of the Korsun'-Novomirgorod pluton; b) of Central Kazakhstan (I - acid-interval of crystallization, II - alkaline-interval); c) in greisenized granites of Kamennye Mogil (Azov region).

Key to figure:

1. Pre-inversion phase
2. Post-inversion phase
3. Acid-interval I
4. Alkaline-interval I
5. Acid-interval II
6. Alkaline-interval II
7. Acid-interval III
8. Feldspar zone
9. Quartz zone
10. 'Honeycomb' quartz
11. Morion
12. Smoky quartz in albite sector
13. Banded quartz
14. Translucent quartz
15. Quartz zone
16. Ice quartz
17. Smoky
18. Citrine
19. Rock crystal
20. Chalcedony
21. Microclinization
22. Albitization
23. Greisenization
24. Late albitization
25. Microcline and biotite
26. Albite II and muscovite
27. Topaz, quartz, and fluorite
28. Albite III, muscovite II, xenotime, quartz and calcite
29. Quartz, fluorite, and pyrite

with the aid of the normal classical methods, modified for the experimental conditions with ultra-small volumes of solution of normal concentration.

The first method is applicable to smaller items, although its accuracy is relatively low. An organic (albuminous) film, whose properties have been described above, is employed as an absorbent of colored compounds, typical of the release of a definite ion. The analysis is fundamentally similar to the drop method on filter paper. However, filter paper for volumes of less than 1 mm$^3$ has turned out to be unsuitable owing to its comparatively coarsely-fibrous structure. The organic film possesses a submicroscopic fibrous construction, is a good absorbent, and retains certain colored reactants (especially those prepared in alcohol solution). Its main advantage is that it permits a clear interpretation of color change under the microscope. In cooperation with engineer-chemist Z.S. Grin'kiv, we have developed a method of determining such ions as $Fe^{2+}$, $Fe^{3+}$, $Pb^{2+}$, $Mg^{2+}$, $Mn^{2+}$, $Cu^{2+}$, $BO_3^{3-}$, $S^{2-}$, and $SiO_2$ in inclusions [47] These components have been systematically determined in inclusions from minerals in the Volyn' pegmatites and hydrothermal veins in the Donbass.

The use of normal micromethods of inorganic chemical analysis for studying the composition of inclusions, a few tens of cubic millimeters in size, was first achieved in the Laboratory of Magmatogenic Processes in the Vernadsky Institute of Geochemistry and Analytical Chemistry (GEOKhI AN SSSR) under the direction of N.I. Khitarov [195]. Large inclusions (7-89 mm$^3$ in volume) in Iceland spar were used in the study. The amount of $CO_2$ and $H_2O$ was determined from the change in mass of the corresponding adsorbents. The soluble components were analyzed by methods of microanalysis after leaching them from the inclusion cavities with water. The concentration of the solution was calculated with respect to the corresponding volume of the vacuole with allowance for its degree of filling. The volume of the cavity [p. 119] was determined from the weight of the removed water and was controlled by continuous ultramicroscopic measurements. Maslova [140, 141] has applied the methods and techniques developed by Alimarin and Petrikova [1] for chemical analysis to micro-inclusions. She has made several new technical appliances for micromanipulation, and the preparation and conduct of analyses.

Ultramicroscopic analyses have been carried out with the aid of special equipment. Most of the operations have been conducted under the microscope, into the field of view of which the observed objects have been moved with the aid of a micromanipulator. The object under investigation and the devices for fixing and retaining it have been set on the microscope stand; in the jaws of the micromanipulator is the instrument for manipulation [? DAB].

Glass capillary micro-vessels, 0.5-1.5 mm in diameter and approximately the same length are used for storage of the solution. They are set in a special holder by the elongated portion (jaw). Measuring capillaries of cylindrical shape are also used. Transfer of the solution or liquid reactants is achieved with the aid of a micro-pipette with a drawn-out tip, 20-40 µm in diameter. The micro-pipette is mounted in a special piston of the device, destined for the smooth intake or ejection of the solution through the pipette. With the aid of the micrometer, the delivery of the piston (and consequently, the dosage of solution also) may be regulated by readings on the vernier. The vessels with the solutions, clamped in the holder, are set in a vacuum chamber. All operations on the microscope stand are conducted in the moist atmosphere of the chamber, protecting the solutions from evaporation. Changes in reactants and solution are made through a temporary opening window in the moist chamber.

The methods of qualitative and quantitative ultramicrochemical analysis as applied to inclusions have been used in practice only for quantities of solutions enclosed in vacuoles of not less than several cubic millimeters; inclusions measuring some tens of cubic millimeters have usually been available for analysis. Qualitative determinations have sometimes been carried out with volumes measured in tenths of a cubic millimeter.

The applicability of analytical methods on a wide scale, besides the usual obstacles, is hedged with difficulties of extracting the contents of the vacuoles. I.N. Maslova has used two methods of opening the inclusions: drilling (for large vacuoles) and crushing the preparations between glass lenses. In the second method, the elutriation of the contents of the inclusions with water does not comply with the requirements of direct methods of analysis. It is regretable that the method [p. 120] described in detail [88] for extracting the solution by slicing the mineral above the inclusion has not found application to the analytical method under discussion.

The solution extracted from the inclusions has been analyzed by the most reliable methods: titration (visual and potentiometric) and colorimetry. Visual titration was carried out under the microscope in volumes precisely measured with the aid of two micro-pipettes; the solutions were stirred with a magnetic rod of original construction. An indicator electrode, consisting of a capillary vessel with a platinum wire soldered into it and accessible to the solution through the capillary by a congruent [? DAB] calomel electrode, was employed for the potentiometric titration. Colorimetry of the solution was done in colorscopic capillaries (short thick-walled cells, which in vertical attitude allow good observation of the color of the solution in a comparatively thick layer.

In addition, a publication [142] has suggested several variants of the technical equipment for measuring the pH of solutions by the electrometric method with a glass electrode. The minimum volumes of measurable solutions, however, do not fall below 1 mm$^3$.

I.N. Maslova has studied the compositions of inclusions in Iceland spar from deposits of different kinds, in quartz crystals from veins in the Western Pamir and the Soviet Far East, in morion from Volyn', and in fluorite from pegmatites from Middle Asia. For this purpose, appropriate control studies were carried out in accordance with current analytical procedures and methods were worked out for conducting experiments to determine such components as: $Na^+$, $Ca^{2+}$, $Fe^{2+}$, $Fe^{3+}$, $Mg^{2+}$, $Al_2O_3$, $K^+$, $Cl^-$, $CO_3^{2-}$, $HCO_3^-$, $SO_4^{2-}$, $F^-$, and $SiO_2$.

Studies of solid components of inclusions. The minerals that are formed from the mother liquor after its isolation within the crystal in the form of an inclusion, have been termed daughter minerals, and the method of determining the composition and concentration of the mother liquor based on the chemical properties of the daughter minerals is known as the mineralogical method. It is likely that the minerals of the inclusions will be incompatible for the formation of the mineral-host. They are usually regarded as mineral-powders, mineral-satellites, mineral-precursors, etc. Owing to the fact that there are no distinct features for distinguishing the solid inclusions listed, and the significance of them with respect to the inclusions of mother liquor is almost identical, we shall from now on refer to them as solid inclusions [i.e., "mineral satellites"].

However, it is impossible to draw a sharp boundary between daughter minerals and solid inclusions. This results from the fact that under definite conditions of formation, a particular mineral may be called either a solid inclusion or a daughter mineral. For instance, the mineral enters the space of the inclusion until its sealing and grows after sealing up of the inclusion at the expense of the mother liquor, as a result of temperature drop.

[p. 121] The daughter minerals in the inclusions, when heated under laboratory conditions, should normally be completely dissolved prior to the temperature of disappearance of the gas phase or at this temperature. They may persist for two reasons: 1) if the temperature of the beginning of crystallization of the daughter mineral under natural conditions has not been reached (such temperature may be greater than that for the disappearance of the gas phase right up to the temperature of isolation of the cavity of the inclusion, that is, the temperature of mineral-formation); if the validity of such a reason can be proven in an actual case (on the basis of syngenetic inclusions), then we may be close to determining the actual conditions of mineral-formation (T and P); and 2) because there is no equilibrium between the daughter mineral and the solution owing to the brief time of the investigation; from observations on changes that occur in inclusions during lengthy exposure (23 days) of samples to a temperature close to that of the disappearance of the gas phase, it is evident that a few hours are sufficient for achieving equilibrium in the closed system of an inclusion.

From the behavior of inclusions during heating and their phase composition, the minerals found within them may be separated, to a certain degree arbitrarily, into four groups:

1. Minerals that occur in inclusions and dissolve below or close to the temperature of disappearance of the gas phase. These are daughter minerals.

2. Minerals that occur both in vacuoles with the mother liquor, and also in the form of individual xenogenic crystals [i.e., solid inclusions] and are partly dissolved close to the temperature of disappearance of the gas phase. Such minerals must also be regarded as daughters, because their material is a component part of the mother liquor, and in the absence of completed crystals after sealing, they may crystallize out in the form of minerals corresponding to the definition of the previous point.

3. Minerals that occur in vacuoles with mother liquor, but are not completely dissolved even after lengthy heating close to the temperature of disappearance of the gas phase. Such minerals may, in special cases only, be dissolved in the inclusions, and be considered daughters: when the pressure of mineral-formation differs greatly from the saturated

vapor pressure in an inclusion at the moment of disappearance of the gas bubble. These minerals are provisionally assigned to the solid inclusion category.

4. Minerals that occur only in the form of xenogenic inclusions [i.e., solid inclusions].

Daughter minerals are usually readily soluble salts. They are mainly chlorides of alkali metals, and less commonly, carbonates, sulfates, fluorides, borates, and silicates of Na, K, Ca, and Mg. The chemical composition of the daughter minerals makes it possible only to judge the concentration of individual quantitatively predominant components of the solution. Other component parts and their concentrations remain unknown.

[p. 122] There are two principal methods of opening inclusions for the purpose of studying the solid phases: 1) drilling the inclusions with a micro-drill [86], and 2) shearing the mineral along cleavage planes in which polyphase inclusions may occur.

The daughter minerals, extracted from the inclusions, are studied by crystal-optical, spectroscopic, and X-ray methods, etc. Examples of comparatively complete mineralogical description may be the data, obtained for daughter minerals from inclusions in the Volyn' topazes (Table 10). The best are those analyses that are nondestructive. R.I.s are measured by the rotating-angle method [? extinction] or in preparations using a convex cover glass[sic]. The Fëdorov stage is used to determine other crystal-optical parameters (optic indicatrix, extinction angle, optic axial angle, orientation of crystallographic elements, etc.).

Table 10 [p. 122-123]. Minerals of Polyphase Inclusions in Topaz from Volyn'

| Mineral number, after [86] | Crystal-optical properties | | | Temp. of solution in inclusion when heated, °C | Interaction between mineral and solvents* | Mineral and its composition |
|---|---|---|---|---|---|---|
| | R.I.s | Birefringence | 2V, ° | | | |
| 1 | $n = 1.544$ | Isotropic | | 110-190 | $H_2O+$ | Halite NaCl |
| 2 | $n = 1.490$ | " | | 30-40 | $H_2O+$ | Sylvine KCl |
| 3 | $\alpha = 1.599$; $\gamma = 1.585$ | 0.014 | +50 | 30-40 | $H_2O+$ | Prosopite (?)<br>AlZnClSi (?)<br>$CaAl_2(F,OH)_8$ |
| 4 | $\alpha = 1.476$; $\gamma = 1.464$ | 0.012 | +51 | 350-380 | HCl-, $H_2SO_4-$ | |
| 5 | $\alpha = 1.918$; $\gamma' = 1.868$ | High | +56 | 25-40 | HCl+ | Hemafibrite (?)<br>$Mn_3[AsO_4] \cdot [OH_3] \cdot H_3O$ |
| 6 | $\alpha = 1.464$; $\gamma < 1.408$ | " | n.det. | n.det. | $H_2O$, immersion liquid + | |
| 7 | $n = 1.578$ | Isotropic | -- | " " | $H_2O+$ | |
| 8 | $n = 1.566$ | Very low | n.det. | " " | $H_2O+$ | |
| 10 | | Isotropic (?) | -- | 232 | | Chlorite (?) |
| 12 | $n = 1.373$ | Isotropic | -- | 340-380 | $H_2SO_4+$ | Elpasolite<br>$K_2NaAlF_6$ |
| 13 | $\alpha = 1.530$; $\gamma = 1.417$ | 0.113 | n.det. | 370** | HCl-, $H_2SO_4-$ | |
| 14 | $\alpha = 1.760$; $\beta = 1.756$ | 0.016 | -60 | -- | $H_2O+$ (?) | Caracolite<br>$PbOHCl \cdot Na_2SO_4$[sic] |
| 15 | $n = 1.342$; | Isotropic | -- | 370** | $H_2SO_4+$ | Cryolite<br>$Na_3AlF_6$ |
| 21 | $\alpha = 1.575$; $\gamma = 1.488$ | 0.087 | n.det. | | -- | |
| 22 | $\alpha' = 1.600$; $\gamma' = 1.576$ | Average | +90 | | -- | |
| 23 | $\alpha = 1.557$; $\gamma = 1.533$ | 0.024 | -60 | | -- | |
| 24 | $\alpha >> 1.782$; $\gamma = 1.627$ | Very high | n.det. | | -- | |
| 26 | $\alpha' = 1.525$; $\gamma' = 1.503$ | Average | " " | | -- | Teepleite<br>$Na_4B_2Cl_2O_4 \cdot 4H_2O$ |
| 27 | $n = 1.519$ | Isotropic | -- | | HCl-, $H_2SO_4-$ | |
| 28 | $\alpha' = 1.471$; $\gamma' = 1.468$ | Low | -68 | | HCl- | Creedite (?)<br>$2CuF_2 \cdot 2Al(FOH)_3 \cdot CaSO_4 \cdot 2H_2O$[sic] |

* + mineral dissolves
  - mineral does not dissolve
** partial solution

[p. 123] The microprobe analysis of daughter minerals measuring <0.02-0.03 mm is carried out on an instrument with a low-voltage spark discharge [58]. The optical part of the instrument consists of a microscope, an MM-1 micromanipulator, and an ISP-30 spectrograph. The crushed mineral or an individual grain of it is transferred onto the end of the electrode in a micro-cavity and is covered with carbon powder. A low-voltage pulse generator is used to energize the spectrum, devised according to Yankovsky's plan [210]. The operating condensers are charged to 300 volts. The capacity of the condensers is regulated between 2600-6500 μF in accordance with the accepted range of the scan. Elements with high potential excitation are analyzed in an inert gas.

There are other variants of micro-X-ray analysis that have been used mainly for determining xenogenic solid inclusions in ore minerals [3, 30]. The method we have suggested has a higher sensitivity and is more convenient for studying microminerals extracted from inclusions.

[p. 124] An important diagnostic indicator of daughter minerals is their X-ray parameters. The microprobe method of obtaining powder diagrams [96] differs from those used earlier in its higher sensitivity, reliability of determination, and the sterile nature of the preparation. A mineral grain, 0.1-0.00001 $mm^3$ in volume, is powdered on a microscope slide with a watch-glass[?]; in order to prevent scattering of the mineral, crushing may be done in a drop of ethyl alcohol. Observations on the crushed material (and also during the operations described below) are done with an MBS stereoscopic microscope. In order to secure the powdered mineral, a fine fiber made of glass, has been used. A microprism is prepared in the following way. A glass fiber, 0.03-0.07 mm thick and 7-9 mm long is secured on a conical plasticine support with the aid of tweezers; at the base of the support is a small metallic disk (such a disk is in a set in the X-ray diffraction camera). The height of the prism, along with the support and disk varies from 12.5 to 14 mm depending on the height of the axis of the collimator of the X-ray camera. The glass fiber in the plasticine must be perpendicular to the basal plane of the support. The mineral selected for study, is crushed to a fine powder between the glasses. With the aid of plasticine, the preparation is set on the object glass with the powdered mineral, so that the glass fiber is oriented horizontally. A thin layer of white unscented natural vaseline is applied with a sharp needle to the tip of the fiber. Then gradually, small portions of the mineral powder are transferred with the needle to the glass fiber. The length of the fiber, covered with powder, is usually 1-2 mm. It is important to imbed the transferred powder on the surface of the fiber in an even layer.

Powder photographs for many minerals from inclusions in topaz have been obtained by microprobe measurements [86, 96]. Lyakhov [133], who has used our method, has obtained microprobe pictures for eight minerals from inclusions in a morion from the Volyn' pegmatites; amongst these minerals, he identified for the first time, a hydrous chloride of ferrous iron, and three minerals not precisely determined, and the X-ray pictures of four others completely duplicated those that we had earlier obtained for halite, sylvine, elpasolite, and cryolite.

The composition of the precipitate from the solution, extracted from the vacuole, has been studied by various methods, using highly-sensitive equipment. These prospective methods have so far had limited use and have been insufficiently developed for practical application. Examples are known of the study of inclusions using electron microscopy, the scanning electron-microscope, and microprobe analysis.

The electron microscope method has been used for determining the quantitative ratio of the substances that crystallize during desiccation of solutions from individual inclusions or their aqueous extracts. The salts are applied to a film-backing with a spray in vacuo. The electron micrographs are evaluated photometrically. The [p. 125] percentage amount of salts is determined by comparison with standard curves. Such a method has been used to determine the ratios of NaCl, NaF, and KCl in the dry residue from inclusions in quartz and topaz [100]. The analytical error does not exceed 5%. The minimal amount of salts investigated is $5 \cdot 10^{-8}$ g. Separate solid phases of the precipitate are determined by micro-diffraction.

Electron-probe analysis is used to determine the elemental composition of the precipitate. There are definite difficulties in obtaining a reliable picture of the distribution of elements in the items examined, and the actual intensity of their signals, owing to the nonstandard nature of the preparations. However, numerous data on the elemental composition of the precipitate from solutions and chemical compounds of the mineral-forming fluids, have been obtained for certain deposits of the cassiterite-quartz association.

## Nondestructive studies of the composition of inclusions (indirect methods)

The principal feature of the indirect methods of determining the chemical composition is the use of the physical and physicochemical properties of the solid, liquid, and gaseous components of the inclusions. The results obtained with special equipment provide no opportunity of directly assessing the composition. Such conclusions are possible only on the basis of comparison of these data with the results of a direct chemical study of similar systems. Indirect methods have been used for determining the total concentration (cryometry, thermometry, refractometry, etc.) or amount of individual compounds in the solution (spectroscopy in the IR field, Raman-spectroscopy, etc.).

Nondestructive investigations of the inclusions are preferred as follows in comparison with the above discussed methods: the inclusions are either completely undisturbed or are restored after the experiments. Therefore, one and the same inclusion may be subjected to a multitude of experiments by different methods. Individual genetic types of inclusions have been examined. A serious drawback in these methods is the incomplete chemical description of the substances examined and the constant dependence on the standard results of direct methods. This is especially the case for inclusions, the composition of which has still been insufficiently studied and may not have been foreseen.

Indirect methods have been subdivided into physicochemical and physical categories in accordance with the use of the properties of the substances studied.

### Physicochemical methods of studying inclusions

Principal properties of gas-liquid inclusions as physicochemical systems. The unifying feature of GLIs in minerals is the certain presence of a liquid phase under surface conditions. It may be combined with the most variable amounts of other solid or gaseous substances. As a rule, the liquid consists of an aqueous [p. 126] solution. Liquid $CO_2$ is encountered much less frequently in the inclusions. The physicochemical state of the inclusions is mainly controlled by these two substances, with the former predominant.

The inclusion-system is marked by its closed state. The surrounding mineral safely isolates the contents of the inclusion from outside effects. However, this system may readily undergo temperature changes, which are also used in physicochemical studies. Lowering of temperature will lead to complication of the phase state of the inclusions. Heating, on the other hand, will contribute to a [p. 127] decrease in the number of phases and will, in the end, lead to the formation of a uniform or homogeneous system. It has been accepted that the temperature at which the contents of an inclusion become homogeneous, be termed the temperature of homogenization of the inclusions (Th).

The composition of inclusions in minerals is varied. In order to establish the most important and most signficant physicochemical properties of the inclusions, we shall consider most simple, and, to some degree, idealized cases of filling of vacuoles with such liquids as pure water, an aqueous solution of salts, pure $CO_2$, and a mixture of water and $CO_2$. We shall not take account of the interaction between the walls and the contents of the inclusions, assigning this question to one of the problems of the homogenization method.

Inclusions of pure water. Under surface conditions, the water in the inclusions occur in a vapor, liquid, and solid state. At room temperature, the liquid phase may occupy 0-100% of the volume of an entire vacuole. The ratios of the volume of the liquid phase to the entire volume of the inclusion, expressed in parts of a unit or as a percentage, is termed the filling of the inclusion. Each of the two water phases in a closed inclusion is marked by a definite density value or the inverse value of its specific volume. In connection with the existence of a dynamic equilibrium in such a closed system, completely defined and constant values of the phase densities, and internal pressure, controlled by the saturated vapor pressure, have been established for a definite temperature.

If we ignore the thermal expansion of the mineral-host, then during heating of an inclusion with 31-34% filling, its homogenization will begin only at the critical temperature of water (374.11°C). Thus, the specific volumes of the liquid and vapor phases gradually change when the inclusion is heated to the critical temperature; the internal pressure at 374.11°C also reaches its critical values. In this case, the specific volumes of both phases converge at the critical point and become equal to 3.1975 $cm^3/g$, and the pressure equals 22.108 MPa. On the graphs (Fig. 47), the process of heating such an inclusion is illustrated by phase equilibrium curve AK. From room (20°C) to the critical temperature, the saturated vapor pressure will gradually change, passing successively through all points on this curve. Each point on the curve denotes that (with the existence of two phases in the inclusions) a definite temperature value may only correspond to one definite saturated vapor pressure (internal pressure).

The change in the volume relationships of the phases in the inclusion during its heating has been controlled by two mutually opposing processes. On the one hand, the volume of the liquid phase is increased as a consequence of its thermal expansion, and on the other, this same volume decreases with rise in temperature owing to the transfer of part of it into the vapor phase. The results of these processes with critical filling of the inclusion towards the moment of homogenization, are mutually compensatory.

Phase transformations take place completely differently in inclusions, the filling of which differs from the critical values. [p. 128] In this case, the effect of one of the above noted processes predominates and the homogeneous state of the inclusion sets in at temperatures

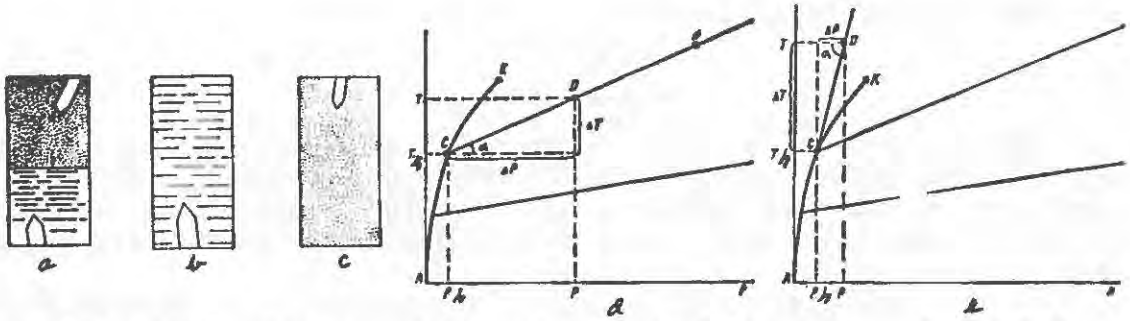


Fig. 47 [p. 126]. Diagram of formation of inclusions (a - c) and P-T conditions of crystallization (d and e), depending on aggregate state of hypothetical closed system (explanation in text).

below the critical point. If the initial filling of the inclusion (at room temperature) is greater than the critical level, the entire volume of the vacuole is filled during the heating process, with the liquid phase, that is, homogenization takes place into the liquid phase. With filling less than the critical level, the inclusion is homogenized into the vapor phase. Th in both cases depends on the filling of the inclusions, and they will be greater, the closer the filling is to the critical level.

The detailed change in the percentage ratio of the phases during the heating process is reflected in the so-called homogenization curves. They have been constructed with 'inclusion filling-temperature' coordinates (Fig. 48). Each curve on such a graph marks the successive change in the filling of the individual inclusion with rise in temperature up to its homogeneous state.

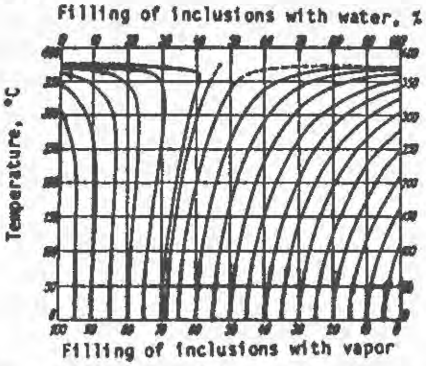


Fig. 48 [p. 128]. Theoretical curves for Th of inclusions of water with initial filling at 20°C.

Let us consider one of the theoretical methods of calculating and constructing the homogenization of water inclusions in thermal-variable volumes.11/ Let the two-phase inclusion, satisfying our previous conditions, have a total volume W, the volume of the liquid phase L, the volume of vapor G, the total mass of water and vapor M, the mass of water $M_L$, the mass of vapor $M_g$, the specific volume of water $V_L$, and the specific volume of vapor $V_g$. Then it is likely that the system of equations for such an inclusion will be:

$$L + G = W \qquad (1)$$

$$M_L + M_g = M \qquad (2)$$

[p. 129] Substituting in the second equation of this system the appropriate values $M_L = L:V_L$ and $M = G:V_g$, we may resolve the system

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11/ Other variants for calculating homogenization curves are also known [26].

with respect to L, which gives

$$L = \frac{MV_L V_g - WV_L}{V_g - V_L} \tag{3}$$

According to equation (3), we may derive the homogenization curves for inclusions with a different phase ratio, beginning with some temperature at which the given system exists. For this, data on the specific volumes of the phases at the appropriate temperatures are usually necessary.

Besides the above noted features of homogenization of pure water inclusions, we may note yet another, which is easily recognized when considering the family of homogenization curves. All inclusions (with the possible exception of those with a filling close to 1%), homogenizing to the gas phase, are marked by an increase in the volume of the liquid phase at the commencement of heating and its rapid decrease and disappearance towards the end of the process. Thus, on such graphs we may discern a turning or *inversion point*, and the coordinates of this point along the filling axis have the greatest significance. The preeminence of the process of thermal expansion of water here is replaced by the opposing process of vaporization. The overall nature of the manifestation of volume thermal-inversion for inclusions, homogenizing to the gas phase, confers no right to separate a special kind of homogenization, with an inversion point [63, 70].

So far we have not taken account of thermal expansion of the mineral-host. Its effect is an increase in the total volume of the inclusion space. Therefore in comparison with thermally-altering volumes, Th will be a little greater for water inclusions, homogenizing to the liquid phase, and on the other hand, lower for those, filled with a homogeneous gas phase. In practice, however, the effect of thermal expansion of a mineral is so small that there is usually no need to take it into account. For instance, of the most common minerals, quartz has the greatest coefficient of thermal expansion, but the maximum discrepancy in Th of inclusions in it and in the thermally-changing volumes is 6°C, and the critical filling may diverge by 0.54% only (Table 11).

*Inclusions of aqueous salt-solutions.* Salts dissolved in the water lower the saturated vapor pressure of the solvent. Therefore, on the P-T diagram for an aqueous solution, the curve of the two-phase L-G equilibrium is closer to the temperature axis. The values of the critical temperatures and pressures concomitantly increase.

The dependence of Th of inclusions of aqueous salt-solutions with constant volume, on the concentration and filling is most graphically

Table 11 [p. 131]. Homogenization Temperature (Th) of Inclusions of Water in Minerals and Thermally-Changing Volumes

| Water Filling at 20°C, % | Theoretical Th, 0°C | | | Water Filling at 20°C, % | Theoretical Th, 0°C | | |
|---|---|---|---|---|---|---|---|
| | in thermally-changing medium | in topaz | in quartz | | in thermally-changing medium | in topaz | in quartz |
| 100 | 20.0 | 20.0 | 20.0 | 40 | 372.0 | 272.0 | 372.0 |
| 95 | 114.0 | 115.0 | 118.0 | 35 | 373.5 | 373.5 | 373.0 |
| 90 | 169.0 | 171.0 | 175.0 | 31.871 | -- | -- | 374.1* |
| 85 | 214.0 | 216.0 | 219.0 | 31.524 | -- | 374.1* | -- |
| 80 | 250.0 | 252.5 | 256.0 | 31.335 | 374.1* | -- | -- |
| 75 | 281.0 | 283.0 | 286.0 | 30.0 | 373.8 | 373.8 | 373.8 |
| 70 | 306.5 | 308.8 | 310.5 | 25.0 | 372.5 | 372.5 | 372.0 |
| 65 | 317.0 | 328.0 | 330.0 | 20.0 | 368.5 | 368.5 | 368.0 |
| 60 | 343.0 | 344.0 | 345.0 | 15.0 | 362.0 | 362.0 | 361.0 |
| 55 | 355.0 | 355.5 | 357.0 | 10.0 | 344.0 | 344.0 | 343.0 |
| 50 | 364.0 | 365.0 | 365.5 | 5.0 | 304.5 | 304.0 | 303.5 |
| 45 | 369.0 | 369.5 | 370.0 | 0.0 | 20.0 | 20.0 | 20.0 |

*Critical temperature

illustrated on an F-Th diagram (Fig. 49), devised by Lemmlein and Klevtsov [124]. To construct such a graph, it is necessary to know the specific volumes (or density) of the solutions and of their [p. 130] saturated vapors at different temperatures. The present authors have obtained such data directly from literature sources [236] or have calculated them in addition from experimental determinations [251]. Appropriate interpolations have been made for a wide range of intermediate values of the density of solutions not examined experimentally.

If the condition of inertness of the walls with respect to the solution is maintained, then the overall mass of the inclusion remains unchanged. The density of a given concentration at the moment of homogenization of the solution will also be equal to that of the inclusion under all conditions of the two-phase L-G equilibrium. It may be determined from the formula

$$d = \frac{M}{W}, \quad d = \frac{Ld \ + Gd_g}{W}.$$

Such a density at room temperature will correspond to only one definite filling of the inclusion with a solution of given concentration. Consequently, confining ourselves to a definite ratio of phases at 20°C (or at any other temperature) and calculating the overall density according to the formula, it is easy to find the Th of the inclusion on the basis of known data for the relationship between the density of a solution of given concentration and the temperature.

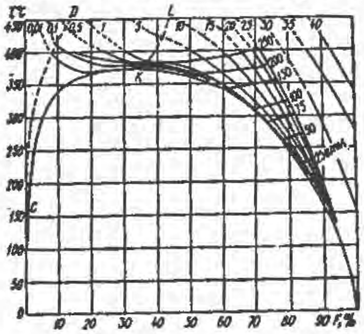


Fig. 49 [p. 130]. Relationship between Th of inclusions of an aqueous solution of NaCl of different concentration on the degree of filling [124]. [ "amm"= atm]

On the F-Th graph (Fig. 49), the lower dome-like curve marks the dependence of Th of inclusions of pure water on their filling at 20°C. Above it, similar curves have been plotted for different concentrations of NaCl. Point K denotes critical values of temperature and the filling of the inclusion with pure water. The curve, extending from this point upwards [K-L] joins the critical temperatures of solutions of different concentration. The dashed line [CD] in the left-hand portion of the graph separates [p.131] the field, where homogenization of an inclusion with a small filling is achieved by the transfer: L-G → G-salt crystals → G.

A comparison between the features of the homogenization of pure-water inclusions and those with salt solutions of different concentrations, leads to the following conclusions:

1. With identical filling of the inclusions, their Th is higher the greater the concentration of solution. The only exceptions to this rule [124] are inclusions with a filling of more than 93% and Th below 150°C. The relationship between Th and their concentration is the reverse of that formulated above.

In comparing the homogenization data for inclusions of water and NaCl solutions, and allowing that the vapor density above the solution at equal temperatures, is always less than above a pure solvent, it may be established that the coefficient of expansion of NaCl solution at low temperatures is greater, and at high temperatures (>150°C), it is lower than that for pure water.

2. An increase in the initial filling of inclusions of aqueous solutions, homogenizing into the gas phase, lowers their Th. Exceptions are infinitely dilute solutions (concentration <0.01%) with a filling close to the critical value. Such inclusions behave like those of water.

The special behavior of solutions in inclusions with a filling less than the critical value has been controlled by a non-proportional redistribution of salt (NaCl) in the liquid and gas phases with rise in temperature. The solubility of the solid component (NaCl) in the vapor phase depends on its density. Whereas a large filling of the inclusion with solution [p. 132] of given concentration will create a vapor density at a given temperature sufficient for complete solution of the salt in it, with smaller fillings supersaturation of the gas phase with a solid component may ensue and it will be concentrated more and more in the liquid phase. In the same way, the Th of the inclusion will increase. Finally, with a definite filling for a solution of given concentration, crystals may be precipitated from the liquid phase, in spite of a rise in temperature. As a result, complete homogenization into the gas phase of a gas-solid crystal inclusion will ensue at a sufficiently high temperature. The filling interval of inclusions, in which a solid phase precipitates with rise in temperature, is expanded with increase in initial concentration, which is reflected in the deviation of line CD (Fig. 49) from the temperature axis.

3. [p. 132] The critical temperature and filling of the inclusions are increased as the concentration of the solution rises (curve KL, Fig. 49).

For example, for pure water Tcr = 374.11°C; Lcr = 31.3% (if Vcr = 3.1975), and for a 0.65 and 1.7% solution of NaCl respectively Tcr = 385 and 396°C, and Lcr = 35.7 and 38.6% [236].

All the features of the homogenization of inclusions of aqueous solutions of salts have been reflected on the homogenization curves. We may note their following characteristic features: 1) Th curves for inclusions with a filling below the critical level have inversion points; 2) Th curves into the gas phase for smaller inclusions intersect those for larger fillings; and 3) the equation for the sectors between the Th curves for the multicomponent $H_2O$-NaCl system, established for $H_2O$ inclusions [88], is not satisfied; complete homogenization of inclusions into the gas phase, where precipitation of crystals from the solution is possible with rise in T, ensues as a result of disappearance of the solution and sublimation of the crystals.

Inclusions of pure $CO_2$. The physicochemical properties of $CO_2$ are marked by its low critical parameters. Amagat [211] has stated [p. 133] that they also have the values: Tcr = 31.35°C, Pcr = 72.9 atm (7.387 MPa), dcr = 0.464 g/cm$^3$. Under surface conditions, the $CO_2$ in inclusions may be in a liquid and gaseous state. As with the $H_2O$ inclusions, homogenization takes place in the liquid or gaseous phase depending on the filling. The maximum Th cannot exceed the critical value (Table 12).

Th curve for inclusions of pure $CO_2$ in thermally-changing volumes are generally similar to those constructed for $H_2O$. They differ only in the fact that their critical filling at 0°C is much higher than for $H_2O$ inclusions (according to Amagat [211], Fcr = 44.99%); for surface

Table 12. Homogenization Temperatures of $CO_2$ Inclusions in Thermally-Changing Volumes.

| Filling of Liquid $CO_2$ at 0°C, % | Theoretical Th of inclusions, °C | Filling of Liquid $CO_2$ at 0°C, % | Theoretical Th of inclusions, °C |
|---|---|---|---|
| 100 | 0.0 | 44.99 | 31.35* |
| 95 | 7.3 | 40 | 31.3 |
| 90 | 13.0 | 35 | 30.9 |
| 85 | 17.5 | 30 | 30.2 |
| 80 | 21.3 | 25 | 28.9 |
| 75 | 24.5 | 20 | 26.5 |
| 70 | 27.1 | 15 | 23.2 |
| 65 | 29.0 | 10 | 18.3 |
| 60 | 30.2 | 5 | 11.0 |
| 55 | 38.8 | 0 | 0.0 |

*Critical temperature

conditions at 0-31.35°C, the inversion point has been established only on curves for inclusions, the filling of which is similar to the critical value (38-45%); if the Th curves are extended to -50°C, then the inversion phenomenon in the inclusions will be noted over a wider field (approximately at F = 20-38%).

Inclusions of $H_2O$-$CO_2$ mixture. Water and carbon dioxide are marked by limited miscibility in the liquid state, that is, at a given T, their mutual solubility occurs in a definite constant ratio. In this instance, if the solubility of $CO_2$ under normal conditions is substantial, then contrariwise, the solubility of $H_2O$ in $CO_2$ will be very small.

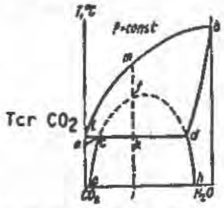


Fig. 50 [p. 133]. Isobaric section of PTX-diagram of two-component system $CO_2$-$H_2O$.

The state of the $H_2O$-$CO_2$ system at constant P, on composition-T coordinates may be illustrated by isobaric sections. Figure 50 shows the somewhat simplified TX sketch-diagram of Nacken [234] for P less than the critical value for $CO_2$.

The TX diagram, owing to the large volatility of both components and the especially low Tcr of $CO_2$, is marked by overlapping of the field of limited miscibility of the $CO_2$ and $H_2O$ liquids by that of the coexisting $H_2O$-gas phases. As a result, as T rises, mixing of the liquid phases does not take place and the critical point of complete miscibility f lies on the extension of the lines ec and hd. At point k, with T below Tcr, the more volatile phase ($CO_2$) begins to pass [p. 135] completely into the gas phase. The composition of the latter will be marked by corresponding coordinates on the line ab. Thus, at a given T, two liquid phases and a gas phase will coexist, the composition of which will correspond to points d, c and l.

In the inclusions (systems with constant overall volume), the coexistence of three phases has been observed over a wide T range. With rise in T, the isobaric system becomes two-phase. The composition of the liquid phase will correspond to the numbered points on curve db, and the composition of the gas phase to those on curve lb. At point m, the system passes into the homogeneous state.

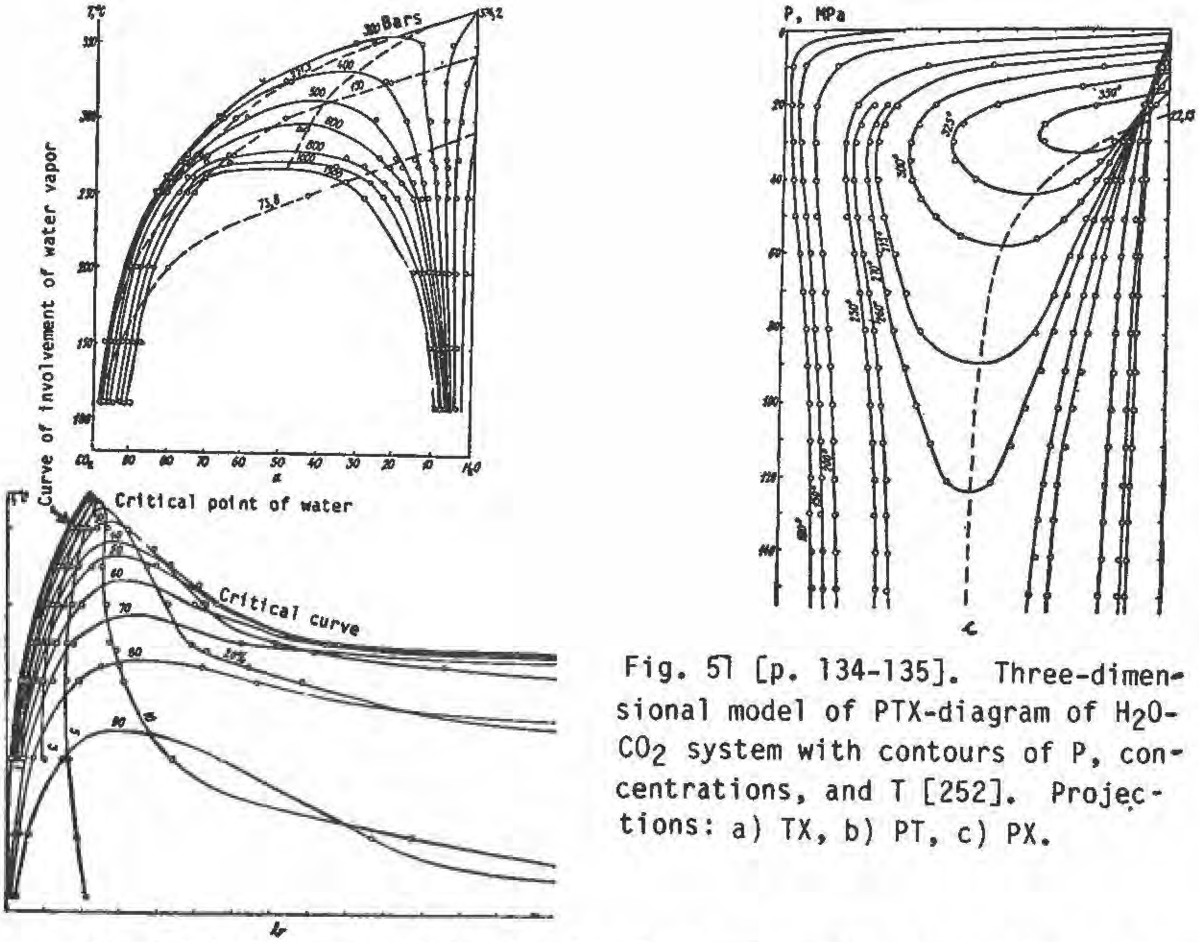


Fig. 51 [p. 134-135]. Three-dimensional model of PTX-diagram of $H_2O$-$CO_2$ system with contours of P, concentrations, and T [252]. Projections: a) TX, b) PT, c) PX.

[p. 136] Mixtures, differing little from the 100% composition of one of the components, are similar in their behavior to one-component systems. For example, with rise in T in the system, for the field of existence of liquid $CO_2$ alone, water will not be condensed, whereas the phases, which arise during heterogenization (liquid $CO_2$ and gas), will have the composition of points on curves ac and al.

With increase in total P to the critical level and somewhat higher, the T of boiling of pure $CO_2$ will approximate to its critical value. As a result, at the Tcr of the $CO_2$ system, the system will pass from three-phase ($H_2O$-$CO_2$-gas) to two-phase ($H_2O$-gas)

R. Nacken's scheme quite graphically illustrates the behavior of mixed inclusions in the field of pre-critical values of T and P, but it will substantially simplify the real state of the system. In fact, the field of liquid $CO_2$, separated by curves ac and ce, virtually does not exist and merges with the T axis (Fig. 50). The field of homogeneous aqueous solution is several times narrower. New experimental data of the system $H_2O$-$CO_2$, published by Khitarov and Malinin [193], and Takenouchi and Kennedy [252], enable us once again to consider the effect of thermodynamic factors on heterogeneous $H_2O$-$CO_2$ equilibrium. Using the data in [252], we have constructed PT, TX, and PX projections with the characteristic iso-lines (contours) and the critical curve plotted on them (Fig. 51).

These projections of the three-dimensional PTX model have the following characteristic features, reflecting the peculiarities of the phase relationships in the $H_2O$-$CO_2$ system.

1. The composition of the $H_2O$ and $CO_2$ solutions on the PTX coordinates is reflected in the irregular dome-like surface, separating the

entire space into a field of existence of a two-phase heterogeneous equilibrium with limited miscibility of phases (with relatively low temperature and pressure) and a field of homogeneous solution (under conditions of high temperatures and pressure). On the TX and PX projections, the left-hand parts of the contours mark the solubility of water in $CO_2$, and the right-hand parts, the inverse situation.

2. Individual parts of the isotherms link at the critical points, where systems of definite composition have complete miscibility of phases. With rise in temperature, these loops converge, gradually coming together towards their boundary -- [at] the critical point for pure water.

3. The curve joining the critical point for water with those for the miscibility of $H_2O$ and $CO_2$ solutions, does not reveal any tendency towards conjugation with the critical point for $CO_2$; it is quite likely that one of the constructions of Smith and John has its confirmation here [73].

4. The possibility of complete miscibility of $H_2O$ and $CO_2$ in large proportions at high temperatures has been confirmed by observations on complex $CO_2$ inclusions in quartz from hydrothermal veins in the Donbass. The composition of two inclusions, which homogenized into the critical state, is shown by points on the TX projection (Fig. 51) [p. 137]. They lie close to the critical curve. Lowering of the Tcr of water, saturated with $CO_2$, is also confirmed.

5. The solubility of $CO_2$ in water at constant pressures less than 150-180 kg/cm$^2$ is also decreased with rise in T, and contrariwise, at high pressures it increases as T rises.

6. The solubility of $H_2O$ in $CO_2$ at 50-200°C falls significantly with rise in P in the 0-120 kg/cm$^2$ range, but as the pressure changes from 200 to 600 kg/cm$^2$, it depends little on this.

Physicochemical methods of determining concentration. The determination of the concentration of solutions by indirect physicochemical methods may be achieved by studying the phase changes in the contents of the inclusions in the regime of temperature rise or fall (homogenization and freezing of solutions, crystallization and solution of daughter minerals, evaporation and condensation of volatiles, etc.).

Long ago, Sorby [248], carrying out thermometric investigations on pure water and solutions filling sealed glass tubes, showed that with identical filling, water homogenized at a lower T than the solution. These experiments served as a basis for deriving empirical formulae for calculating the Th of inclusions from the ratio of phases and concentration of the solution. Later, Ingerson [63], on the basis of Sorby's data, constructed an F-Th diagram for water and for a 10% solution of KCl and NaCl. Such diagrams make it possible, from the ratio of the liquid and gas phases and the concentration, to determine Th without heating the inclusion. New experimental work, based on a study of densities at high temperatures, critical temperatures, and the phase composition in the $H_2O$-NaCl system, has enabled the calculation of an extremely complete F-Th diagram (see Fig. 49).

In order to demonstrate the effect of different components of a solution on Th, we may use the proximate formulae of Sorby (Table 13) [124].

In comparing the calculated data for chlorides and sulfates of Na and K, we may see that for identical degrees of filling the Th values of solutions of various salts and their mixtures, differ by an insignificant amount. A more marked [p. 138] excess in filling arises mainly in solutions with the K ion. Up to 200°C, this excess, however, is <0.6%. In this respect, for two-phase inclusions, the composition of

Table 13 [p. 137]. Comparative Th of Inclusions of 25% Salt Solutions.

| | Th, °C | | | | | | |
|---|---|---|---|---|---|---|---|
| F, % | $H_2O$ (from Sorby's formula) | $H_2O$ (from Fig. 49) | NaCl (from Sorby's formula) | NaCl (from Fig. 49) | KCl | $Na_2SO_4$ | 12.5% NaCl + + 12.5% KCl |
| 91.7 | 140 | 151 | 150 | 161 | 158 | 150 | 152 |
| 89.6 | 157 | 171 | 175 | 192 | 185 | 175 | 178 |
| 87.5 | 177 | 190 | 200 | 222 | 210 | 198 | 202 |

which differs little from that of the solutions examined above, it is possible using the F-Th diagram for NaCl, and on the basis of the known Th and the phase relationships, to determine the total concentration. G.G. Lemmlein and P.V. Klevtsov have suggested analyzing the dry residues of aqueous extracts of the types of inclusions studied, to obtain an approximate composition. The Tcr of the inclusions may be used to determine the overall concentration, according to the same diagram. It is then not necessary to determine the degree of filling.

Using this method, we must, however, draw attention to a particular aspect. The gases that frequently occur in inclusions under pressure (e.g., $CO_2$), form an additional factor, which is not taken into account on the F-Th diagram. Therefore, when determining the concentration, it is essential to be sure that the excess Th arises at the expense of the above-listed chlorides and sulfates, and has not been due to the effect of gases that are poorly-soluble in water.

A fundamental preliminary condition for determining the concentration of a solution, based on the temperatures of dissolving daughter-minerals, is the absence of additional components (including material of the surrounding mineral) in the inclusion systems examined, besides those components that exist as solid phases. The most simple case of a two-component system is a soluble salt-water type. If, in fact, the relationship between saturation concentration and T has been studied for it, then at the moment of disappearance of the solid phase during heating, it is possible to determine precisely the composition of the solution. For certain three-component systems, most common amongst inclusions, diagrams of combined solubility have been constructed on the basis of experimental determinations (Fig. 52). The two principal [p. 139] fields of this diagram show the composition of the solution, coexisting with NaCl or KCl crystals at various temperatures, corresponding to the isotherms plotted. The points on the curve that demarcates these two fields, correspond to the saturated state of NaCl or KCl (curve of eutonic solutions). To the left and below is the field of existence of the solution in the solid state. The lower univariant point corresponds to the conditions of the four-phase equilibrium NaCl-KCl-solution-ice. For the 'pure' system NaCl-KCl-$H_2O$, and knowing the

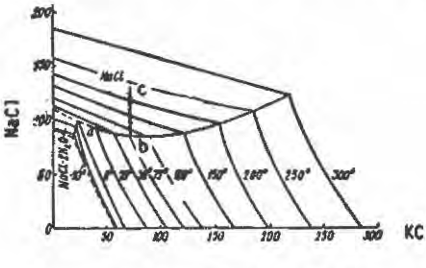


Fig. 52 [p.138]. Diagram of combined solubility of NaCl and KCl in water [126]. (moles/1000 moles $H_2O$)

temperature of passage of the solution from the saturated to the unsaturated state with respect to both components, it is easy to find the concentration of NaCl and KCl.

The determination of the concentration of the solution in the inclusions may be separated into two main stages: 1) establishment of the composition of the daughter minerals and the degree of purity of the system; and 2) determination of the concentration of the solution.

Direct determinations of the composition of the daughter minerals are conducted according to the method described above. The results of analyses of aqueous extracts make it possible to recognize quantitatively the predominant components of the solutions and in this way to stipulate the possible composition of the solid phases. From then on, the minerals are more confidently determined by their R.I.s. Other control studies may be conducted by indirect methods, such as crystal-optics (birefringence, crystal-shape, etc.), thermometry (rate of solution during heating or crystallization during cooling), etc.

The absence of components in the solution of inclusions, which are not involved in the composition of the daughter minerals, may be determined from the correspondence of the R.I. of the solution in the inclusion and in the experimentally-studied corresponding systems. The R.I. is measured in this case on a Fëdorov Stage. The purity of the solution may also be assessed from the value of the temperature deviation at the cryohydrate point. Microchemical data are also of substantial assistance. The accuracy of the determinations of concentration depends directly on the degree of purity of the solution examined with respect to the material of the mineral-host, because the solubility of the latter as the temperature rises has not usually been taken into account in the essential diagrams. Some authors [116] believe that the mineral-host material does not affect the results of the determinations, because owing to the brief time of the thermometric study (0.5-1 hour), it cannot be substantially dissolved, especially as the surface of the vacuole walls is smooth.

The principal meaning is evidently correct but the results of some experimental studies are contradictory. Of course, in order to achieve equilibrium between the solution and the mineral-host, a certain time, probably not very great, is necessary. It is known that equilibrium between $SiO_2$ and strongly alkaline solutions at high T and P in autoclaves is reached after a few hours. Our experiments with prolonged maintenance of multiphase inclusions in topaz (23 days) at the temperature of disappearance of the gas phase, have shown that Th remains unchanged. This indicates the preservation of the total volume of the inclusion cavity during the process of the entire experiment.

[p. 140] The freezing temperature of diluted aqueous solutions (up to the state of saturation) is lowered [in proportion to their] concentrations.

In the case of high concentrations, at T <0°C, a crystal-hydrate (e.g., $NaCl \cdot 2H_2O$) first begins to precipitate from the solution, and then eutectic crystallization of ice and crystal-hydrate takes place. The values of lowering of Tc of ice and $NaCl \cdot 2H_2O$ (the principal components of inclusions) may be judged from the TX diagram for this system (Fig. 53).

Temperature measurement of the phase changes and of the concentrations of the solutions corresponding to them in the inclusions is complicated by two factors: 1) the single-component nature of the inclusion-systems, and 2) phenomena of metastable supercooling of solutions.

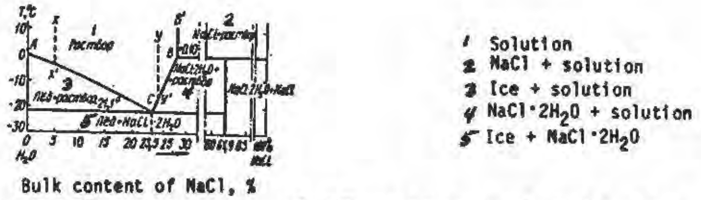


Fig. 53 [p. 140]. Diagram of XT system $H_2O$-NaCl for the low-temperature field.

In the inclusions, besides water, there is a predominance of NaCl, although other compounds are often present in large quantities (KCl, $CaCl_2$, $NaHCO_3$, $Na_2SO_4$, etc.). More complete diagrams taking account of the actual composition of the inclusions, are therefore necessary. Such diagrams were presented for the first time by Dobretsova [48], and later by Borisenko [11].

Problems of the correct determination of the phase transitions, taking account of the properties of the solutions in the inclusions to maintain the liquid state down to very low T (-50 to -80°C) have been discussed in detail by Roedder [242]. It has been shown that Tc must be taken as the temperature of melting of the last ice fragment or crystallite of $NaCl \cdot 2H_2O$ under conditions of rising temperature, beginning at the moment of momentary crystallization of the supercooled solution[sic].

Equipment for physicochemical studies of inclusions

The physical and chemical properties of inclusions may be studied without disrupting their integrity by visual observations with precise definition of the phase transformations of the contents in a prescribed regime of temperature changes. In this case, equipment is used, specially adapted for conducting experiments on a microscope stage in the field of positive (heating stage) and negative (cooling stage) temperatures.

Microthermometry stages. Microthermometry involves instruments that enable us, with the desired precision, to determine the temperatures of the phase changes in inclusions, to ensure the necessary rate of rise (or fall) in temperature, to obtain good visibility of the micro-objects, to cover a wide temperature range, and automatically to regulate the temperature during lengthy heating of the preparations.

[p. 141] The mineral-thermometric apparatus usually consists of electric heating (laboratory autotransformer and thermochamber), temperature recording (thermocouple and millivoltmeter), and optical (microscope) portions. Photomicro- or movie-cameras are used to document the homogenization process.

The microthermochamber is the main instrument. Particular ancillary equipment is most commonly used, according to its constructional possibilities. The technical possibilities of thermochambers are mainly dependent on the choice of medium for the transmission of heat from the heat source to the preparation being examined. This medium may be liquid, gaseous, or solid.

The accuracy in measuring the temperatures of transformation of materials in the inclusions depends on the degree of uniformity of the temperature field, in which the preparation is placed, and the measuring element (thermometer, thermocouple), that is, the medium (heat conductor) in which they occur, must be well controlled thermostatically. The last is unattainable without reliable heat-insulation of the entire heating system of the chamber.

The heating of preparations in a liquid medium will enable us to obtain extremely accurate results. They are more reliable, if there is good external insulation, and in addition to convective intermixing of the liquid, there is forced circulation also. The achievement of high temperatures, however, in such heating equipment is restricted to the stability of the liquid, which disintegrates at 250-300°C.

The method of heating preparations with inclusions in a liquid medium was replaced at the beginning of the 1940s by a method of heat transfer from the electric heater to the preparation through the atmospheric medium [63]. Owing to the extended temperature range, thermochambers of this kind have played a positive role in the study of natural geological objects, in spite of the fact that one of the main requirements of the experiment (accuracy of temperature measurement) was not adequately fulfilled. The conditions were eventually met during an attempt to make a comparative analysis of the temperatures of the laboratory synthesis of quartz crystals, measured with the aid of inclusions [87].

Allowing for the fact that both the thermochambers with an atmospheric heating medium, and also the elements of their construction are used more and more in individual laboratories, we shall discuss in greater detail the reasons for obtaining greater errors in temperature measurement due to non-observance of a uniform temperature field in the inner part of the chamber and the reliability of its heat insulation.

The microthermochamber with atmospheric heating medium [63] consists of a metallic body of cylindrical shape, a metallic cap, and a thin-walled metallic (or quartz) cylinder located in the center of the chamber, onto which a nichrome heating coil is wound. The preparation is set in the inner part of the cylinder; the cylinder space is insulated above and below by mica or glass slips.

Thus, the heating appliance in the central portion has a heat-insulated working space (insofar as the conditions permit) in which the plate with the inclusions is set in a special preparation [p. 142] holder. The latter has the form of a mica (or glass) circlet, set in a metallic ring. The thermocouple junction is clamped to the upper surface of the sample plate. The air of the working space is heated from the metallic internal cylinder.

The working space of the thermochamber is separated by the preparation-holder into two parts (upper and lower), with restricted heat-exchange between them. In its normal position, the lower part is significantly larger, more securely insulated, and better heated, than the upper portion. The working space above the preparation-holder has ready passage to the surrounding atmosphere through numerous slits in the chamber cap. There is also lesser heating from the electric-coil and poor thermal insulation owing to the direct contact between the internal heated air and the thermally conductive metal of the chamber cap. Therefore this part of the atmospheric chamber is cooler than the lower part.

Heat is admitted directly to the preparation from the mica circlet of the preparation holder and from the air in the upper part of the chamber. The temperature of the thermocouple junction is set in accordance with that of the surrounding air and the upper surface of the preparation. We must also take account of the fact that the hot thermocouple junction always has substantial measurements, and only a small part of its surface [corresponds to] the preparation. Therefore, the effect of the cooled air of the upper part of the chamber on the entire thermocouple junction will be greater than that of the heated mica circlet. Thus, in the mineral plate, the temperature will decrease from bottom to top. In the general case, the temperature drop will be greater, the more significant the difference in the temperatures between the upper and lower parts of the chamber working-space, the greater the relative surface of the thermocouple junction that does not touch the preparation, the higher the preparation-holder has been raised towards the upper end, and the higher the heating temperature of the sample.

As detailed studies, using improved thermochambers and normal paraffin micro-dishes[sic] have shown, the Th obtained during heating of inclusions in thermochambers with atmospheric medium is always underestimated. On average, the measurement errors are 30-50°C, although they depend in substantial measure on a combination of the factors listed above. Under the most unfavorable conditions, individual results deviate from the actual temperatures by 70-80 and even 120°C. When a chromel-kopel or chromel-alumel thermocouple is used for measurements, the hot junction of which has been flattened and is 2.0 x 1.8 mm in size with a height of 1.2 mm, then the Th, measured in the atmospheric thermochamber, will be below the actual values by 20-30°C in the range 100-200°C; below by 40°, if 200-300°C; and below by 50-60°C, if 380-400°C.

The results of the experimental measurements presented may in certain cases be used to correct published T values.

[p. 143] The conclusions about the systematic errors in measurements when using the atmospheric thermochamber may be illustrated by examples taken from Ermakov's work [63, p. 205; 67, p. 99; 69, p. 297]. He has suqqested that the Th of GLIs in quartz and calcite can be found without heating, on the basis of a filling-temperature diagram (the so-called visual method of determining Th). The basis for the standard diagram has been numerous measurements of regular tubular or planar inclusions in quartz and calcite, carried out individually for each mineral by two investigators in different chambers with atmospheric heating (analysts R.F. Sukhorsky and V.F. Lesnyak). On the F-Th diagram, all the points that correspond to the data obtained lie almost without scatter on the quartz and calcite curves. This may indicate a small instrumental error in the measurements. However, a large monotonously increasing divergence between these curves has been established: from 10-30°C with inclusion fillings of 99-96% to 40°C with 75% fillings. The data obtained, moreover, are very underestimated as compared with the calculated values for hypothetical aqueous inclusions (see Table 11). Thus, with filling of the inclusions varying from 99 to 75%, the divergence increases: a) for quartz, from 15-20 to 60-65°C, and b) for calcite, from 30 to 100-110°C. It must be expected that with lower fillings (and higher Th), the discrepancy will increase.

According to Ermakov [67, p. 298], the discrepancy between the Th of inclusions in two minerals and the deviation from the calculated data for inclusions of water and a 10% NaCl solution (incidentally, presented by the author in the same publication) into the lower-temperature field, is explained by the peculiarities of thermal change in the volume of the minerals, and by the effect of the composition of the solutions and the hydrostatic pressure.

From handbook data it is well known that quartz possesses the highest coefficient of thermal expansion; but inclusions of water in it, according to the data in Table 12, could have become homogeneous at a temperature exceeding the Th of inclusions of constant volume by not more than 6°C. The deviation of the temperatures because of heterogeneous concentrations of the inclusions in quartz and calcite is also unlikely. If we support Ermakov's conclusions, the experimentally derived F-Th curves must be located not below, but above the calculated curves for inclusions of water or NaCl solutions.

Thus, the discordance in the Th discussed, cannot possibly be explained by a difference in the volume thermal expansion of the minerals studied, the effect of the concentration of solutions, or a hypothetical difference (having no bearing at all on the present question) in the hydrostatic pressure. The single reason for the discrepancy is the unilateral systematic (and differing in value for identical equipment prepared in a different way) errors in measurement using chambers with an atmospheric heating medium. It is preferable to [p. 144] determine the Th of inclusions of different concentration by the well known Lemmlein-Klevtsov diagram than by visual estimation for which laborious measurements of temperature and construction of graphs have been made.

Yet another example, pointing to the necessity to introduce appropriate corrections to the data obtained on the basis of measurement with imperfect chambers with atmospheric heating arrangements, may be the graphic data or fundamentally important information on the temperature limits of existence of the aggregate states of the media in the inclusions or in natural crystallizers, presented in a number of publications. In particular, this applies to the diagrams of 'types and kinds of homogenization of inclusions' in the topaz from Volyn', according to Ermakov[sic] [63, p. 344, 387; 70, p. 87; 70, p. 8], repeated many times in publications, and to certain tables [70, p. 95, 97], etc.

The above information also emphasizes that the principle of heating preparations with inclusions in atmospheric thermochambers is basically unsound. It is virtually impossible to achieve an identical degree of heating the inclusion and the thermocouple junction, under conditions when they are separated by the heat-insulating mineral plate and together with the latter, they are surrounded by a heat insulator (air), which at the same time serves as a medium for the even conduction of heat. On the other hand, in order to even out the temperatures, the well-insulated heat-exchange medium must have maximum heat-conductivity. Only under these conditions will a virtually even degree of heating be possible at different points in such a medium. In order to achieve such a heating principle for the preparation, solid bodies (metals) appear to be the most suitable. On this basis, a new kind of thermochamber has been constructed [87, 88].

The main part of the heating equipment is a thick-walled metallic vessel 1 with screw thread on the inner cylindrical [p. 145] surface (Fig. 54). The thermocouple 5 is inserted through an opening in the base of the vessel; its spirally-curved end, insulated by thin mica

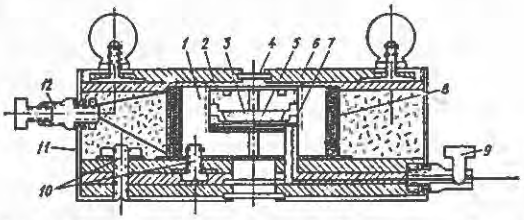


Fig. 54 [p. 144]. Microthermochamber with contact method of heating preparation (x 0.6): 1) metallic thick-walled container with screw thread; 2) stopper of container; 3) preparation; 4) upper glass window; 5) thermocouple junction; 6) asbestos cap of chamber with metallic rim; 7) metallic clamping nut; 8) heating element; 9,12) terminals; 10) mounting screws; 11) metallic body of chamber.

discs, is secured by a metallic clamping nut 7; on the latter the preparation 3, which is also firmly secured by a massive cap, the stopper of the vessel 2. Thus, a solid, good heating-conducting material (stainless steel, brass, and aluminum) forms the medium for even heating of the preparation along with the thermocouple junction which lies close to the object being studied. Openings in the floor and cap of the vessel serve for illumination and observation of the object. The comparatively great depth and small diameter (2 mm) of the openings enable the light to pass as through a diaphragm. Therefore, when observing the contours of the phase boundaries in planar inclusions, they will be seen more clearly, and vaguely in three-dimensions. It is not advisable to impart a conical shape to the lower opening, with expansion in the direction of the light source, because the thin part of the metal at the thermocouple junction will disturb the even nature of the heat field. In constructing a thermochamber for observing three-dimensional inclusions, an inserted microcondenser is specified, which is easily set above the illumination opening. The microcondenser will provide just as intense lighting as a Laxo lens[sic] on a petrographic microscope. It is a short-focal lens ~2 mm in diameter and is prepared extremely simply from normal or heat-resistant glass. The maximum heating temperature of the chamber is 600°C; the thermocouple is chromel-kopel or chrome-alumel; the heating element is a nichrome wire 8. The insulated thermocouple leads are taken to terminals 9 and 12. The central cylindrical portion of the chamber is insulated with thick layers of compact asbestos sheet. It is secured by screws 10 to the chamber body 11. The upper part of the chamber is insulated by several layers of asbestos sheet. For better heat insulation, the cap of the thermochamber 6 is prepared from thick asbestos sheet and in the center it has a small opening for observation, which is covered by a glass disk 4; the cap is protected along the periphery by a metallic ring with a thread to screw it into the chamber body. Observation is carried out with the aid of objectives with long focal length; decrease in the size of the chamber details, located above the preparation, enable us to use normal objectives of average magnification.

The current fed to the nichrome coil is regulated by an autotransformer type LATR-1. This controller ensures the appropriate increment of heat to the sample, that is, its heating rate. Heating must be kept at such a rate so that with a given heat-insulation of the equipment and heat-conductivity of the mineral, the difference between the temperature of the inclusion examined and that of the thermocouple junction will be at a minimum. At an infinitesimally slow heating rate, this difference will be determined by the heat-insulation alone.

During the last two decades, heating equipment of many kinds has been used in the thermometry of inclusions. The principal forms [p. 146] have been discussed in detail in publications [110, 135]. The above described chamber has been prepared by individual teams in the experimental-mechanical workshops of the Academy of Sciences of the Ukrainian SSR and has been used in many laboratories in the Soviet Union. The chamber constructed by Dolgov and Bazarov [135] is widely used by investigators of inclusions, having originated from a constructive solution of working designs and the exterior plan of the microthermochamber of Ikorsky [80] and Groshenko [41]. A new chamber constructed by Kormushn [110] gives better accuracy.

The study of phase changes of inclusions in melts in magmatic minerals requires the use of thermochambers with heating to T >1000°C, frequently in an inert gas or a vacuum. We suggested the vacuum high-temperature chamber in 1965 [90]. A thermochamber for heating in an atmospheric medium was developed by Bazarov [5], and in an inert gas medium by Chepurov and Pokhilenko [200]. Heating under the microscope to 1300-1500°C, using a silite[SiC] heating element, has been achieved by Mikailov and Shatsky [147], and Zhovtulya [72].

Microthermochambers for studying inclusions must satisfy many requirements, for instance, simplicity of design, an extremely wide range of working temperature, multi-purpose nature, convenience in operation, optical range with high magnifications, stereoscopic features, polarized light arrangements, etc. But the main merit of the chamber as a measuring instrument, intended for quantitative study of the nature of the inclusion substances, is the precision and reliability of the numerical characteristics obtainable. Neglect with respect to the precision of experiment [68, p. 6-8; 70, p. 56] leads to increases in errors, and on that basis, to the development of incorrect hypotheses.

In spite of the definite successes in improving the thermochambers, their construction so far cannot be regarded as completely satisfactory. This is evidenced, in particular by the results, obtained on the initiative of Naumov [148] in many laboratories of the USSR, of tests of the precision in measuring the Th of standard GLIs. According to an analysis by Kormushin [110], the mean value of the results differs from carefully checked temperatures, close to those under conditions of synthesis of quartz crystals (allowing for pressure corrections), by only 2-5°C. At the same time, the mean-square error is ± (12-16°C), and many of the measurements deviate from the mean by 23-43°C. It is only possible to suggest how much the above errors in measuring the Th of hydrothermal inclusions (up to 300°C) are exceeded by those for magmatic inclusions with the aid of high-temperature chambers; no control checks for the latter have really been carried out. The substantial variation in temperatures, measured in chambers of a particular kind of construction by different investigators, is explained by the imperfections in designing individual instruments. It is evident that the accuracy [p. 147] of operation of thermochambers of different construction may to some degree be described by the author's conclusion: deviations between Th measurements for particular inclusions range from 4-8° for chambers of V.A. Kalyuzhnyi's system up to 40-45° for those of N.P. Ermakov's system and Dolgov and Bazarov's system [110, p. 7]. Perhaps the comments below will be useful in constructing new models of the temperature-measuring equipment.

The impossibility of directly measuring the temperature of the inclusion makes it necessary to create a heat field in the hot portion of the chamber with uniform or maximally similar temperatures. Leveling out of the temperature in the preparation and at the recording point is achieved by: a) intense convection (in a liquid medium) or high thermal-conductivity (in a solid heat-conductor), and b) reliable thermal insulation in the equipment. Both conditions are equally important and mutually supplement one another. But in addition, a signficant role is played by the relationship between the thermal heat capacity of the materials used for the internal heating and external thermal insulating parts of the chamber.

The latter condition above shows up most intensely in chambers with convective heat-exchange. It especially affects the incomparably greater efficiency of equipment with a liquid heat-conductor than those chambers with atmospheric heating. Even with the very good heat-insulation in Ermakov's chambers, the low-density atmospheric medium which possesses little thermal mass, will, with most insignificant disturbances of the hermetic sealing of the inner space, rapidly change in temperature depending on the changes in external conditions and in the same way will destabilize the heating of the preparation and the thermocouple junction. The low specific heat of the preparation and the mica support for it is in no state to stabilize the heat field. Replacement of the mica (or quartz) preparation-holder by a metallic unit is only a half-measure and will not eliminate the indicated causes of disturbance of the heat balance, the more so since, as indicated above, thermochambers of this construction are very poorly insulated from the outside.

The new chamber, described by Pashkov [159], is also not devoid of the above deficiencies. In essence, the passage in this construction of the equipment to the 'convective-heat-conductive' method of heat transmission, as in the above described modification of the chamber with an atmospheric coolant [70, p. 53], is recognition of the feasibility of using contact heating of the preparation. But judging from the sketch presented, the relationship between the volume of the miniature internal heating portion of the chamber and that of the surrounding 'heat-insulation' atmospheric space cannot contribute toward preserving the stability of the heat field of the working part of the equipment. The convective heat-exchange in the relatively large volume of the atmospheric space between the 'cold' (or at least cooled) metallic body and the small coolant often creates an unstable regime of heating the preparation, depending on random external causes. Incidentally, Yu.N. Pashkov has referred to the necessity to preserve the commensurability of the volumes of the heat-conducting body and the atmospheric space, but his design for the equipment is not in keeping with such a statement. The [p. 148] sketch of the heating high-temperature unit, mounted in the chamber body of the construction under discussion, presented in the paper, is completely unconvincing (if not odd). The measurable temperature with the aid of such a 'unit' may most likely reflect the degree of imperfection of the equipment and the effect of unstable external and other conditions for the conduct of the experiment, but not the moments of the phase transitions of the inclusions in the regime of changing temperature.

The high-temperature chambers of Dolgov and Bazarov [135] and Bazarov [5] have been prepared on the basis of heat-transfer through a solid body of quartz glass. They are simple in manufacture and convenient in operation. But the applied method of heating the preparation creates large temperature surges in the auxiliary lamina and in the preparation with inclusions, and as a result there is no guarantee of adequately accurate measurements. The contact method of transfer of heat to the preparation (unidirectional) from a material with high heat-conductivity (metal) has been used in the chambers of Kormushin [110], Chepurov and Pokhilenko [200], and others. In V.A. Kormushin's chamber, the thermocouple junction is brought as close as possible to the item being examined, and it is the coolant of the instrument[sic]. This, like good external heat-insulation, contributes to high precision in the chamber operation.

We must point out other factors that lead to disturbance of the uniformity of the thermal field of the chamber. In some kinds of equipment, water cooling is used to lower the temperature of the body or to protect the microscope objective from heat. Such undesirable heating indicates an imperfection in the insulation of the chambers, so that we must give prime attention to its elimination. Forced-air cooling will contribute to the creation of a more contrasting temperature drop through the entire chamber system, also including its operating space. This also applies to the imperfection in the insulation from the aspect of the inspection window, which also serves as a slot for the insertion of the microscope objective. A particularly significant disturbance of the thermal field arises during the use of objectives with short focal distance and water cooling. Attempts to resolve the problems of heat insulation have, as is well known, been undertaken by using the most reliable vacuum thermal insulation. Besides our own vacuum chamber, we must note the well-constructed high-temperature 'vacuum furnace' of Smith [173], for examining inclusions under the microscope. Apparently, the vacuum type of insulation is most promising for designing the most efficient and accurate thermometric instruments for studying the contents of inclusions.

Microcryochambers. The systematic study of inclusions in the temperature field below 0°C was begun comparatively recently [14, 123, 241]. The demands imposed on cryometric equipment are mainly the same as for the above described thermal-measuring instruments, used in the field of posititve temperatures. But, in addition, the complicated phase changes, liquification of the gas components, metastability, etc., i.e., heterogenization of the contents of the inclusions, that take place in a comparatively narrow temperature [p. 149] range, require greater precision in measurement using cryochambers.

Liquid nitrogen was used for the first time by Tsurinov and Vol'nova [199] for cooling purposes in cryometric microchambers. Roedder [241] used acetone, pumped from a thermostat into the chamber at temperatures > -35°C. In chambers in current use, nitrogen serves either directly as the medium for cooling the object studied [144], or cools the metallic chamber of the instrument, connected to the metallic support for the preparation [110]. In both cases, the objective of the microscope is inserted directly into the atmospheric (gas) space of the inner cooling slot of the instrument. The arrangement of the objective above the preparation, unprotected by insulation, the low thermostatic capacity of the gas, and the insufficiently smooth regulation of the supply of liquid nitrogen, do not contribute to the required accuracy of measurement of the phase transformations of the inclusions.

The cryometric chamber with a liquid thermostatic medium, a vacuum external insulation, and combined supply of gaseous and liquid nitrogen does not have these deficiencies [92].

The chamber consists of a thermally resistant glass beaker 6 (8 cm in height and diameter) with plane-parallel-ground inner walls[sic; bottom?] (Fig. 55). The preparation 8 is placed on the floor of the

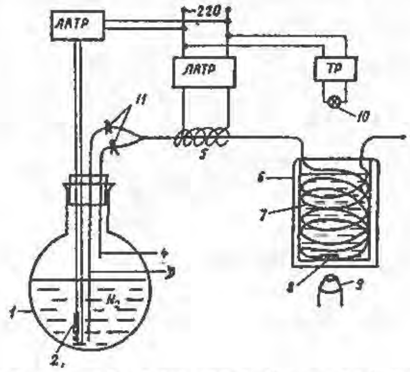


Fig. 55 [p. 149]. Sketch of cryometric equipment: 1) iron Dewar flask with liquid nitrogen; 2) heating coil; 3,4) copper tubes; 5) muffle furnace; 6) glass beaker (body of cryochamber) with ethyl alcohol; 7) double-wound coil of copper tubing; 8) preparation; 9) microscope objective; 10) microscope condenser; 11) clamps on connecting rubber tubes.

beaker, which is filled with ethyl alcohol with a [p. 150] freezing T of -117°C. A copper tube in the form of a double-wound curved spiral 7 is immersed in the liquid, through which is passed a current of gaseous or liquid nitrogen. A tube of this shape permits even cooling of the alcohol and the preparation immersed in it. The preparation is observed from below, through the floor of the chamber, with the aid of an MIM-6 microscope 9.

The flow of nitrogen is [thermally] regulated by a heating coil 2, lowered into a metallic Dewar flask 1, plugged with a rubber stopper. Two copper tubes pass through the stopper, one of which (3) reaches almost to the bottom of the flask (for the supply of liquid nitrogen), and the other (4) does not reach the surface of the liquid nitrogen (for the supply of gaseous nitrogen). Outside the flask, these tubes are connected by rubber hoses and a glass T-junction to a third copper tube (11), leading to the double-wound coil 7. During heating of the coil 2, which is regulated by an LATR auto-transformer, pressure is created in the Dewar flask. Under its influence, liquid or gaseous nitrogen (depending on which of the hoses will have been closed by a clamp) enters the spiral tube of the cryochamber. With the passage of liquid nitrogen, there is rapid cooling, and [subsequently] precise temperature regulation is achieved by the delivery of gaseous nitrogen. Heating may be carried out by the same jet of nitrogen, but it is heated with the aid of a muffle furnace 5 around the copper tube which leads to the coil in the cryochamber.

Construction of the cryochamber enables us to use a short-focal-length objective (x 9) and a long-focal-length OSF objective (x 22), for observations, which ensures good visibility of inclusions measuring 0.01-0.005 mm. Temperature measurements are made with a mercury (> -38°C), alcohol (> -80°C), or pentane (> -110°C) thermometer with an accuracy of 0.1 to 0.5°C, depending on the scale dimensions of the thermometer. Copper-constantan thermocouples and resistance thermometers are also used, ensuring measurements down to -170° to -175°C. The uniform nature of the temperature field in the cryochamber around the preparation and the top of the thermometer is ensured by stirring the alcohol with a weak jet of gaseous nitrogen.

Calibration of the cryochamber is achieved using the freezing temperatures of standard pure liquids (distilled water, chlorobenzene, N-butyl alcohol, etc.), sealed in glass capillaries. The freezing temperature is taken as that of the melting of the last crystal of previously frozen pure liquid substance. Increase or decrease in temperature in the field, close to the temperature of the phase transformation in the inclusion or the standard, is carried out at the rate of 1° per 5-8 minutes, which ensures complete reproducibility of the results of measurements within the limits of accuracy of the method.

The described principles of measuring temperatures and cooling of the preparations, with certain simplifications in thermal insulation and the method of observing the objects, have been used in the construction of the chamber of Vosnyak and Galaburda [19].

## The study of inclusions on the basis of their physical properties

The microrefractometric method of determining the overall concentration of solution in inclusions. The R.I. of a solution bears a direct relationship to its concentration. Such relationship, with only one known component in the solution, will enable us, on the basis of light-refraction, to determine the concentration with great accuracy

(Fig. 56). The solutions present in inclusions are multicomponent systems. Therefore, the R.I. will enable us to determine only the overall (total) concentration of the solution, expressed in refraction units or in quantities equivalent to the predominant compound (e.g., NaCl).

We have measured the R.I. of the solution using the universal Fëdorov Stage, which has been repeatedly employed as a microrefractometer. The procedures for using three possible methods had already been suggested by Fëdorov [182]. K. Nakashima has used a Fëdorov Stage for measuring the R.I.s of liquids. Some time later, Melankholin [143] improved the procedures for such measurement. An original and comparatively accurate method for measuring R.I.s on the universal stage was suggested by Lodochnikov [182].

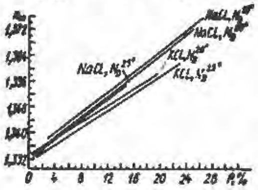


Fig. 56 [p. 151]. Relationship between light-refraction in sodium light ($N_D$) of aqueous solutions of NaCl and KCl and concentration and temperature.

However, not one of the listed methods can be effectively used for measuring substances in inclusions, mainly owing to the telescopic method of observation. The latter is marked by focussing the microscope tube, in the same way as the ocular tube of a normal refractometer, at infinity, which is achieved by insertion of a Bertrand-lens. In this respect, the investigator does not see the object being measured. The phenomena of complete internal reflection and the corresponding angle are fixed on the boundary line (which divides the field of view of the microscope into light and dark portions) with respect to the cross-hairs of the ocular. Owing to the complexity in shape, small size, and the multiphase nature of the inclusions, the boundary line is not observed. The material of the mineral-host has a special effect on the precision of measurement.

An example of the application of the normal laboratory refractometer for measuring the R.I. of liquids in inclusions is known in the literature. In 1826, Brewster [214] determined the R.I. of an aqueous solution (1.2946) and liquid $CO_2$ (1.1311), which had been found in cavities in topaz. However, his results deviated from the true values by at least 0.030-0.040. The inaccuracy in the measurements probably arose because account was not taken of the above factors.

[p. 152] A suggested micromethod [82, 84] for measuring the R.I. with the aid of a Fëdorov Stage differs fundamentally from that referred to above. The microscope method of observation (without Bertrand lens) enables us to measure the R.I. of the mother liquor of microscopic inclusions that occur in minerals, both in the free and enclosed states. The theory and practice of determining the R.I. by the microscope method of fixing the boundary line have not been worked out previously. Apparently, F.I. Radzhabov's attempt to use the Fëdorov Stage for these same purposes (ref. [43; 67, p. 205]) was unsuccessful, because no results were published.

The set-up for measuring the R.I. of substances occurring in inclusions consists of a microscope and a universal stage. The light source is a collimator or sufficiently remote electric lamp from the microscope (>5 m). A bundle of parallel rays is directed onto the segment of the stage and the object of investigation from a planar microscope mirror. The lower segment of the stage with greatest R.I. (1.647) is used, like the hemisphere of a normal refractometer, for proper concentration of the bundle of rays and the setting of the object examined on it. The angle of slope of the segment is measured on the vernier of the stage axis. In order to exclude the effect of the upper segment and the portion of the mineral, lying above the inclusions, the boundary line of the complete internal reflection is fixed with respect to some selected point, lying directly on the separation boundary of the media.

The boundary ray of complete internal reflection, depending on the angle of slope of the stage, may pass through the segment and preparation by two routes (Fig. 57). All the rays lying to the left of the limiting ray will be reflected at the interface of the media, because their angle of inclination is greater than that of the complete internal reflection. In the field of view of the microscope, this portion of the segment will be dark. The rays located to the right of the center of the segment have an angle of inclination less than that of the limiting [p. 153] ray, and being refracted at the interface of the media, they will penetrate into the liquid, lighting up the corresponding part of the microscope field of view. Thus, in the ocular of the microscope, the layer of the substance examined will be separated by the boundary line of complete internal reflection into two portions: light and dark.

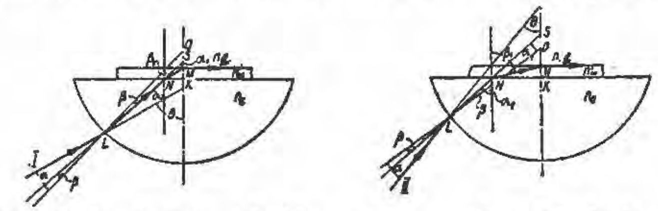


Fig. 57. Two possible cases of the course of a limiting ray through the lower segment of a Fëdorov Stage and a plane-parallel slide: OK) distance of center of spherical surface from planar surface of segment; MK) thickness of mineral slice (distance from inclusion being measured); OS.SK) sectors of segment axis; R) radius segment; Θ) angle of slope of stage; $n_c$) R.I. of segment; $n_m$) R.I. of mineral-host; $n_l$) R.I. of layer of free liquid or solution of inclusion.

If the measured layer of liquid is parallel to the surface of the segment, then the relationship between the angle of slope of the stage and the R.I. of the liquid $n_l$ may be illustrated by two somewhat different systems of equations with respect to two possible cases of the course of the limiting ray. In the first case (OK>SK), ray I falls on the spherical surface of the segment at an angle α (this direction is determined by measuring the angle Θ on the vernier of axis I of the stage), is refracted (angle of refraction β), falls on the boundary between the segment and the slice at angle $\alpha_1$, and is here again refracted ($\beta_1$), and then passes through the plane-parallel layer of mineral and falls at the limiting angle $\beta_1$ on the mineral-liquid interface. According to the laws of refraction, the relationship between the above values will have the form

$$\frac{\sin\beta_1}{\sin 90^\circ} = \frac{n_\ell}{n_м} \text{ или } \beta_1 = \frac{n_\ell}{n_м}; \qquad (4)$$

$$\frac{\sin\alpha_1}{\sin\beta_1} = \frac{n_м}{n_o}; \quad \sin\alpha_1 : \frac{n_\ell}{n_м} = \frac{n_м}{n_c}; \qquad (5)$$

$$\sin\alpha_1 = \frac{n_\ell}{n_c}.$$

From the triangles NKM and NSK, we obtain KN = MK tan $\beta_1$, and KN = SK tan $\alpha_1$, hence

$$SK = \frac{\operatorname{tg} \beta_1}{\operatorname{tg} \alpha_1} MK; \tag{6}$$

$$OS = OK - SK. \tag{7}$$

From the triangle $LOS$ $\frac{R}{\sin \alpha_1} = \frac{OS}{\sin \beta}$ or

$$\sin \beta = \frac{\sin \alpha_1}{R} OS; \tag{8}$$

$$\sin \alpha : \sin \beta = n_c, \quad \sin \alpha = n_c \sin \beta; \tag{9}$$

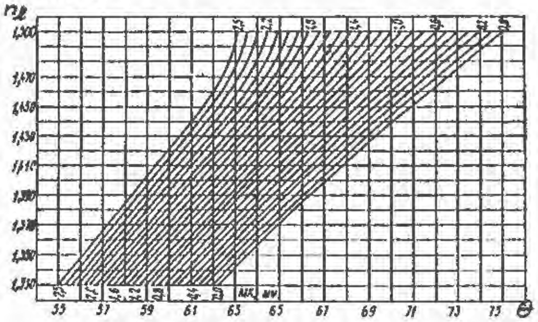
$$\alpha - \beta = [180 - \alpha_1 - (180 - \theta)] = \theta - \alpha_1,$$

$$\theta = \alpha_1 + \alpha - \beta. \tag{10}$$

In the second case (OK<SK), all equations above are identical, except for (7) and (10). Equation (7) will have the form OS = SK-OK; and equation (10) will be $\Theta = \alpha_1 - \alpha + \beta$ .

The system of equations (4)-(10) have turned out to be virtually unsolvable. Therefore, on their basis, tables have been computed and the corresponding graphs constructed (Fig. 58). The tables have been computed as in [82]: for a definite mineral, for example, topaz with a mean R.I. of 1.615, for various R.I. values of liquids (ranging from 1.33 to 1.50), and for various values [p. 154] of MK (0-2.5 mm), the corresponding values of the angle of slope have been computed. Such a method has been used to compute tables for minerals with R.I.s of 1.548 and 1.615, and also for calcite with $n_0$ = 1.658. Using these tables or graphs, we may by interpolation also obtain the R.I.s of liquids on other weakly birefringent minerals (birefringence <0.009), the R.I. of which varies from 1.548 to 1.658.

Planar inclusions, selected for R.I. measurement, may have a greater or smaller inclination towards the plane of the preparation (plane-parallel slice). Let us consider the non-parallel nature of the measured layer of material relative to the plane of the segment surface.



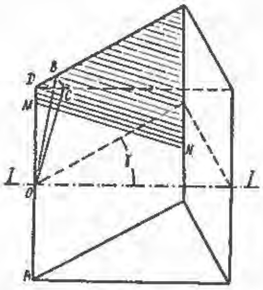


Fig. 58 [p. 154]. Relationship between slope of stage Θ, the R.I. of liquids examined ($n_1$), and the thickness MK of a plane-parallel layer of mineral with R.I. = 1.548 (quartz).

Fig. 59 [p. 154]. Location of boundary line NM in the plane of a wedge-like slice.

The slope of the plane of the measured layer of liquid relative to the axis of rotation of stage I may occupy the most varied positions. However, two extreme cases have been established: 1) the line of intersection AD of the planes of the measured layer of liquid and the planar surface of the segment is parallel to the [p. 155] horizontal axis of rotation of the stage (Fig. 59); and 2) the line AD is perpendicular to axis I.

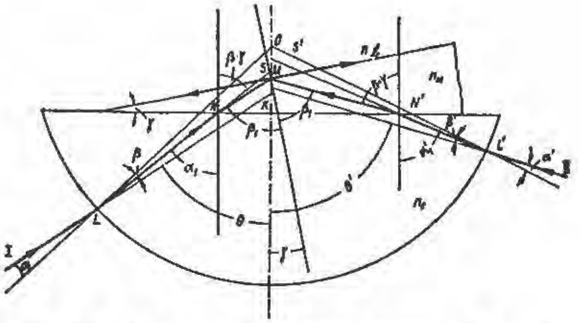


Fig. 60 [p. 155]. Course of limiting ray through segment of Fëdorov Stage and wedge-like slice.

Depending on the course of the ray relative to the slope of the measured layer, the system of equations (4)-(10) will have the following form (Fig. 60):

$$\begin{aligned}
&\sin\beta = \frac{n_l}{n_M}; && \sin\beta_1 = \frac{n_l}{n_M};\\
&\frac{\sin(\beta_1-\gamma)}{\sin\alpha_1} = \frac{n_c}{n_M}; && \frac{\sin(\beta_1+\gamma)}{\sin\alpha'_1} = \frac{n_c}{n_M};\\
&SK = \frac{\tan(\beta_1-\gamma)}{\operatorname{tg}\alpha_1}MK; && SK' = \frac{\tan(\beta_1+\gamma)}{\operatorname{tg}\alpha'_1}MK;\\
&OS = OK - SK; && OS' = OK - SK';\\
&\sin\beta = \frac{\sin\alpha_1}{R}OS; && \sin\beta' = \frac{\sin\alpha'_1}{R}OS;\\
&\sin\alpha = n_c\sin\beta; && \sin\alpha' = n_c\sin\beta';\\
&\theta = \alpha_1 + \alpha - \beta. && \theta = \alpha'_1 + \alpha' - \beta'.
\end{aligned}$$

Directions I and II (Fig. 60) virtually correspond to the course of the limiting ray with the slopes of the stage both diametrically opposite (towards and away). In this case, the axes Θ and Θ' obtained on the vernier of axis I are not equal owing to the non-parallelism of the planes of the measured layer of liquid and the planar surface of the segment (the angle between them is denoted by γ). A study of the derived systems of equations for the given case demonstrates that: [p. 156] a) the use of the mean values of Θ and Θ', obtained from the slope of the stage on both sides from a zero position, to a significant degree, but not completely, excludes errors of measurement; b) the results of measurement are always underestimated as compared with the true values; and c) as γ, the R.I. of the liquid, and the thickness of the mineral MK increase, so does the magnitude of the errors.

The second case of measuring the R.I. of a layer of material, lying at an angle γ to the plane of the segment, when line AD is perpendicular to I, is marked by a complex mathematical relationship between the elements of the stage and the preparation, set on it. Therefore, we shall confine ourselves to general explanations.

Owing to the fact that the maximum angle of slope of the plane of the measured layer does not correspond to that measured on the vernier of axis I and is greater than it, the results of measuring the R.I. are always underestimated. However, in the position when AD is perpendicular to I, the discrepancy noted reaches maximum values, and if angle γ does not exceed 10°, it virtually gives no marked errors in the measurements. Figure 59 explains this diagrammatically. Here MN is the boundary line, corresponding to a certain limiting angle of slope Θ. The limiting rays and the refracted rays corresponding to them for each point on the boundary line, lie in planes, perpendicular to line MN. Figure 59 shows such a distribution for one of the planes OBC. It is clear that the greater the angle of slope of the slice, the smaller the angle at which the plane OBC deviates from the line AD and the smaller the angle BOC, and hence, the smaller the errors of measurement. Since during measurement, the slope on the stage will not be less than 56°, the angle BOC does not exceed 1° (with the condition that $\gamma < 10°$). The error in R.I., corresponding to an angle of 1°, is less than 0.0002. The maximum errors correspond to the position AD||I. Consequently, for satisfactorily precise R.I. measurements the inclined layer of liquid must be oriented with the slope along axis I.

The variation of measurements of the obliquely arranged layer of liquid under consideration has been analyzed in detail and completely by Bakumenko [6]. Using a computer, he has calculated working tables based on our formulae, for a number of other values of optical constants of various minerals and elements of the Fëdorov stage.

In the calculation formulae for the proposed method, the value of MK, or the thickness of the slice (d), is entered, in place of fixing the boundary line of complete internal reflection. Normally, in measuring the thickness of mineral grains in microscopic preparations, the so-called powder method is employed, which only gives approximate results. If we denote the actual thickness of the slice by d, the difference in readings from the vernier scale on the microscope during heating on the sharpness of the powder reflections in the lower and upper surfaces of the measured grain, by d, and the R.I. of the mineral by $n_m$, then the formula for calculating the thickness of the slice will have the form, $d = d_1 n_m$ [8]. It is derived by replacing the tangents in the equation $d = d_1 \frac{\tan i}{\tan r}$ by sines, that is, [p. 157] the multiplier $\frac{\cos r}{\cos i}$ is actually eliminated:

$$d = d_1 \frac{\sin i \cos r}{\sin r \cos i} = d_1 n \frac{\cos r}{\cos i}.$$

The ratio $\frac{\cos r}{\cos i} > 1$, and the more it differs from it, the higher the R.I. of the mineral. This is clearly illustrated by the result of such a transformation:

$$\frac{\cos r}{\cos i} = \frac{\sqrt{1 - \sin^2 r}}{\sqrt{1 - \sin^2 i}};$$

after dividing the numerator and denominator of the fraction by sin r and replacing 1 - sin r by m

$$\frac{\cos r}{\cos i} = \sqrt{\frac{m^2 - 1}{m^2 - n^2}}, \quad \text{hence} \quad m^2 - 1 > m^2 - n^2.$$

On the basis of numerous measurements of the thickness of slices by the powder method and comparison of the result obtained with data on the direct micrometric determination of d, the following has been established: 1) for an object of one aperture (usually an 0.40 objective is used) and a medium with a definite R.I., the ratio $\frac{\cos r}{\cos i}$ is a constant value or close to it; and 2) the average value of the cosine ratio for quartz (1.03) and topaz (1.04) enables us to introduce precision into the calculation formulae for the thickness of slices of quartz and topaz:

$$d_{qtz} = 1.03\, d_1 n_{qtz} \pm 0.01; \quad d_{tpz} = 1.04\, d_1 n_{tpz} \pm 0.01.$$

The precision of measurement indicated (±0.01) results from that of measuring (±0.003) the thickness by the two methods noted above, and also the accuracy of the value of n (for quartz, $n = 1.548 \pm 0.005$, and for topaz, $n = 1.612 \pm 0.002$).

The accuracy of measuring the R.I. of regularly planar objects by the refractometer method depends on the values of the errors resulting from inaccuracy in measuring the thickness of the slices, the indeterminacy of the R.I. of a birefringent mineral in a given section, and the inaccuracy in reading the angles of slope of the stage. Using the working tables for quartz and topaz [82], it is possible, on the basis of partial errors, to derive the overall total error of the method. As is seen from Table 14, this error depends directly on the value of the R.I. of the layer of liquid being examined and the thickness of the mineral, separating this layer from the surface of the segment.

Each working table [82] may be divided into two parts based on accuracy of measurements. If the original data [p. 158] of the measurements correspond to the left-hand upper parts of the tables, then the total error does not exceed ±0.003. For the right-hand lower parts, the error is greater than ±0.003.

**Table 14 [p. 158].** Maximum Errors in Measured Refractive Indices

| $n_1$ | Errors, corresponding to d = 0-2.5 mm | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | | 1.00 | | 2.00 | | 2.50 | |
| | Quartz | Topaz | Quartz | Topaz | Quartz | Topaz | Quartz | Topaz |
| 1.33 | 0.0020 | 0.0019 | 0.0024 | 0.0024 | 0.0032 | 0.0028 | -- | 0.0032 |
| 1.37 | 0.0019 | 0.0018 | 0.0025 | 0.0024 | 0.0039 | 0.0027 | -- | 0.0033 |
| 1.41 | 0.0018 | -- | 0.0030 | -- | 0.0053 | | | |
| 1.46 | 0.0017 | 0.0016 | 0.0038 | 0.0026 | 0.0056 | 0.0030 | -- | 0.0036 |
| 1.50 | -- | 0.0014 | -- | 0.0026 | -- | 0.0036 | -- | 0.0041 |

The accuracy in measuring R.I.s of substances that occur in real inclusions is somewhat lower. Investigators of gas bubbles or liquid $CO_2$ in inclusions, have given a partial concept of the accuracy of the method [82].

Measurement of R.I.s of substances in inclusions involves such operations as: 1) inspection and setting the Fëdorov stage on the microscope stage; 2) selection of inclusions and setting up preparations; 3) measurement of slope of stage, corresponding to complete internal reflection; and 4) determination of R.I.

The principal starting positions for setting the stage are as follows:

1. Axis I of the stage must be parallel to plane of the surface of the lower segment, must lie in the plane of the layer of liquid under examination, and must be perpendicular to the bundle of parallel rays.

2. The rays, reflected from the plane mirror, must be directed parallel to the optic axis of the microscope.

These points are completely satisfied by the following simple procedures:

1. Axis I of the stage is made congruent with the planar surface of the segment. For this, the stage is set and centered by the normal method on the microscope, the upper segment is removed, and the deviation of the powders [i.e., dust specks?] on the planar surface of the segment from the horizontal cross-hair of the ocular during rotation of the stage about axis 1 on both sides of the vernier zero is observed. By raising the inner circle of the stage we can set the segment so that

the deviation of the powders is minimal. The portion of the inner circle can be recorded, for example, by the number of turns of the ring on the screw thread from its extreme lower position.

2. After screwing on the upper segment, all three horizontal axes of the stage (I, H, and K) are set to zero and clamped.

3. The microscope tube is raised until the image of the light point (lamp filament) is not seen in the ocular and by turning the mirror this image is brought to the center of the ocular cross-hairs (such an operation is best performed immediately before measurement itself after setting up the preparation being examined).

[p. 159] The accuracy achieved by such procedures is completely adequate for such measurements. For instance, it has been shown experimentally that the deviation of the plane of the measured layer from the conjugate position with axis I per millimeter does not produce marked errors in measuring angle Θ. At the same time, a precision of conjugation, equal to 0.1-0.2 mm, is easily achieved. Other errors (resulting from inaccurate matching of axis I with the segment surface and its imprecise perpendicularity to the bundle of rays) have one common character, and result from the fact that the maximum angle of slope of the stage does not correspond to that measured on the vernier of axis I. It is in all cases greater than angle Θ. Therefore Θ and the R.I.s corresponding to it in the tables are underestimated. Experiments have shown that with zero settings of the stage, $\Theta = 62.5°$, and with a slope around axis H of 10°, $\Theta = 61.9°$, that is, the average error per degree of the slope around axis H is 0.06. The precision of reading by indices of small arcs of axis H is ±0.5. Consequently, the possible error in reading angle Θ is 0.03°, which is less than the errors in reading angles along axis I (0.10°). Such a small error is controlled by the special setting of the stage and by measuring Θ as an average of two read-outs on the vernier with slopes of the stage in a particular direction from the horizontal position.

For measurements the investigator must select planar inclusions of not very small size, parallel to one of the planes of the slice (the deviation must not exceed 10°). Therefore, the inclusions are initially scanned and studied under the microscope with average magnification (x 340). Only planar or negative forms of inclusions are selected, having a size, sufficient for observations at low magnifications (x 50-100). The planar inclusions must have no defects on the bounding planes. The resolving capacity of the microscope, with a normally significant difference between the R.I.s of the mineral and the solution, is completely adequate for detecting such defects. Planar and flattened inclusions are distinguished from three-dimensional forms by light effects and the degree of visibility of the contours of the vacuoles and the individual phases in them.

During observation of the phenomenon of complete internal reflection in planar inclusions, the boundary line instantaneously passes through the entire layer being examined, that is, with absolute minimal rotation around axis I, the line moves rapidly from one edge of the inclusion to the other. The inclusion immediately becomes dark. As a result, when inclusions are of insufficient size, the boundary line is sometimes not observed, although darkening is quite clearly defined at the first instant.

In discoid inclusions, the boundary line is shifted slowly, and the inclusion darkens only with a distinct rotation of the stage. Such 'extinction' of the inclusion is sometimes controlled by a significant difference in the angles of inclination of the light ray in different sectors of the discoid surface of the inclusions. Approximate R.I. values may be determined even with such inclusions, if the boundary line can be identified along their central portion, where the tangential plane is approximately parallel [p. 160] to the planar surface of the segment. It is recommended that such a method of fixing the boundary line be applied also to planar inclusions.

After the inclusion has been selected, the preparation is repeatedly, so far as necessary, polished in such a way that the inclusion is arranged parallel or almost parallel to the plane of the slice. Polishing is controlled with the aid of a microscope. Polishing is not normally necessary for inclusions located in the plane of such minerals as topaz.

The order of measuring R.I.s of liquids present in planar inclusions is as follows:

1. The thickness of the layer of mineral, separating the inclusion from the plane of the slice parallel to it, is measured. The precise formulae of the powder method are used for this.
2. The stage is set on the microscope in accordance with the principal positions.
3. If the plane of the segment coincides with axis I, then in order that axis I may lie in the plane of the liquid being examined, the inner circle of the stage is depressed by the measured thickness of the mineral layer. This is easily done, using the micrometer screw of the microscope stage or knowing the thread dimension of the inner circle of the stage.
4. The preparation is set on the lower segment so that the layer of mineral, the thickness of which has been measured, is in contact with the segment surface. For correct lighting of the field of view of the microscope, one of the upper segments is screwed on with n = 1.647 or 1.548, depending on the thickness of the mineral. At the same time, a liquid with R.I. close to $n_m$ is introduced between the slice and the segments. The correct setting of the stage is checked.
5. The microscope is focussed on the inclusion, which has been placed in the center of the field of view. A selected point in the middle of the inclusion is matched with the boundary line or the moment of darkening of the layer being measured, by the slope of the stage around axis I, at first on one side, and then on the other of the vernier zero. The mean of the two readings is taken as corresponding to angle $\Theta$. Having rotated the circle n around its vertical axis, say by 90-120°, two readings are again taken of the angle of slope and the mean value is recorded. Then this operation is repeated once or twice. From the mean values of $\Theta$ obtained, the maximum is chosen, which corresponds to the position of AD normal to I. The angle $\Theta$ determined from the table or graph and the thickness of the mineral layer MK, give the R.I. of the liquid.

During measurements of $\Theta$, the outer circle of the stage m must be set so that the pivots and screws, clamping the small measuring arcs, do not interfere with the greatest inclination of the stage. It is best to use an objective with magnification 3.7 or 3.0, which will make it possible to incline the stage on both sides by 69-70°. For best illumination, the lower polar of the microscope should be removed.

We shall consider an example of measuring the R.I. of a solution in an inclusion in rock crystal from a vein of alpine type. A slice of quartz has been polished so that a planar inclusion, measuring 0.45 x 0.30 mm, is parallel to the plane [p. 161] of the slice. Then the distance of the inclusion from one of the planes of the slice is measured. The slice is set on the stage so that the plane to which the distance MK has been measured, is brought into contact with the lower segment and the inclusion is located on the axis of rotation of I (the segment is depressed by the value of MK from the initial conjoint position of its plane with the axis of rotation). After this, from the slope of the stage on one side, the boundary line in the middle of the inclusion is derived and the reading taken (61.5°). In the same way, the boundary line is matched with the middle of the inclusion with the slope on the other side (angle of slope 59.3°). The mean of these readings is 60.4°. Having rotated the preparation along with the circle of the stage around the vertical axis by 120° and performed those same operations as above, we obtain the following values of $\Theta$ for the solution from this inclusion: 61.6° and 59.4°, mean 60.5°, and after rotation by a further 120°, 61.1° and 59.7°, mean 60.4°. Thus from the maximum value of the slope of the stage, 60.5°, we get the appropriate R.I. value = 1.337 from the table. From the value obtained, the concentrations of dissolved substances in the inclusion are insignificant: translating this into actual figures, the solution may, for example, contain 2.5% NaCl or KCl.

Solutions extracted from inclusions (or 'free' liquids in general) may be studied by refractometry, if they can be placed between the segments of the stage or (for increasing the upper limit of R.I. measuring) between the auxiliary highly-refractive plane-parallel slice, set on the lower segment, and the upper segment. The theory and practice of measuring differ in no essential way from those described above. However, the accuracy during measurement with an isotropic standard slice or without it exceed that established according to the tabular data. The highest index which may still be measured by our method using the auxiliary slice, the R.I. of which is close to that of topaz, is 1.5. Without the additional slice, the R.I. of substances up to 1.42 may be measured. Such limitation in determinations is dependent on the relatively low R.I. of the segment of the stage.

The proposed method is also suitable for measuring the R.I. of inclusions occurring in calcite and other highly birefringent uniaxial negative minerals. For this purpose, from the two boundary lines, observed in the field of view of the microscope and corresponding to the R.I.s of the two polarized rays, we select that which corresponds to the R.I. of the ordinary ray, constant in all sections of the mineral ($n_o$ = 1.658). This line is located in the field of view of the microscope on the side of the raised portion of the stage. A similar method may also be used to measure the R.I. of planar inclusions in optically uniaxial positive crystals with high birefringence. Biaxial crystals require special orientation for refractometer measurements of the inclusions in them. It amounts to matching the optic axis of the crystal with the axis of rotation of the stage and the plane of polarization of the microscope. Such a set-up substantially complicates the derivation of the calculation formulae.

[p. 162] Significant limitations to the method of working with microinclusions are the requirements concerning shape, size, and spatial arrangement of the vacuoles. They must be flattened and have individual, comparatively regular boundary planes. The interface of the medias must be parallel to the plane of the segment surface (deviation <10°); inclusions <0.1 x 0.1 mm$^2$ in size significantly lower the accuracy of measurement.

Allowing for the above difficulties, the R.I. measurement of inclusions of complex shape is carried out after their opening and extraction of the solution from the cavity onto the surface of the mineral slice [92]. The sequence of operations is as follows: a) preparation of a plane-parallel slice with the inclusion and polishing of one of its planes over a close distance to the inclusion (0.05-0.15 mm); b) placing of a drop of liquid, indifferent with respect to the aqueous solution, on the plane of the slice above the inclusion (castor or silicone oil); c) opening up of the inclusion with the aid of a Pobedit [WC] needle; d) placing of the slice with the solution squeezed from the cavity of the inclusion and covering it with a neutral liquid on the plane of the stage segment; and e) measurement of the R.I. of the layer of solution flattened between the planes of the slice and the segment by the normal method. The last two operations may be carried out in a different way: the solution of the inclusion, together with the isolating liquid, is flattened by a supplementary plane-parallel slice of known thickness and definite R.I. (e.g., topaz); after this, the preparation is mounted on the stage and the R.I. of the solution is measured.

Opening up of very small inclusions (<0.05 mm) is carried out by a different method. Onto the slice with its surface polished close to the inclusion is placed a micrograin of corundum or carborundum (its size must be no larger than the inclusion). The grain of abrasive is attached immediately over the inclusion by light moistening with water vapor during exhalation of air. The cohesion between the grain and the slice, resulting from exhalation, is sufficient to keep the grain in place; the preparation is moistened with a drop of neutral liquid (oil). Following pressure on the auxiliary topaz slice and the corundum grain, the wall of the inclusion is ruptured (Fig. 61). The solution, squeezed out onto the surface, is flattened by the slice, and after mounting the preparation on the Fëdorov Stage, is measured in the normal way.

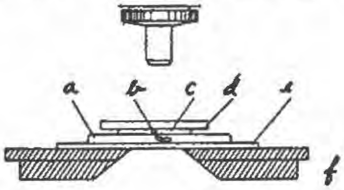


Fig. 61 [p. 162]. Sketch showing opening up of inclusions with the aid of micrograins of abrasive in a neutral liquid medium: a) preparation with inclusion; b) micrograin of abrasive; c) neutral liquid; d) translucent plane-parallel slice of great hardness (topaz or corundum); e) object glass; f) microscope stage.

[p. 163] It is completely understood that all micromanipulations for opening inclusions and mounting the preparation must be carried out during direct observation with the aid of a stereoscopic (MBS, etc.) or normal microscope.

Gigashvili [32] has opened inclusions with a Pobedit [WC] needle under a layer of silicone oil. The solution squeezed from the inclusion was transferred along with the silicone oil by micro-pipette onto the planar surface of the hemisphere of the Fëdorov Stage. Subsequently, measurement of the R.I. of the solution was carried out in the usual way.

The method of microrefractometry of inclusions has rarely been used. Measurements of the R.I. and concentration of the solution by Loskutov [132], Goncharov and Sidorov [136], and others are well known. It may be stated, however, that the refractometer method is not inferior in accuracy of the results obtainable to the widely used cryometric method. In essence, both methods give approximate values of the overall mineralization of the solutions. Allowing for the complex nature of direct ultramicrochemical determinations and the inadequate precision of the method of extraction, the results obtained are of important significance in resolving many problems concerning the chemical composition and physicochemical state of the inclusions.

If additional data on the ratio of the components in the solution, obtained by the method of aqueous extraction, are known, then there is the possibility of determining the chemical composition of the inclusions. This has, for instance, been achieved by us [103] for fluids in hydrothermal veins from the Donbass, and also by Gigashvili [32] for solutions in inclusions from 'honeycomb' quartz from Volyn'.

The R.I. constant reflects the overall physical state of a solution in a closed inclusion. Its magnitude depends mainly on the total salt concentration. Other factors, such as the presence in the inclusions of gases, soluble in water, the internal pressure, the complexity of the elemental composition of the solution, etc., also have an effect, albeit comparatively small. As a rule, NaCl predominates in the inclusions. The NaCl content in the solution is on average an order of magnitude greater than that of any other substance. Therefore, the total concentration is expressed as the amount of NaCl in the solution, equivalent to the R.I. Neglect of the multicomponent system of the inclusion may give a variable error. It does not exceed 1-2, and frequently is less than 4-5% (weight percent).

It should be noted that the accuracy in determining the concentration by the cryometric method also has the above limitations. This arises from the effect of the same physicochemical factors. It is possible that more significant changes arise from the effect of internal pressure and the concentration of dissolved gases, in particular $CO_2$. Depending on the kind of dissolved compounds, and judging from Dobretsova's [48] and Borisenko's [11] diagrams, the deviation of the true concentration from that determined on the basis of NaCl-equivalent does not exceed 4-5% (weight percent).

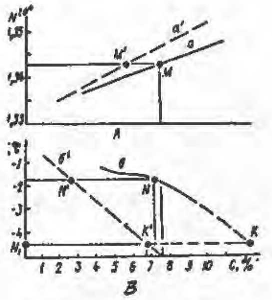
[p. 164] It is well known that the concentration of individual components in the solution from inclusions may be determined from analyses of aqueous extracts, if the total water content of the inclusions in the samples examined is known. This amount is usually found by Penfield's method, from the quantity of water released from samples on heating to 800-1000°C. The deficiencies of the thermal method of determining the volatiles (including $H_2O$) are well known. There are two methods for calculating the quantitative amount of components in the inclusions (including water) from the total concentration found by the refractometer or cryometric methods.

According to the first method, the concentration of the components (NaCl-equivalent), determined by the indirect method, is distributed proportionally to their percentage ratio in the extract. Such a method does not, in fact, take account of the gas components and the multicomponent nature of the components of the inclusions. The second, and more accurate method, has been used for the quantitative determination of the composition of the solution of uniform inclusions of the concluding third phase of mineral-formation in the hydrothermal polymetallic veins from the Donbass [103]. A standard solution has been prepared, the ratio of components in which corresponded to the analyses of the extract. With the aid of a normal refractometer, the R.I. of the standard solution was measured at different degrees of dilution, that is, at different concentrations but a constant ratio of components. From several such measurements, a standard graph was constructed, with the aid of which the concentration was determined and then the quantitative composition of the aqueous fluid of the inclusions was calculated. If the R.I. of the solution is measured outside a closed vacuole, but after its extraction into an inert liquid, then a greater precision is achieved.

The reliability of the various methods of determining the concentration may be graphically demonstrated from a study of 'honeycomb' inclusions in quartz from the Volyn' pegmatites [32]. The selected samples of 'honeycomb' quartz from 19 different pegmatite bodies have similar T values for the melting of the last crystallite from the solution in the inclusions, and similar values of overall concentration. Inclusions of 'sot' [honeycombs?] from one of the pegmatites have been studied in greater detail. The inclusions were opened in silicone oil, the inert nature of which with respect to the solution was checked by special experiments. The R.I. was measured after transferring a drop of solution, along with the silicone oil, to the hemisphere of the stage. The temperature of thawing of the last crystallite of ice (or salt), extracted from the inclusion, was also measured by a special procedure: the drop of solution, squeezed onto the surface of the preparation into the layer of silicone oil, was covered with a cover glass, the edge of which was sealed from the exterior by silica gel. The standard solution was examined on an IRF-22 refractometer and in cryometric chamber; the solutions, sealed in glass capillaries, served as the material for cryometry.

The results of investigations of the 'honeycomb' inclusions have been shown on a graph (Fig. 62), somewhat modified from [p. 165] the original [32]. Figure 62 shows that different methods of determining the concentration do not give equally significant results, although in general, the use of standards and measurements of the solutions from inclusions in the free state do enable us correctly to estimate the magnitude of their saturation with salt components. Thus, if we use the refractometer method, then from the R.I. of the solution extracted from the inclusion (1.343) and in accordance with the standard curves for solutions, corresponding to the composition of the extract (line a) and the NaCl-standard (line a'), the mass (weight) concentration respectively equals 7.3 (point M) and 5.4% (point M'). The concentrations, found by the cryometric method, are respectively 7.3 (point N) and 2.6% (point N'), if we measure the temperature of melting (-1.8°C) in the solution extracted from the inclusion. If the temperature of melting, obtained under conditions of a closed inclusion has been measured (-4.5°C), then the mass (weight) concentration will be respectively 12-14 (approximately point K) and 6.6% (point K').

The data presented indicate a lower temperature of melting for a frozen solution in a closed inclusion with respect to that extracted from the inclusion, which, as is well known, has been controlled by increased pressure and the effect of soluble gases ($CO_2$). A somewhat smaller discrepancy in the concentrations, obtained by the refractometer method (points M and M'), than that of the concentrations obtained by the cryometric method (points N-N' and K-K'), has been recorded. The discordance between the data, obtained by measuring a free solution by one or the other method, evidently does not exceed 2-5%; the use of the graph for the NaCl standard gives underestimated results, as a consequence of neglecting the multicomponent composition of the solution. Finally, the concentration of the solution from the 'honeycomb' inclusions examined has been found to be 7.3%.



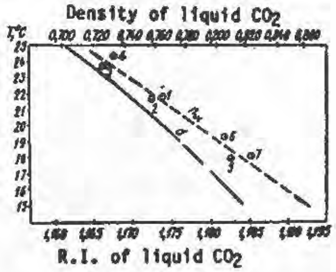


Fig. 62. Relationship between R.I. (A) and melting point (B) of standard solutions, and their concentration. Lines a' and b' respectively show the relationship between R.I. and melting point, and concentration of NaCl solution; M and M' are points, corresponding to R.I. of solution from inclusion (1.343); N and N' are points, corresponding to melting point of solution, extracted from inclusion (-1.8°C); K and K' are the same for unopened 'honeycomb' inclusions (-4.5°C).

Fig. 63. Results of measuring R.I.s of liquid $CO_2$ in inclusions in topaz at different temperatures (points along dashed line $n_1$) on a Fëdorov Stage; line d is the relationship between density of liquid $CO_2$ and T.

The R.I.s of the fluids may be determined, in addition to the overall concentration of the solutions in the inclusions without opening them, by the refractometer method. Such a method has confirmed the validity of the identification of daughter minerals of low-refractive index in inclusions in topaz (cryolite and elpasolite). We measured the R.I.s of liquid $CO_2$ in inclusions for the first time (Fig. 63) by refractometry.

[p. 166] It is well known that liquid $CO_2$ possesses a large coefficient of thermal expansion. This is reflected in its density, and consequently, in the variation in R.I. A large inclusion (1.50 x 0.75 mm) of mixed kind (aqueous solution-liquid $CO_2$-gas) has been found in a crystal of Volyn' topaz. The liquid $CO_2$ is located in the central, regularly flattened portion of the inclusion over distances of 0.402 and 0.761 mm from the plane of the slice. The measurements were carried out at different temperatures and only its final establishment[sic]. According to handbook data, the R.I. of liquid $CO_2$ at 15.5°C in sodium light is 1.192. No corresponding data have been presented in the literature for other temperatures. In order to compare the handbook data and those obtained, a graphic extrapolation of the results of measuring up to 15°C has been carried out (Fig. 63). The basis for such an extrapolation has been a comparison between the curve for the temperature variations of the R.I. of $CO_2$ and that for the dependence of the density of liquid $CO_2$ on the temperature. The curve for the $CO_2$ densities at T = 15-25°C has no breaks or bends. The curve on the R.I.-T diagram must behave likewise. Thus, having extended the curve for the R.I. of $CO_2$-T relationship to 15°C and having recognized the possible field of errors, we have graphically obtained $n = 1.191 \pm 0.003$ at 15.5°C.

These results confirmed very well what has been stated above about the accuracy of the method. Verification of the data at 18.5-24.5°C, after obtaining the corresponding R.I. values by more accurate methods, may turn out to be especially interesting.

Sorby [258] suggested the use of inclusions with a primary homogeneous filling to determine the temperature of crystallization [Tc] of minerals. He believed that, by restoring the primary homogeneous state of an inclusion by heating, it is possible to determine the minimal, close to actual conditions of trapping. Sorby's work even nowadays has not lost its scientific status, and this author has rightfully been considered the founder of the method of homogenization. However, the state of science at that time, especially in regard to the theory of physical chemistry and crystallography, did not permit a detailed analysis of the procedural possibilities.

The Th (independently of the final phase transition) represents the last possibility of visual observation during experimental reproduction of the process of evolution of an inclusion. Nevertheless, this point frequently marks the original parameters of the development of a closed vacuole in a mineral. Further reproduction (following homogenization) of the changes in the conditions of existence of an inclusion is possible only when one considers the physicochemical systems that correspond to its composition. The better the correspondence between the experimentally-studied systems and the inclusion system, the more accurately may one trace the possible changes in P, T, and X during the process of transition of the inclusion from the conditions of formation to the surface environment.

## Aggregate state

Minerals normally capture portions of the mother liquor in a homogeneous state in the form of inclusions. However, trapping very often takes place, along with the principal fluid phase, of minor solid, liquid, and gaseous substances. The simultaneous capture of several phases in the cavity of the inclusion is possible when the solution boils. Additional minor and xenogenic substances are relatively accurately detected during a bulk examination of the inclusions. An analysis of the genetic groups of inclusions is essential for determining the overall aggregate state of the mineral-forming medium and the role of its individual phases during the crystallization process. Identification of the inclusions is carried out by taking account of the above-mentioned characteristic features of primary and secondary vacuoles which have been post-genetically transformed and are of heterogeneous origin.

The phase composition and its identification on the basis of inclusions of heterogeneous origin and necked down forms*. The identical filling and equal Th values of many hundreds of inclusions, occurring in a particular sealed-off fissure, are normal phenomena for crystals of hydrothermal origin. Such a state of infilling is typical, not only to GL, but also for LG inclusions. In the Volyn' topazes, it is possible to scan scores of preparations (taken from a single pegmatite body), in which huge amounts of uniform, early-secondary inclusions homogenize exclusively into the gas phase at identical temperatures (the range is ≯ 5-10°C). But amongst the latter, on very close inspection, we may find isolated GL inclusions. Such an inclusion (a) is depicted in Figure 2; its Th = 383°C into the liquid phase, whereas all the other

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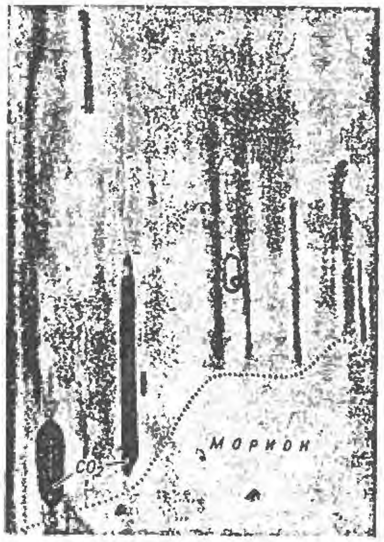
*[From context, I believe the word used, **расшнурованным** , is equivalent to Western usage of "necked down." Ed.]

neighboring inclusions homogenize at this same temperature, but into the gas phase. Signs of refilling or necking down have not been observed here.

A different distribution of the contents of inclusions is shown in Figure 3, where the primary inclusions, also present in topaz (Volyn'), are arranged in the plane (011) or (001) and are elongated along L2 axis of the crystal. The nucleation of the inclusions resulted from accumulations of xenogenic crystallites. Th of the inclusions, into the liquid phase, took place at 390-400°C. As an exception syngenetic primary inclusions without solid phases have been identified between them, homogenizing in the gas phase at similar temperatures (400-415°C). Inclusions with intermediate filling have sometimes been observed.

These samples of groups of syngenetic inclusions in topaz indicate that crystallization of that mineral and sealing of the fissures took place from a boiling solution, and in this instance, sealing of the fissures took place from a solution in which there were no solid xenogenic phases, [and was] accompanied by capture of bubbles without traces of a liquid aqueous solution. Sometimes inclusions that have captured homogeneous liquid have been found. There has been no refilling or necking down since the inclusions arranged in series have no disturbances of the filling (and the Th). Boiling of the solutions during the period of crystallization of the topaz is confirmed by the different kinds of filling of the primary inclusions (see Fig. 1). The turbid material of the crystallites and their clasts has been the reason for the nucleation of the inclusions, which homogenize in the liquid phase, like the effect of lycopodium particles on the capture of gas bubbles (see Fig. 10). When xenogenic material is lacking, capture of gas bubbles, without any trace of liquid solution, takes place.

The family of primary tubular (fibrous) inclusions in quartz (Fig. 64) consists mainly of LG inclusions with liquid $CO_2$ and aqueous solution of variable volume: (5-7%) $L_2$:(3-5%) $L_2$:(88-92%) G; there are



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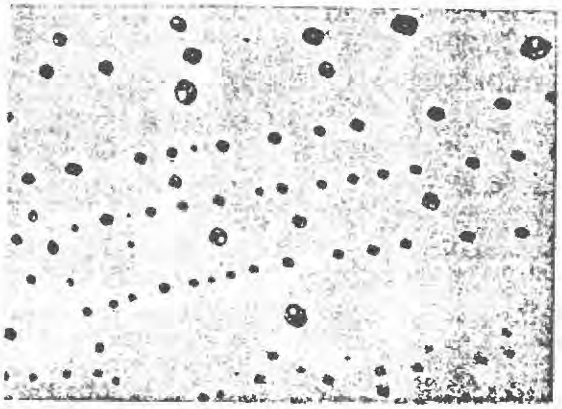


Fig. 64. Primary inclusions of heterogeneous origin, occurring at the base of a translucent quartz, in the zone of regeneration of morion crystals (Volyn'); X 170. Note: Word at the bottom right of figure = 'Morion.'

Fig. 65. A family of early-secondary inclusions of mainly homogeneous capture in morion (Volyn'); X 180.

**essentially** liquid inclusions without visible liquid $CO_2$, with persis**tent** Th (230°C); very rarely, inclusions of intermediate filling have been observed.

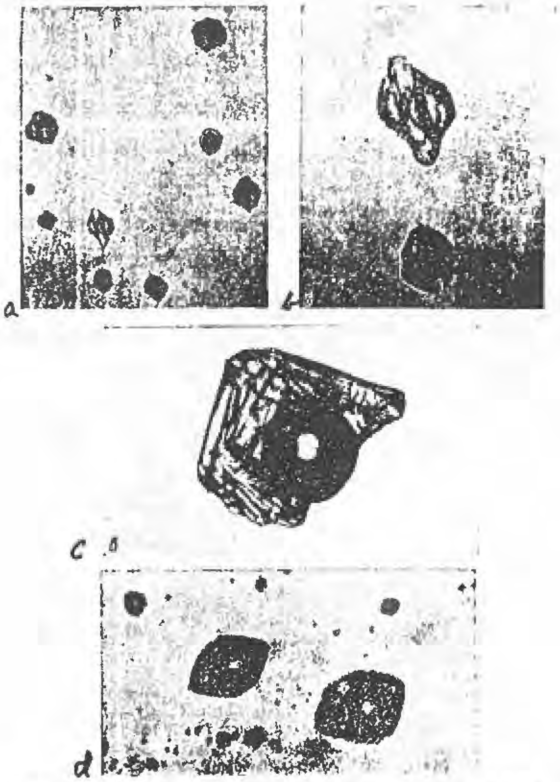
Inclusions of this type have been investigated by Voznyak [18]; they were studied earlier by Lemmlein & Kliya [127]. By analogy [p. 169] with the capture of gas bubbles by crystallizing salts under laboratory conditions, these authors believe that they originated from a boiling solution, when the phase of gaseous $CO_2$, released in the form of bubbles on the growing crystal face, was captured by the growing translucent quartz.

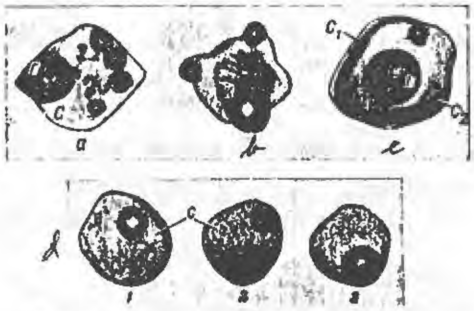
Figure 65 shows a family of variously-filled, early secondary inclusions in morion. The origin of these kinds of inclusions may here be explained by the sealing of a crack [in the presence of] a heterogeneous solution. It seems that the solution, with small gas bubbles, originally filled the crack. Growth of dendrites, during sealing of the fissure, led to capture of these bubbles, without (or almost without) any addition of solution. Single inclusions of liquid solution are the result of homogeneous capture of a highly-concentrated aqueous solution. Sealing took place under [p. 170] relatively stable conditions of temperature, composition, and pressure. Dissociation phenomena have not been observed here.

The 'honeycomb' quartz from the Volyn' pegmatites, consisting of a paramorph of the low-T modification (β-quartz) after the high-T variety (α-quartz)[sic], contained LG, early-secondary inclusions with 30-40% L. A solid phase, poorly defined under the micoscope, is almost always present, consisting of elongate flakes, irregular grains, or lumpy segregations. The inconstant nature of the composition and quantity of the solid phase indicates its xenogenic origin. Complete confirmation of this has been obtained during a study of a 'honeycomb-quartz' crystal (Fig. 66). Along the periphery of the zone of 'honeycomb' cracking, there are gas-solid (GS) inclusions, crammed with crystallites and their fragments (Fig. 66a, b). Such inclusions are located in the planes of the 'honeycomb' cracks. As one moves away from the edge of the zone, the GS inclusions gradually disappear, and only normal LG inclusions remain, sometimes containing small solid particles (Fig. 66d). Such a picture has also been observed in other pegmatite bodies [146]. An insufficiently careful study of such inclusions may lead to an incorrect conclusion about the capture of magmatic melt into the vacuole and its crystallization as the temperature falls. In fact, the origin of such inclusions is controlled by the intake of turbid material into the cracks along with the [p. 171] solution. The capillary cracks in quartz at the moment of their origin acted like a filter, separating the xenogenic material in the outer parts of the crystal and not allowing it to pass into the deeper cracks. Detailed thermometric studies of such GS inclusions have been made by Gigashvili [31], who has demonstrated the xenogenic, and not magmatic nature [of the crystallites] (Fig. 67).

Secondary inclusions of homogeneous and heterogeneous capture in quartz are shown in Figure 68. Partition [variations] of vacuoles as a result of necking down is shown in Figure 69. It is typical that there is not a single two-phase inclusion amongst them, that repeats the filling of another.

These examples of inclusion-formation under natural conditions, confirm the earlier conclusions (see Page 36 [of Russian text]). The question of a regular analysis of the informative nature of the morphologically very similar inclusions from families that have arisen during





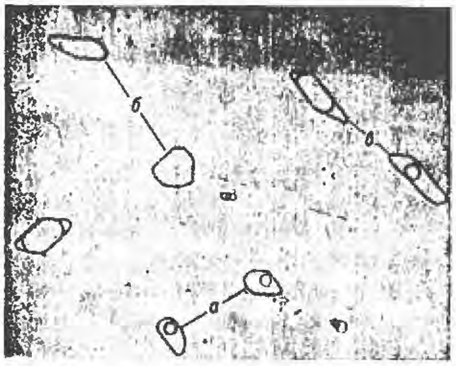


Fig. 66 [p. 172]. Gas-solid (GS) 'honeycomb' inclusions in morion crystals from the Volyn' pegmatites. a) group of inclusions of different composition, X 86; b, c) details from preceding photograph, at X 270 and X 400 respectively; d) normal 'honeycomb' inclusions, X 400.

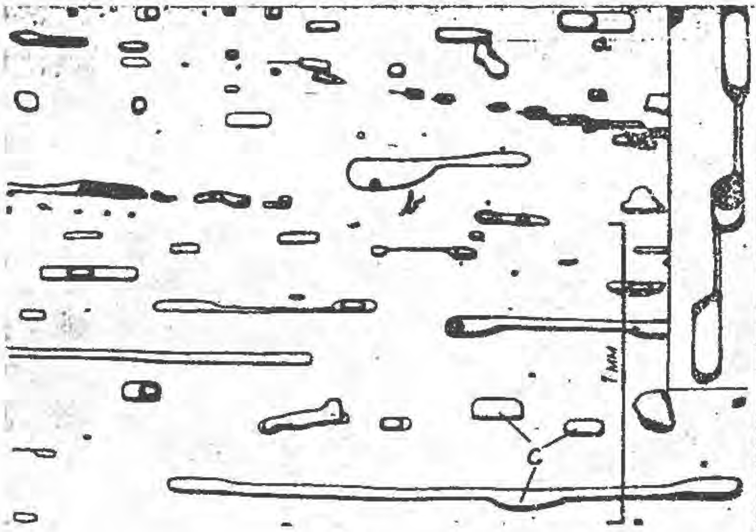
Fig. 67 [p. 173]. Primary GS syngenetic inclusions in morion (Volyn') after heating in a micro-heating chamber, containing different relative quantities of glass, gas, and solid phases: a) several gas bubbles [г] in glass (C), X 230; b) acicular crystallites (K) and gas bubbles in glass, X 400; c) inclusion with two glasses of different composition and R.I. and gas bubble [г], X 140; d) inclusion 2 has been homogenized to a melt at 920°C, and 1 and 3 have remained heterogeneous at 900°C, X 500.

Fig. 68 [p. 173]. Secondary, variously-filled inclusions in quartz from hydrothermal veins from Transcarpathia, X 500. a) homogeneous capture of liquid phase; б) homogeneous capture of gas phase; в) heterogeneous capture.

boiling of a solution, and as a result of necking down of the cavities, is of practical importance.

The families of uniform inclusions of homogeneous capture, not affected by subsequent changes in the phase relations of a defined growth zone of a crystal or a particular sealed crack, have as a rule a uniform filling and an even Th within the limits of error of the thermometric method. This has been confirmed by numerous observations and indicates that after the crack was sealed, there has not been any significant change in temperature, pressure, and composition of the solution, that is, the time of sealing was so relatively brief that the changes in thermodynamic parameters during that interval were almost infinitesimal and are virtually not reflected in measurements by the usual methods. Thus, the inclusions in a sealed crack or in a single growth zone of a crystal, were formed under identical conditions, which suggests that they were mutually syngenetic.

Up to now, we have been dealing with syngenetic inclusions in sealed



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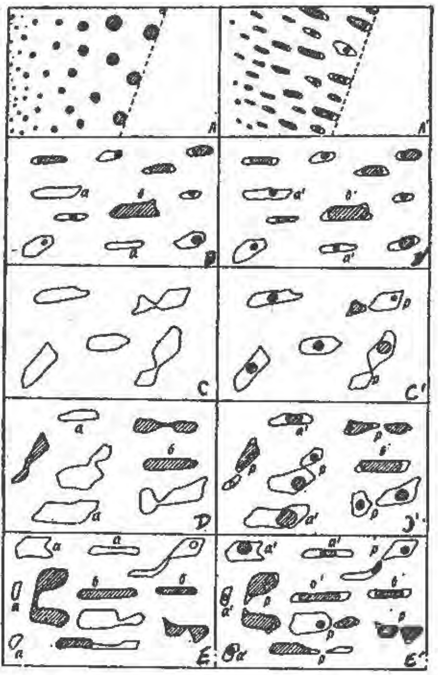

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Fig. 69 [p. 174]. Variously-filled inclusions, which have developed by sealing of cracks in NaCl and have been converted by necking down of cavities: a-c) inclusions of different filling; below right) redistribution of phases in a not completely separated vacuole [241].

Fig. 70 [p. 175]. Sketch of formation of inclusions during sealing of crack in a crystal from a heterogeneous (A, B, D, E) and homogeneous (C) medium: A) initial state of crack prior to its sealing; B-E) after sealing of crack but prior to temperature drop; A'-E') final state of inclusions after temperature drop and necking down (C'-A'); a, b and a'-b') inclusions of homogeneous capture of liquid or gas phase; p) necked inclusions.

cracks. , Sealing of the cracks and the formation of inclusions may take place from homogeneous or heterogeneous (boiling) solutions. In this case, the formation of each inclusion prior to the moment of its isolation takes place under conditions of a crack which communicates with the external environment, that is, the crack is open. Necking down of the inclusion takes place after its isolation, that is, in the closed state. Consequently, during the formation of inclusions, boiling always occurs earlier than the superimposed process of necking down, but whereas the process of sealing the crack is relatively brief, necking down may take a long time (on the geological scale). Different variants of the effects of boiling and necking down during the process of sealing are possible.

1. Sealing of the crack and the formation of inclusions may occur without necking down (Fig. 70, A-A', B-B). Consequently, a solution that is not boiling, but filling a crack, will produce inclusions of persistent fillings and Th. A heterogeneous solution, sucked into a crack during its development, is a fine capillary layer of the solution with individual [p. 175] gas bubbles (Fig. 70A). Overgrowth of the crack will take place as a result of development of dendrites from the wedged-out portion towards its opening. The capture of the gas bubbles and the liquid solution in this case, may be achieved by capture of the gas alone and the aqueous solution alone into the vacuoles, and/or filling of the inclusions with both phases of different volume. In the first case (Fig. 70, A-A')

[176], inclusions will be observed (in this case, they may be single inclusions), homogenizing in liquid (a') and gaseous (b') phases with identical temperatures [Ed.'s note - presumably refers to Fig. 70B]. The inclusions formed in the sealed crack in the second case (Fig. 70, B-B'), will have a varied filling, excepting only rare cases of the formation of inclusions of homogeneous capture and equal Th. These inclusions will also include others, formed with an insignificant addition of the other phase. Thus, inclusions with a maximum repetition of identical and lowest Th are suitable for thermometry.

2. After sealing of the cracks by the means indicated, necking down of the inclusions of irregular branching shape (Fig. 70, C-E) takes place; these differ markedly from the [surface-] energy-stable demarcated cavities, that is, negative crystals. If the sealing has been achieved from a homogeneous solution, then necking down of the inclusions may take place before separation of the gas phase (communities of inclusions appear without irregularities of filling), and after formation of the gas bubble (families of variously-filled inclusions develop) (Fig. 70, C-C').

It is necessary to indicate the characteristic peculiarity of necked inclusions, which may often distinguish them from those that develop from a boiling solution. Such inclusions do not, as a rule, often have repeated identical Th (see Fig. 69), which has been controlled by their irregular, asynchronous release over a vast interval of time. Hence, very often, the pinched vacuoles are single-phase liquids in series with higher-temperature two-phase forms. In the case when there are proofs of the homogeneous squeezing-out of such daughter inclusions from the principal (parent) forms, their Th will correspond to the true temperatures of their release. In contrast to the necked forms, the groups of inclusions of heterogeneous origin (of homogeneous or heterogeneous capture) will have more or less frequently repeated, identical Th.

The variously-filled inclusions, which have developed as a consequence of necking of vacuoles originally formed from a homogeneous solution, will homogenize into liquid and gas phases. For thermometric studies, we must select inclusions that have not been affected by necking: they will have the most often repeated identical (intermediate in value) Th in the liquid phase (Fig. 70, C-C').

We shall not consider the cases of sealing of cracks from gaseous (pneumatolytic) solutions. In essence, identical conclusions have been reached here. For instance, for thermometric purposes, inclusions must be selected with multi-repeated Th, but homogenizing in the gas phase. It is well-known that heterogenization of a gas solution during sealing of cracks is a very rare phenomenon and is controlled by capillary condensation.

[p. 177] 3. Necking of inclusions, developed after sealing of the cracks from a boiling solution, will vary, according to the state in which isolation of the solution in the vacuoles took place (homogeneous (Fig. 70, D-D'[sic]) or heterogeneous (Fig. 70, E-E')). Homogeneous capture of the gas or liquid phase individually, is usually accompanied by the formation of regularly-shaped cavities of inclusions (equant vacuoles or negative crystals), which may very rarely be subjected to necking down. Should such necking take place, then variously-filled inclusions will be found in the sealed crack, homogenizing into the liquid and gas phases. In this case, the inclusions not subjected to necking (there will be many in this case), will have repeated identical Th both in the liquid and in the gas phase. Necked inclusions will not possess such repetition; moreover, they will be recognized by their irregular shape, the presence of remnants of connecting canals, a chain-like arrangement, etc. For thermometric analysis, we must select in the main, those inclusions that homogenize into the liquid phase with identical temperatures. To confirm the validity of the selection, we may also use inclusions that homogenize into the gas phase at the given temperature. The temperatures of the released inclusions [i.e., by necking down?] will have intermediate values.

4. Heterogeneous irregular capture of a solution by secondary inclusions, with their subsequent necking down, somewhat complicates the above-described process (Fig. 70, E-E'), although the recommendations for selecting the inclusions remain as before. The complication mainly depends on the much lower frequency of inclusions of homogeneous capture.

Thus, in spite of the effect of variations in the combination of the phenomena of boiling of the solution and necking of the vacuoles during the process of isolation of the fluid, we must select for thermometric determinations amongst syngenetic inclusions (primary or secondary), those that have the greatest repetition of equal Th mainly into the liquid phase, that is, those of homogeneous capture and not disrupted by processes of necking.

Groups of syngenetic inclusions of heterogeneous origin and necked, may be mutually distinguished on the basis of features in Table 15. The establishment of the reason for varied filling of syngenetic inclusions is essential in order to determine the aggregate state of the mother liquor.

Sealing of cracks and necking of inclusions takes place most intensely at the beginning of the process, when the solubility of the mineral under investigation is high in association with increased temperature and pressure. This results in the determined Th being close to the actual Te [temperature of crystallization].

Peculiarities of boiling in natural vug crystallization. The widespread occurrence of boiling phenomena in mineral-forming media has been confirmed by many facts concerning the varied filling of mutually-syngenetic inclusions, which have not undergone post-genetic changes. Boiling is a process of continuous passage into vapor of the liquid within [p. 178] its volume, being marked by the formation and growth of bubbles of saturated vapor. It may possibly be only a consequence of disruption of the two-phase liquid-vapor equilibrium. In natural vug crystallization, the cause of boiling of the aqueous solution may be

**Table 15 [p. 178].** Distinguishing Features of Inclusions of Heterogeneous Origin and Necking Down

| Features | Inclusions | |
|---|---|---|
| | heterogeneous origin | necked |
| Th | Repetition of equal temperatures. | Temperatures are, as a rule, not repeated; great range in their values. |
| Shape of vacuoles | Negative crystals (especially with essentially gas filling) or elongated tubular inclusions. | Irregular and branched; usually relicts of connecting canals. |
| Ratio of phases | Filling of individual inclusions has no connection with their arrangement in rows. | Filling of individual inclusions has connection with neighbors; overall ratio of phases of groups of necked inclusions is equal to that of non-necked groups; single-phase liquid inclusions freqent. |

pressure-drop resulting from rupture of the walls of the vug. Such boiling may continue for a long time only under conditions of constant removal of the vapor phase, that is, the natural system must be open. However, the attempt to study the inclusions shows that infinitely lengthy boiling may also occur in a closed system [88].

We first discovered and described (date in laboratory journal April 4, 1950) boiling of the solution within inclusions at temperatures close to critical. The complete text of the description given, without alteration, in the journal, has been set out in publications [63, pp. 341-352; 70, pp. 95-97], where the date of the record and the names of the analysts have been incorrectly stated (R.F. Sukhorsky did not take part in the experiment).

Boiling of the solution in inclusions during heating in microthermochambers has never been observed at a temperature much below the critical value for water. Brief (fractions of a second) boiling has occurred at the moment of heterogenization of the inclusion during rapid cooling of the preparation. Boiling has only been observed at temperatures 10-15° below critical. A connection has been noted between boiling temperature and the critical phenomena (Table 16), and also some extension of the range of boiling in inclusions, homogenizing directly into the critical state. In very small inclusions, homogenizing into the critical state, boiling has not always been observed.

Table 16 [p. 178]. Temperature at Commencement and Ending of Boiling of Solutions in Some Inclusions

| Enclosing mineral | T°C<br>Beginning of boiling | <br>Point of homogenization and end of boiling | Type of homogenization | Notes |
|---|---|---|---|---|
| Topaz | 370 | 384.5 | Into gas phase | Manifestation of critical state have been noted close to point of homogenization |
| | 345 | 357 | Into liquid phase | |
| Quartz | 377 | 379 | | |
| | 360 | 367 | | |
| | 375 | 378 | | |
| | 366 | 372 | | |
| | 366 | 371 | | |
| | 357 | 372 | | |
| | 380 | 382 | | |
| | 380 | 387 | Into gas phase | Homogenization from critical point |
| Topaz | 405 | 407 | | |
| | 345 | 359 | Into gas phase | Homogenization from critical point; at 20°C, the inclusion contains a significant quantity of liquid $CO_2$ |

During effervescence, the gas bubbles in the inclusions appear approximately at a single site on the surface of the cavity; they move in one definite direction -- towards the principal origin gas bubble; the gas bubbles en route from the site of origin diminish in volume or disappear completely; the overall volume of the gas phase at constant temperature is constant; boiling may continue in any manner as long as the temperature remains constant.

The following experiments have been undertaken to establish the cause of boiling of the solution in inclusions. Assuming that the dynamics of the boiling process depend on the uniformity of heating of the cavity, the preparations with inclusions have been established so that we may certainly obtain the higher temperature of inclusions at definite sites, than in others[sic]. Topaz laminae with 'boiling' inclusions of various shapes have been identified in a vertical position in Ermakov's thermochamber [63]. Their lower portion has been squeezed between two copper plates, which pass into the internal heated part of the thermochamber. The inclusions examined, lying in the upper part of the preparation, are located above the copper plates, and the heat resulting from this is passed through the mineral slice from its more heated lower portion to the upper portion. Hence, uneven heating of the inclusions has been created. Observations have been conducted with a horizontal microscope. The topaz plate has been firmly clamped to the thermochamber, which has enabled us to rotate it along with the heating equipment. Observations were made in three positions: a) the hotter portion of the plate was set below, and the cooler part, above; [p. 180] b) the position of the heating equipment was as previously; the preparation was rotated 180°, so that the parts of the inclusions, hotter and cooler, changed places; and c) the thermochamber, along with the preparation was rotated 180°, so that the hotter portion of the plate lay above, and the cooler, below.

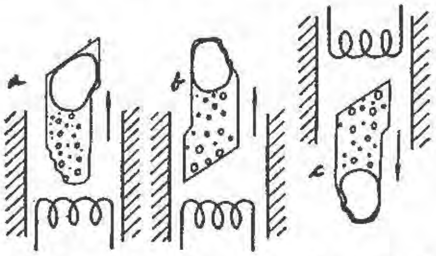
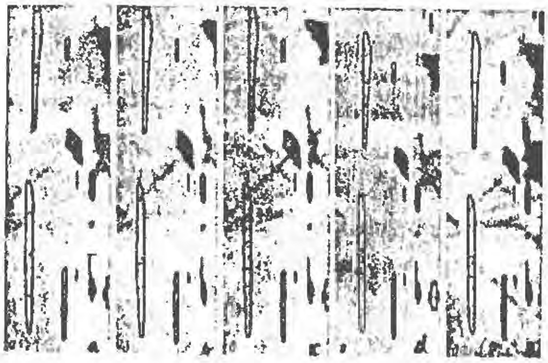


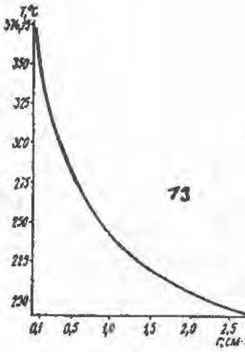
Fig. 71 [p. 180]. Boiling of inclusion solution in topaz (Volyn') at constant temperature in a thermal-gradient heat field (sketch): a-c) arrangement of inclusion with respect to heat source and direction of movement of effervescence bubbles (arrow) towards principal gas bubble; heat source indicated by electrical heat coil.

In all three series of observations on 'boiling' inclusions, it has been noted that the gas bubbles arise at the more heated sites, and move towards the lower-temperature side, even downwards, that is, in opposition to the buoyancy force (in the third position of the preparation being examined). Inclusions, which have 'boiled' in Ermakov thermochambers, do not so boil when set in improved (up-dated) thermochambers with uniform heating.

Experiments with 'boiling' inclusions were repeated by us in 1980 (experiments in which I.M. Naumko took part). The previous observations and conclusions were confirmed (Fig. 71) on the basis of numerous thermometric analyses of inclusions of different shape and varied origin. In addition, the interesting fact of the displacement and spatial stabilization of the gas bubble in the heat field during the process of heating at temperatures some tens of degrees lower than that of boiling of the solution, is interesting. In all cases (Fig. 71), the initial gas bubble has been displaced into the cooler portion of the inclusion, gradually occupying its most extreme part and remaining there until homogenization of the vacuole. If the heat source is from above, then the bubble gradually sinks downwards into the relatively cool part of the vacuole. This phenomenon has been identified on photomicrographs (Fig. 72), where the initiation of effervescent bubbles, their retardation [p. 181] at an obstacle, and their amalgamation and surmounting of the 'barrier' along the route towards the main part of the gas phase, are shown.

Attaction of the gas bubbles towards or repulsion from the more heated portion of the vacuoles in inclusions (and also their sinking) were observed by Hartley (1876-1877). His studies [221], as compared





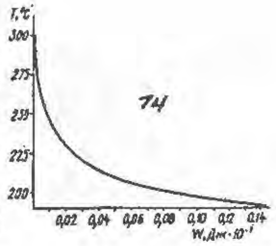


Fig. 72 [p. 181]. Early-secondary inclusions in topaz (Volyn'), X 80. Displacement of phases and boiling of solution in a thermal-gradient heat field (heat source overhead), °C: a) 20, b) 250-280, c-e) 380-400, 400-410 -- homogenization into gas phase with critical phenomena (T values approximate).

Fig. 73 [p. 182]. Changes in radius of incipient gas bubble, $R_{min}$[sic; should be $r_{min}$], with rise in temperature to the critical value for water (374.15°C) (with constant thermal stress).

Fig. 74 [p. 182]. Changes in work of formation of incipient gas bubble, W, in the temperature field, approximating the critical value for water (at constant thermal stress). [Note: at lower right of figure, replace 'ДЖ' by 'J'.]

with ours, were conducted at much lower temperatures and in a less contrasting thermal field. In regard to the sinking of the gas bubble as a result of inversion of phase densities [252], Malyshev [138] attempted to calculate the pressure existing within the inclusion. However, he took no account of the effect of the thermal gradient and arbitrarily used the temperatures of decrepitation and homogenization of the inclusions. As a consequence, he obtained unlikely parameters for equalization of the density phases (178°C and 35 MPa or 130°C and 60 MPa).

Such an explanation may be given for the phenomena of boiling of the solution in closed systems of the fluid-inclusion type. The state of the inclusions at constant temperature is marked by points on the boiling curve on the PT diagram and is dynamically in equilibrium. However, in a thermal gradient, different points in the material of the inclusion absorb variable quantities of energy (heat), and have a different temperature, in which respect, the equilibrium is disturbed. This leads to an increase in fluctuations and the development of heterogeneities in the liquid medium, relatively to P, T, $\gamma$, and other parameters. In order that gas bubbles may arise in the liquid, the heterogeneities must be quite large. An analysis and theoretical calculations have shown [15] that the incipient gas bubble in a liquid under these conditions [p. 182], cannot be smaller than a defined size, because when it has a small radius, its surface tension is spatially closed (capillary pressure $P\sigma = \frac{2\sigma}{r}$):

$$r_{min} = \frac{2\sigma}{(dP/dT)\ \Delta T} \cdot \frac{\gamma_l}{\gamma_L - \gamma_V} \qquad (11)$$

where $\sigma$ is the surface tension; dP/dT is the derivative, taken from the saturation curve and determined by the Clapeyron-Clausius equation $dP/dT = L\gamma_L\gamma_V/T(\gamma_L - \gamma_V)$; $\Delta T = T_W = T_S$ ($T_W$ = wall temperature; $T_S$ = boiling temperature under prescribed conditions of the two-phase equilibrium curve); $\gamma_L$ and $\gamma_V$ are the density of liquid and vapor; and L is the heat of vapor-formation. From formula (11) it follows that the most favorable conditions for the development of gas bubbles occur in the liquid layers abutting the vacuole walls; here, $\Delta T$ will be at a maximum.

The work of formation of a nucleus of minimum radius is

$$W = \frac{16\pi\sigma^3}{3A}, \quad W = \frac{16\ \pi\sigma^3}{3[(P_S-P')) (1-\frac{v'}{v''}]}, \qquad (12)$$

where $P_S$ is the saturation pressure; $P'$ is the external pressure; and $v'$, $v''$ are specific volumes of liquid and vapor.

Using formulae (11) and (12), and also the dependence of the values of $\sigma$, $dP/dT$ and $A$ on temperatures in the Tcr field [33], it is not difficult [p. 183] to show that

$$\lim_{T \to Tcr} r_{min} = 0, \quad \lim_{T \to Tcr} W = 0.$$

The graphs (Figs. 73 and 74), calculated from available handbook data [1], illustrate the nature of the changes in $r_{min}$ and W in a certain interval close to Tcr.

Consequently, at a constant temperature (with constant thermal gradient), under low-T conditions, there is [in?]sufficient energy for the formation of incipient bubbles; as T rises, the moment arrives when the energy supplied is sufficient for the development of bubbles with $r_{min}$, that is, boiling. This has also been observed in inclusions. During the establishment of a thermal gradient of constant magnitude near the critical temperature, boiling may continue for a very long time. In the closed system of an inclusion under these conditions, evaporation will also occur (in the more heated portion), and condensation (in the less heated portion).

Thus, in a natural vug, boiling is possible in two cases: a) owing to rapid pressure drop during rupture of the vug wall; and b) as a result of uneven heating of the vug at a tmeperature somewhat lower than the critical value; the wider the boiling-temperature range, the greater the unevenness of heating. The gas phase will develop at the sites of superheating in the form of bubbles, which will disappear, as soon as the thermodynamic conditions within the solution are equalized. Such boiling is of a local nature, although it may continue for a long time. Because the growth of crystals is directly associated with the walls of the vug, the effect of boiling of this kind on the formation of minerals and families of inclusions of complex phase composition may be extremely significant.

The aggregate state of a fluid in a mineral-forming system is controlled by the ratio of its PTX parameters.

PT-conditions of mineral origin in a single-component system $H_2O$.[12] The principal parameters of the thermodynamic conditions of crystallization of minerals (temperature and pressure) are clearly mutually dependent. The problem of developing the desired methods of determining the pressures from inclusions in minerals is simultaneously the problem of acceptably accurate determinations of the true temperatures of mineral-formation.

1. We shall assume that crystals grow in a closed two-phase $H_2O$-vapor system at a temperature substantially exceeding room temperature (see Fig. 47). On the diagram of such a system, one of the points [p. 184] (e.g., C) will correspond to the curve of the two-phase equilibrium AK. The crystals, growing from the liquid phase, will enclose the medium,

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[12] With the object of simplifying the constructions here and elsewhere, no account has been taken in the component composition of the solutions of the material of the crystallizing mineral, the solubility of which is very low under conditions of normal post-magmatic mineral origin.

which is marked by the parameters of this same point C. This will also apply to inclusions, developing in crystals that grow from the gas phase. The difference between such inclusions amounts to the variable specific volume of the captured portions of the mother liquor. This will also be revealed during cooling of the inclusions to room temperature. The filling of such inclusions will not repeat the whole of the closed system, either in the heated or cooled state, because the inclusion will capture only the portion of gas or liquid with a specific volume, not equal to the total specific volume of the system. During heating, the inclusion will accurately repeat, but in inverse sequence, all the parameters (P, T, and V) from the moment of its origin and up to the equilibrium state under surface conditions. At the moment of homogenization, T, P, and V will correspond precisely to the conditions of its trapping. The difference in the total specific volumes of the gas-liquid and essentially gas inclusions will indicate a difference in the aggregate state under the conditions of their capture by the crystal.

Thus, in this case, T, P, and the aggregate state of mineral-formation found by the homogenization method, will correspond to the true values, since the pressure at the moment of formation of the inclusions will correspond to the saturated vapor pressure of $H_2O$.

2. If we raise the temperature in a closed system (see Fg. 47a), then depending on the initial ratio of phases, it will be entirely filled with liquid (see Fig. 47b) or vapor (see Fig. 47C). The T and P in such a system, during further heating, will change according to the curve of equal specific volume (isochores). Depending on whether the cavity is filled with liquid or vapor, the isochore will extend from the curve of the two-phase equilibrium into the field of the liquid or gas phase. The conditions of existence of inclusion-systems after homogenization into the liquid phase are marked by a significant rise in internal pressure over the saturated vapor pressure at the prescribed temperature. On the other hand, the pressure of the vapor-filled system is lower than the saturated vapor pressure under the same temperature conditions. Thus, the isochores of the liquid phase are at a low angle to the pressure axis, whereas those in the gas-phase field lie at about 90° to the pressure axis.

We shall assume that crystal growth and capture of inclusions take place in the liquid-filled system (see Fig. 47b) at T and P (see Fig. 47d). Overall cooling of such a system in a sealed inclusion in a crystal will take place evenly, and will correspond to points on the isochore DC and to the sector CA on the two-phase equilibrium curve. During cooling of the inclusion, its filling will correspond to the initial filling of the closed system (autoclave). During heating of the inclusion, prior to the moment of homogenization, its P and T will change in reverse direction from A to D.

Consequently, with the aid of the PT diagram for water, the possible direction of changes under the thermodynamic conditions within the inclusion [p. 185] (corresponding to the reverse direction of the natural process) is unambiguously determined from the phase-equilibrium curve and the appropriate isochore. However, when the inclusion is heated to Th, we find only the beginning of the isochore, and the point on it, corresponding to conditions of closure of the inclusions, remains unknown. The coordinates for the beginning of the isochore are always below those of any point on the isochore. Therefore, Th of the inclusion is the minimum temperature of mineral formation.

From the diagram (see Fig. 47), it has been established that the more substantial the excess in pressure that had existed at the moment of sealing of the inclusion, over the saturated vapor pressure, the greater the difference between the actual temperature and Th. If the angle between the isochore and the *P* axis is denoted by $\alpha$, and the difference in pressures existing at the moment of sealing and at homogenization, by $\Delta P$, then the temperature of formation of the inclusions, $T = Th + \Delta T$ or $T = Th + \Delta P \tan\alpha$.

Hence, the discrepancy between Th and the temperature of mineral formation is determined by the magnitude of the second term on the right-hand side of the equation, or mainly by the size of the slope of the isochore towards the *P* axis. A small angle of slope of the isochores in this part of the *PT* diagram will lead to the situation that a small rise in *T* over Th will correspond to a significant pressure interval ($\Delta P$). Therefore, temperature corrections for pressure ($\Delta T$) are comparatively small. The $\Delta T$ correction for water may be determined from the *PT* diagram (see Fig. 21).

The pressure within the inclusion at the moment of homogenization [Pn] also corresponds to some minimum value of that of mineral-formation. The following equation will be operative for this:

$$P = Ph + \Delta P, \text{ or } P = Ph + \Delta T \cot\alpha.$$

However, determination of the pressure is limited in this case, mainly by two factors. First, the pressure in the inclusion cannot be as readily measured as the temperature, and it may only be calculated from the state and composition of the inclusion, in accordance with experimentally-studied systems. Second, as may be seen from Figure 47, the term $\Delta T \cot\alpha$ is marked by relatively large absolute values owing to the small values of $\alpha$; here, neglect [error?] of the temperature will lead to a marked change in the total correction for pressure temperature-wise ($\Delta P$).

Thus, inclusions of small overall specific volume, preserved at the high pressures and relatively low temperatures of hydrothermal solutions, may be used to determine the temperature of mineral-formation, but are virtually unsuitable as mineralogical barometers. Similar inferences could also be repeated for inclusions, formed in a closed system from a gas solution (see Fig. 47*c*). Their state during heating will be reflected by the appropriate isochores for the gas-phase field (see Fig. 47*e*). However, the possibilities of applying such inclusions have been opposite to those discussed above. This is controlled by the increase in the slope of the isochores towards the *P* axis and their closeness to the [p. 186] *T* axis. The compressibility of gases is great, and therefore, the effect of pressure on the discrepancy between Th and the temperature of mineral-formation is also very large. On the other hand, the pressure changes little in spite of significant temperature changes. Therefore, inclusions that have a greater overall specific volume and are preserved at high temperatures and relatively low pressures of gas solutions, may be used for determining pressures, but are virtually unsuitable as mineralogical thermometers. For intermediate values of the overall specific volume of the inclusions, approximating to the critical value, the possibilities and accuracy of the determinations occupy an intermediate position.

The natural process is more varied and complicated than the above described crystallizaton scheme. But all cases of natural mineral-formation form gas and liquid solutions, may in principle be reduced to the three described above.

PT-conditions of mineral origin in a two-component system of the $H_2O$-NaCl type [problems of thermometry]

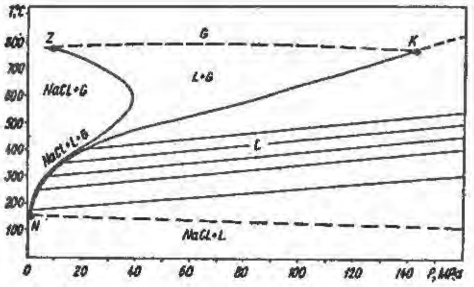
Fluids, the physicochemical state of which correspond to systems without critical phenomena in saturated solutions of the three-phase B + L + G equilibrium, probably occur under natural endogenic conditions. To a marked degree, these confirm the experimental studies of the $H_2O$-$SiO_2$ system [229], the parameters of the complete miscibility of the components of which, however, are extremely large (critical P and T are respectively $9.7 \cdot 10^8$ MPa and 1080°C). Chlorides of Na and K, the typical components of such systems, are very widely distributed in fluid inclusions. An examination of the peculiarities of such fluid media is thus very appropriate.

A correct assessment of the degree of correspondence between Th and the actual conditions of crystallization, is impossible without a physicochemical analysis of the state of the system of the natural crystallizer as a whole, and also of the fluid enclosed in the vauole. PT, PTX, and VTX diagrams were first used for interpreting temperature measurements during phase transitions of liquid inclusions by R. Nacken, Ostrovsky, and Vul'chin. In spite of certain errors, tolerated in the application of VTX diagrams to systems of volatiles ($H_2O$)-nonvolatiles (silicate) in isolated inclusions under these conditions, the publications of Ostrovsky [158] and Vul'chin [25] have played a positive role, attracting the interest of investigators of inclusions to the theoretical aspects and to an objective discussion of the basis for Sorby's homogenization method.

Three-dimensional PTX and VTX diagrams are most important and convenient in thermobarometry, because with their aid, it is easy to study the state of inclusion-systems (items usually marked by constant overall composition and specific volume).

## The PTX diagram for a system of the $H_2O$-NaCl type

[p. 187] An analysis of PTX diagrams of this kind, as applied to inclusions, was first undertaken by Vul'chin [25]. He discussed the general kind of diagram and presented examples of construction of their PT sections within the experimental parameters known up to that time, for the $H_2O$-NaCl and $H_2O$-KCl systems. We have compiled a more complete section of the PTX diagram for the $H_2O$-NaCl system with constant composition X = 30% (Fig. 75), on the basis of new data [251, 122]. Here, we show the portion of the diagram, located below 0°C[sic], that is, in the field of the triple invariant point and eutectic crystallization. The lines and points on the section are intersections between the planes and lines on the three-dimensional PTX diagram [73, p. 291], and the plane of constant composition. The line B + L + G is the trace of the intersection of the cylindrical surface ('fold') normal to the PT plane; it defines the PT conditions of the coexistence of crystals, solution, and vapor phases. N is the point of intersection between the compositional line of the liquid phase of the two-phase L + G field ('lamina') and the line of intersection of the solubility plane for the third phase; a small slope towards the P axis is suggested for the latter, if we begin from an increase in solubility with a rise in pressure from 0 to 400 MPa, according to Adams' data [251]. The distribution of the three-phase equilibrium in the high-temperature field is limited by the intersection of the B + L + G line with the gas branch of the two-phase L + G 'lamina' at point Z; K is the intersection between the line of critical points and the plane X = 30% NaCl (mass component).



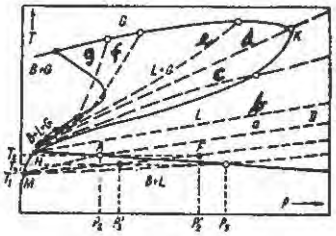


Fig. 75 [p. 187]. PT section of PTX diagram for $H_2O$-NaCl system with X = 30%, with isochores in the field of the homogeneous-liquid phase (thin straight lines); constructed from [251, 122, and 175].

Fig. 76 [p. 188]. Diagrammatic PT section of PTX diagram of the $H_2O$-NaCl system of constant composition. a-g) possible routes of homogenization (or PT evolution) of inclusions with initial composition B + L + G (explanation in text

All the listed elements of the diagram, except for the lines between the fields L + G and G, and B + L and L (dashed lines), have been plotted [p. 188] from experimental measurement data or from results of close interpolation and extrapolation (point K).

Several variants of the course of homogenization of inclusions, containing crystals of NaCl, solution, and gas under surface conditions, are fundamentally possible (Fig. 76). Seven typical kinds of homogenization of inclusions of constant overall composition, but of different specific volume (filling), have been recognized. From a to g, the overall specific volume increases (the filling decreases). To the left of the line of homogenization, achieved in the critical state (curve d), the inclusions are filled with the gas phase, and to the right, with the liquid phase. Final homogenization of the inclusion a takes place as a result of solution of the crystallite at point A. A special kind of homogenization is represented by curve b, at invariant point N on which, transition into liquid ensues as a consequence of the simultaneous disappearance of the crystal and gas bubble. As a result of the disproportional redistribution of components in the liquid and gas phases of inclusions during their heating, between compositions b and d in the L + G field, there is an area of crowded isochores (more precisely, curves of two-phase equilibrium), which on the actual model (see Fig. 75) merge with a branch of the liquid phase of the two-phase 'lamina.' Their continuation after homogenization is shown by dashed lines in the field of liquid phase L. The field of such isochores is of particular interest with respect to methods being developed for the determination of pressures. Besides the normal course of homogenization of inclusions into the gas phase (e and g), case (f) of complex much-repeated transitions of liquid and solid phases is possible; this has been controlled by crystallization or melting of the solid phase during the process of temperature increase. All the listed variants of homogenization have been confirmed by construction of the VTX diagram and its sections, discussed below.

Individual questions about the state of the system of $H_2O$-NaCl type within restricted parameter limits, have been discussed earlier. For example, the generalized graph of calculated Th of inclusions of NaCl solutions, according to Lemmlein & Klevtsov [124], is shown in Figure 49. Very important experiments have been conducted by Samoilovich [168], Khetchikov & Samoilovich [189], and Ikornikova [79]. These studies have provided a significant addition to our knowledge about the PT-dependence of inclusions of salt solutions of different concentrations and densities in the field of the liquid phase on the PTX diagram. [p. 189] The work of Lemmlein & Klevtsov, based on a study of these systems, with the object of determining pressures and temperatures close to the actual values, is distinguished by the care in carrying out the experiments, the maximum account taken of all the factors, and the caution displayed in the conclusions [122, 248-258]. Unfortunately, the method of calculating the pressures used by them, has been employed without profound analysis and experimental verification over a broad, essentially unstudied field in the system [163, 164].

With the object of bringing the PT conditions of mineral formation, determined by the homogenization method, into line with the real state, Lemmlein & Klevtsov [122, p. 253] have suggested taking into account the T and P of the content of the inclusions at the moment of final homogenization into the liquid phase, taking place according to the pattern: B + L + G → B + L → L. In this case, the authors, on the basis of experiments, have also calculated the value of dP/dT in the inclusion prior to disappearance of the solid phase, $T_1$ into the state of an enclosed fluid after solution of the NaCl crystallite (temperature $T_2$). In fact, according to the PT section of the PTX diagram (see Fig. 76), the changes in the parameters of such an inclusion must take place along curve a (MAD). In this instance, following homogenization B + L → L at point A, the pressure changes with rise in temperature along the isochore AD, belonging to the general family of isochores of field L.

Piznyur [164], cited in [122, p. 253], has determined the pressure, based on inclusions of composition B+L+G in such a sequence: a) the temperatures of disappearance of the gas bubble ($T_1$) and solution of the halite crystallites ($T_2$) are measured; b) from point M, defined on the basis of $T_1$, on the three-phase equilibrium curve (the author has incorrectly figured the line of liquid-vapor boiling), is plotted the isochore, corresponding to the density of the component of the inclusion (data are usually employed for a 30% solution); and c) the pressure is read at point F, plotted on the isochore in accordance with $T_2$ (see Fig. 76).

Numerous results have been published, obtained by the method from inclusions with very high concentration and a large temperature increment, $T = T_2 - T_1$ [164]. However, this hastily used method of calculating pressures is far from flawless, owing to incorrect theoretical premises and tolerated errors in the practical achievement of the measurements. It is obvious that no method may be accepted for use without calculating the possible errors and true limits of application. We shall note the main obstacles and errors that arise during the use of such inclusions in barometry.

1. It is insufficient to discuss a binary system of the $H_2O$-NaCl type, using planar models alone; in order to take account of all factors, an analysis of the state of the system using three-dimensional coordinates is essential. In publications [164, etc.], no account has been taken of the effect of phase transitions on the regime of changes in the PT parameters, which the greater they are, the greater their deviation from those checked in detail by experimental means [122]. This also concerns the carefully-conducted complex calculations of Lyakhov [134] for clarifying [p. 190] the errors in this method and their sources (they have, however, not been revealed by the author).

2. It is fundamentally incorrect to construct PT diagrams without a complete understanding of the phase composition of the system. On these coordinates, the changes in the parameters of these inclusions are divided into three stages, according to the pattern B + L + G → B + L → L. The

concluding stage of PT changes in a homogeneous liquid medium alone is completed along a straight-line isochore. The first two stages of true homogenization of inclusions, have a more complex non-rectilinear trend, like that of two-phase liquid-vapor equilibrium. The straight-line portion of the isochores of inclusions of this kind does not begin on the line of two-phase equilibrium and does not end at the critical point, as has been stated in [164]. It commences on the solubility line B + L - L, crossing the critical parameters without apparent phase changes.

3. The continuation of the rectilinear (or sub-rectilinear) trend in the changes in the isochore of field L in the two-phase B + L area is evidently possible only for the transfer of phase B + L → L near 300°C. This is associated with the identical slope of the isochores of different concentration with respect to the pressure coordinate, as has been established from the graph [122, p. 183]. From this same diagram, it follows that the initial isochores at lower temperatures increase their slope as compared with those of solutions of low concentration (more precisely, $H_2O$) and, on the other hand, the higher-temperature inclusions are marked by a comparative flattening of the isochores. At other phase-transition temperatures, there is, in all probability, no rectilinearity in the isochore changes. In such a case, the error in measuring pressures by the proposed method may be both positive and negative. At T <300°C, the line of change MA deviates to the left of the 'straight-line' isochore MF (the illustration of the latter corresponds to the principles of the proposed method) and the determinations will be over-estimated; in the case when T >300°C, the result $P'_3$ turns out to be underestimated as compared with the true $P_3$ (see Fig. 76).

4. We need now to reckon with the indeterminate position of the B + L - L line at increased temperatures and pressures. Adams [251] has studied it along the 25°C isotherm. Evidently, at pressure up to 400 MPa, it has a slope in the direction of pressure increase, as shown in our graphs.

5. Intersection between the isochores and the NaCl solubility line takes place at an acute angle, in which respect the error in determinations may be very substantial. Allowing, moreover, that there are not data on the changes in the system in the B + L field, the errors, especially in the high-pressure field, may amount to 10 percent and more.

## A sketched VTX diagram for the volatile-nonvolatile system and methods of constructing the TX- and TV-sections for inclusion systems

[p. 191] Figure 77 displays a sketched VTX diagram for a binary system of the volatile-nonvolatile kind, without critical phenomena in saturated solutions ($H_2O$-NaCl and $H_2O$-$SiO_2$) and sections with constant specific volumes. These diagrams have been described in detail by Roseboom [244] and Niggli [155], and also with additions by I.A. Ostrovsky and E.I. Vul'chin (Fig. 78). We may briefly recall that the $V_L$ and $V_G$ curves (see Fig. 77) correspond to projections of the specific volumes of the coexisting liquid and gas phases on the VX plane as the temperature falls (fall denoted by arrows) in equilibrium with solid phase B. The isothermal sections are shown by triangles of coexisting phases aah, bbh, ... Dashed lines mark the B + L, L, L + G, and G fields outside the limits of the three-phase B + L + G equilibrium. The phase triangle is shown separately in Figure 79. On a diagram, I.A. Ostrovsky has shown the compositions at critical points approximately on the sites where the isotherms of the coexisting phases L and G bend. E.I. Vul'chin, on a VTX diagram, has displayed the line of critical volumes $V_{cr}$, which evi-

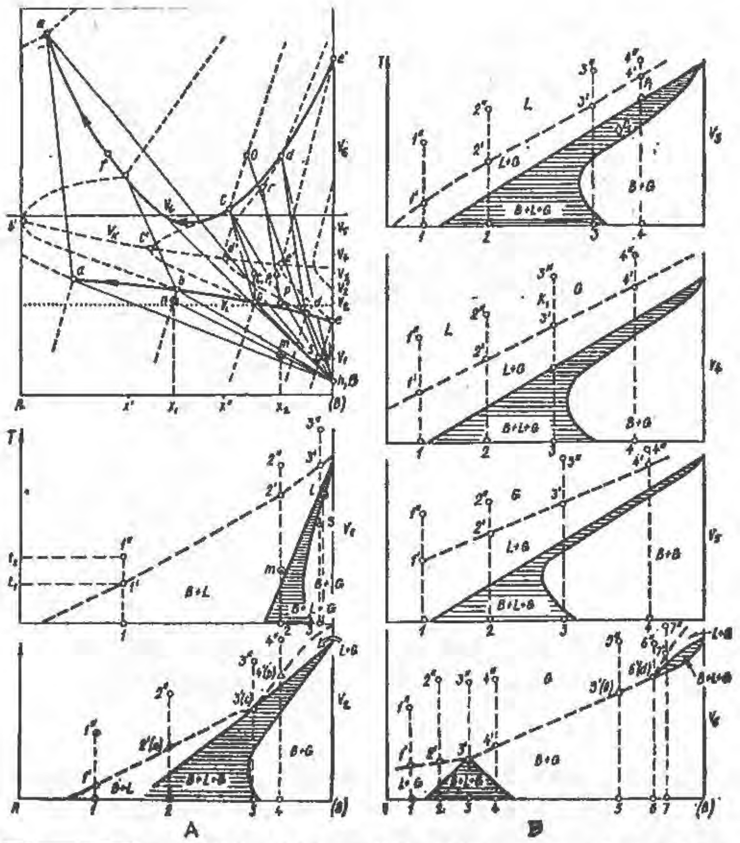


Fig. 77 [p. 192-193]. VTX diagrams of system A + (B) without critical phenomena in saturated solutions and TX sections (at constant volumes $V_1$-$V_6$): A) readily-volatile component ($H_2O$); (B)) component of KCl and NaCl type; trend lines of specific volumes of fluids: $V_G$) gaseous, $V_L$) liquid, $V_K$) critical depending on temperature; b', c', d', e') critical points of two-phase equilibrium L-G; aa, ee) lines joining coexisting L and G eutectic and pure component (B); 1-1'-1"...7-7'-7") sequence of phase changes in systems of constant composition and volume (i.e., inclusions) as temperature changes; 1'-1"...7'-7") magnitude of ΔT correction to Th of inclusions. It is accepted that the volume of solid phase B does not depend on temperature.

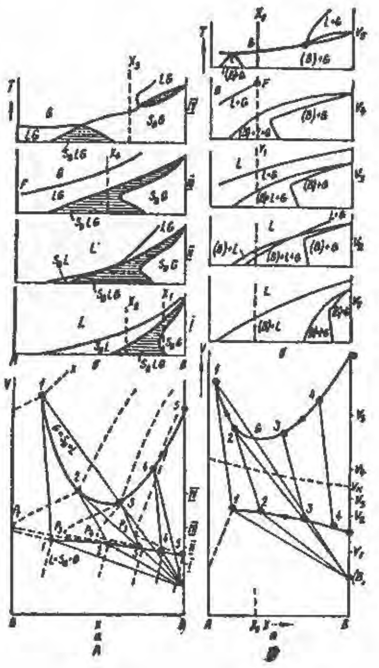
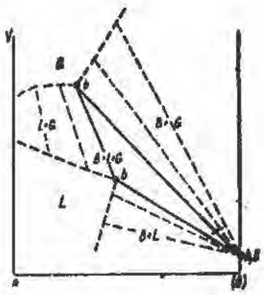


Fig. 78 [p. 194]. VTX diagram of binary system without critical phenomena in the field of a three-phase equilibrium of the volatile ($H_2O$)--poorly-volatile ($SiO_2$, NaCl) kind, according to I.A. Ostrovsky (A) and E.I. Vul'chin (B): a) projections of VTX diagrams onto VX plane; b) isochore sections of VTX diagrams; A,B) volatile and poorly-volatile components of system; $S_B$ or (B), L, and G) solid, liquid, and gas phases.

dently joins up the corresponding points on Ostrovsky's diagram. From the diagram, however, this has not been identified, because the fields of isothermal coexistence of the single- and two-phase equilibria are absent from it. The authors have also discussed a VTX diagram for systems with critical phenomena in saturated solutions. We shall not analyze this case here. A VTX diagram in projections on three planes is illustrated in Figure 80.

The object of studying inclusions of mineral-forming media is to determine, with a maximum degree of confidence, the thermodynamic and geochemical conditions of crystallization as a whole in the entire system. With the aid of a VTX diagram, we shall consider the possibilities of determining the temperature. In this case, the diagrams may be described separately:



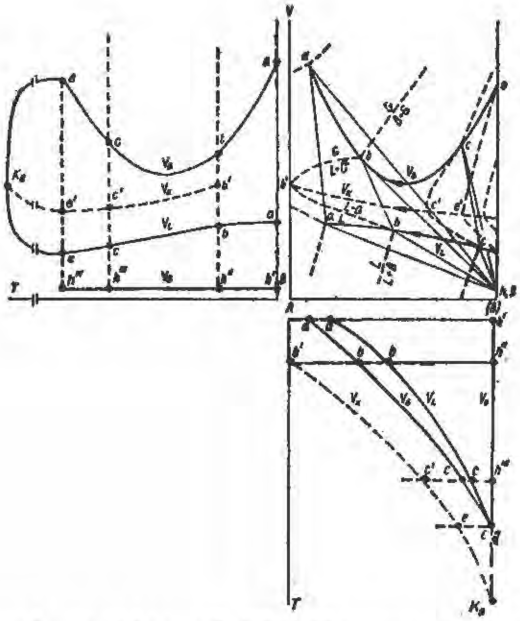


Fig. 79 [p. 195]. Sketch of isothermal section of VTX diagram (phase triangle). The phases B+L, L+G, and B+G coexist outside the triangle (see Fig. 77).

Fig. 80 [p. 195]. Projection of sketched VTX diagram of $H_2O$-$SiO_2$ (NaCl) type on VX, VT, and TX planes: $V_B$, $V_L$, $V_G$) lines of specific volumes of phases; $V_K$) line of critical volumes, $K_B$) critical point of non-volatile component; aah, bbh, cch) isothermic sections; A) volatile component of system, (B) non-volatile component.

1. The overall state of the whole macrosystem, consisting of components A + (B) (microinclusions are not taken into account here).

2. The microsystem of the inclusion, captured by a growing crystal B in this same binary system A + (B).

3. The state of the microsystem A + (B) in an inclusion, which has been captured by a growing solid phase (e.g., quartz), poorly soluble under the conditions of normal microthermometry.

The first case excludes the study of inclusions. It is ideally described by VTX diagrams in their normal understanding. The second case may correspond to a system of the $H_2O$-NaCl kind, etc. The inclusions here must be considered as part of an entire system. The heterogeneous state of the latter will lead to the capture of a medium of different specific volume and composition as compared with the entire macrosystem. It is completely accepted that capture of inclusions will take place only in the areas where a solid phase B exists or is developing (the B + L, B + L + G, and B + G fields and their boundary lines). [p. 194] The method of construction and the properties of sections for inclusion-systems of this kind coincide to a marked degree with those described above, being assigned to the third case of interpretation of the diagram, and we shall not dwell on them (although certain characteristic features of them will be noted).

[p. 198] The third case assumes a low solubility for the enclosing mineral during its crystallization, which usually corresponds to the formation of hydrothermal veins, minerals of the zanorysh [chamber] pegmatites, and metasomatites. The weak influence of the mineral-host on the density and composition of the solutions has been indicated by experiments with continued heating of two-phase and multiphase inclusions (with min-

Table 17 [p. 196-197]. Possible Variants of Course of Homogenization of Inclusions of $H_2O$-KCl(NaCl) Type (re VTX diagram and its TX Sections

| Number | Nature of isochore TX section VTX diagram | Field of TX sections (aggregate state of entire system) | Corresponding TX section of system of inclusion of homogeneous origin | | Route of homogenization of inclusion (the reverse of the natural process of heterogenization) | Type of Homogenization | Relationship between Th and actual temperature |
|---|---|---|---|---|---|---|---|
| | | | liquid | gaseous | | | |
| 1 | Below $V_L$, section $V_1$ | L | $V_1$ | -- | $V_1$(1-1", 2-2", 3-3") | Into liquid phase | Th<T |
| 2 | | B+L | $V_1$, $V_2$ | -- | $V_1$(1-1', 2-2', 3-3'); $V_2$(1-1', 2-2') | " " | Th = T |
| 3 | | B+L+G | $V_2$ | -- | $V_2$(3-3') | " " | " " |
| 4 | | B+L+G | -- | $V_6$ | $V_6$(3-3', 6-6') | Into gas phase | " " |
| 5 | | B+G | -- | $V_6$ | $V_6$(4-4', 5-5') | " " | " " |
| 6 | Intersects $V_L$, section $V_2$ | L | $V_2$ | -- | $V_2$(1-1", 2-2", 3-3", 4-4") | Into liquid phase | Th<T |
| 7 | | B+L | [$V_2$] | -- | $V_2$(1-1', 2-2') | " " | Th = T |
| 8 | | B+L+G | [$V_2$] | -- | $V_2$(3-3') | " " | " " |
| 9 | | B+L+G | -- | $V_6$ | $V_6$(3-3', 6-6') | Into gas phase | " " |
| 10 | | L+G | [$V_2$] | -- | [$V_2$] (4-4') | Into liquid phase | " " |
| 11 | | L+G | -- | $V_4$, $V_5$ | $V_4$(4-4'), $V_5$(4-4') | Into gas phase | " " |
| 12 | | B+G | -- | $V_6$ | $V_6$(4-4', 5-5') | " " | " " |
| 13 | Between $V_K$ and $V_L$, section $V_3$ | L | $V_3$ | -- | $V_3$(1-1", 2-2", 3-3", 4-4") | Into liquid phase | Th<T |
| 14 | | L+G | $V_2$, [$V_3$], $V_4$ | | $V_2$(4-4') [$V_3$] (1-1', 1-1', 3-3', 4-4',, $V_4$(1-1', 2-2') | " " | Th = T |
| 15 | | L+G | -- | $V_5$, $V_6$ | $V_5$(3-3', 4-4'), $V_6$(7-7') | Into gas phase | " " |
| 16 | | B+L+G | $V_2$ | -- | $V_2$(3-3') | Into liquid phase | " " |
| 17 | | B+L+G | -- | $V_6$ | $V_6$(3-3', 6-6') | Into gas phase | " " |
| 18 | | B+G | -- | $V_6$ | $V_6$(4-4', 5-5') | " " | " " |
| 19 | Intersects $V_K$, section $V_4$ | L | $V_4$ | -- | $V_4$(1-1", 2-2") | Into liquid phase | Th<T |
| 20 | | Line $K_L$ | $V_4$, V and $X_{cr}$ | $V_4$, V and $X_{cr}$ | $V_4$(3-3") | Critical state | " " |
| 21 | | G | -- | $V_4$ | $V_4$(4-4") | Into gas phase | " " |
| 22 | | L+G | $V_2$, $V_3$ | -- | $V_2$(4-4'), $V_3$(1-1', 2-2', 3-3', 4-4') | Into liquid phase | Th = T |
| 23 | | L+G | -- | $V_5$, $V_6$ | $V_5$(1-1', 2-2', 3-3', 4-4'), $V_6$(7-7') | Into gas phase | " " |
| 24 | | B+L+G | $V_2$, $V'_2$ | -- | $V_2$(3-3'), $V'_2$(like 3-3' section of $V_2$) | Into liquid phase | " " |
| 25 | | B+L+G | -- | $V_6$ | $V_6$(3-3', 6-6') | Into gas phase | " " |
| 26 | | B+G | -- | $V_6$ | $V_6$(4-4', 5-5') | " " | " " |
| 27 | Between $V_K$ and $V_G$, section $V_5$ | G | -- | $V_5$ | $V_5$(1-1", 2-2", 3-3", 4-4") | " " | Th<T |
| 28 | | L+G | $V_2$, $V_3$ | -- | $V_2$(4-4'), $V_3$(2-2', 3-3', 4-4') | Into liquid phase | Th = T |
| 29 | | L+G | -- | $V_6$ | $V_6$(2-2', 7-7') | Into gas phase | " " |
| 30 | | B+L+G | $V_2$ | -- | $V_2$(3-3') | Into liquid phase | " " |
| 31 | | B+L+G | -- | $V_6$ | $V_6$(6-6') | Into gas phase | " " |
| 32 | | B+G | -- | $V_6$ | $V_6$(4-4', 5-5') | " " | " " |
| 33 | Intersects $V_G$, section $V_6$ | G | -- | $V_6$ | $V_6$(1-1", 2-2", 3-3", 4-4", 5-5" 6-6", 7-7") | " " | Th<T |
| 34 | | L+G | $V_2$, $V_3$ | -- | $V_2$(4-4'), $V_3$(1-1', 3-3', 4-4') | Into liquid phase | Th = T |
| 35 | | L+G | -- | $V'_6$ | ($V'_6$>$V_6$) $V'_6$(like 1-1', 2-2', 7-7' section of $V_6$) | Into gas phase | " " |
| 36 | | B+L+G | $V'_2$ | -- | $V'_2$(like 3-3' section of $V_2$) | Into liquid phase | " " |
| 37 | | B+L+G | -- | $V'_6$ | $V'_6$(like 3-3', 6-6' section of $V_6$) | Into gas phase | " " |
| 38 | | B+G | -- | $V'_6$ | $V'_6$(like 4-4', 5-5' section of $V_6$) | " " | " " |

eral-captives) in quartz and topaz, and the experiments of Kennedy et al. [229] based on a study of the $H_2O-SiO_2$ system, etc. It is likely that their interaction only becomes marked in intensely alkaline solutions of the NaOH ($Na_2CO_3-SiO_2$) type, at temperatures and pressures close to the fusion of silicates. These cases, of course, must be considered from different aspects.

Six of the most typical isochoric sections have been separated (see Fig. 77), which occur: below $V_L$, at the intersection with $V_L$, between $V_K$ and $V_L$, at the intersection with $V_K$, between $V_K$ and $V_G$, and at the intersection with $V_G$. All the determinant variants of the course of homogenization are set out in Table 17.

There may be as many systems of different aggregate state as the fields shown on the section (for simplicity, we have not taken account of the systems that occur on the boundary lines and points, separating the fields). In this respect, each of the fluid phases of heterogeneous or homogeneous solution is captured in the vacuole, and initially, a liquid, gaseous, or an inclusion in the critical state, may be formed (the last is virtually unlikely). For brevity, the route of homogenization of an inclusion is denoted by the appropriate point numbers. Changes in the phases should be read in accordance with these points on the appropriate sections. On the diagram and the sections, individual examples of mutually-related parameters of the system as a whole and the inclusion captured in an initially homogeneous state, are marked by characteristic points. Inclusions of heterogeneous capture are not considered here.

Example 1. Total specific volume of two-component system A+(B) ($H_2O$-NaCl)-$V_1$ (see Fig. 77, section $V_1$). Capture of an inclusion by a growing mineral (quartz) may occur in all four fields of the section. If capture takes place in field L at temperature $t_2$, then during the cooling process, heterogenization of the inclusion will take place at $t_1$. Reverse heating will lead to solution of the solid phase B at $t_1$. Consequently, $Th<Tc$ [Tc = temperature of crystallization]. In the case of crystallization in field B+L of this same section (see Table 17, No. 2), the liquid phase may be captured at different T and X. Let us assume that this corresponds to point m and composition $x_2$. The composition of the captured liquid phase will not correspond to that of the whole system, because part of the component (B) has crystallized in the form of the solid phase. According to the isothermal section (phase triangle bbh), constructed for the given temperature, the composition of the liquid phase, occurring in equilibrium with B, will correspond to point n with ordinate $x_1$. Therefore, the inclusion, as a physicochemical system, must be reflected in section TX, which passes through point n, that is, $V_2$ (see Fig. 77). Point 2' on it indicates the beginning of capture, whereas line 2'-2 corresponds to a change in phases in the newly-formed inclusion. The [p. 199] course of homogenization will be reverse 2-2'. At point 2', homogenization into the liquid phase will take place. Th will correspond to the true temperature.

Example 2. One of the phases of the B+L+G field (see Table 17, No. 3; point 1 of section $V_1$). The composition of the captured liquid phase will be described by point d on the $V_L$ curve. On the corresponding section, which is fundamentally like section $V_2$, the point of capture will correspond to that where the fields L - L+G - B+L+G - B+G join up, that is, at point 3'. The state of the separately captured gas phase (see Table 17, No. 4) will be reflected by point d on the $V_G$ curve or point 6' on section $V_6$. In a somewhat different situation, the gas inclusion will have the composition of point f on the $V_G$ curve or point 3' on section $V_6$. In both cases, Th is equal to the temperature of mineral-formation.

Example 3. Crystallization takes place in the B+G field of section $V_1$ (see Table 17, No. 5). Suppose that the gas inclusion has been captured in the plane of the isothermal section cch (point s). The composition of the captured gas will correspond at this same temperature to point 0 (5') of section $V_6$. Homogenization will take place through conversion of the gas-solid inclusion into the gaseous form, that is, B+G → G (5-5'); Th = T.

Example 4. Let us consider the crystallization that takes place in the L+G field of section $V_3$ (point $p_1$). The capture of the liquid or gas phase in such a system will correspond at the given temperature to the points (respectively) p and r. On the $V_2$ section, point p will correspond to point 4'. The route of homogenization (see Table 17, No. 14) will be 4-4' or B+G → B+L+G → L+G → L. The corresponding section, which will be similar to section $V_6$, may also be constructed for point r. It will lie similarly to point 7' of the section. The route of homogenization (see Table 17, No. 15) will be 7-7' or B+G → B+L+G → L+G → G.

According to section $V_3$ (point $C_1$), crystallization in the B+L+G field will give corresponding points on the $V_G$ and $V_L$ (c,c) curves and the corresponding sections (see Table 17, No. 16, 17).

The analysis of the VTX diagram and its sections, as applied to the method of homogenization, will enable us to make such important conclusions for the practical study of inclusions.

1. For the second and third cases recognized, Th is always lower than or equal to the temperature of crystallization of the mineral (isolation of the inclusion); there are no grounds for suggesting [25, 158] excess of Th over T, as already noted by the present author [71].

2. In the second case (when capture of the inclusion has been achieved by a crystal of B of the system), an area of inapplicability of the method of homogenization may be recognized, corresponding to conditions of crystallization and capture of inclusions in the B+G field, because solution of the originally precipitated cognate mineral-host of material on the walls of the vacuole, has not been observed.

In respect to the fact that fluid from a heterogeneous system alone (along with the fluids there must be a solid phase B, preserving the inclusion) and consequently, only a portion of it with different values of V and X, may be captured in the inclusion, the sense of I.A. Ostrovsky's [p. 200] meaning is lost: '... with equilibrium heating it is impossible to pass out of the field, where one of the phases is solid B, and instead of the true temperature of precipitation, we come to the point of fusion of B' [158, p. 147]. Thus the sections TV on the VTX diagram do not make it possible to display graphically the value of the positive correction to Th, as Vul'chin and Ermakov have suggested [26, fig. 1).

3. In the third case (when the inclusion has been isolated in a poorly-soluble mineral of the quartz type), a large pressure is developed during cooling of the captured liquid phase in field L of section $V_1$ and crystallization of solid phase B within the inclusion, as a consequence of which, inclusions of B+L type may occur at high pressure and at room temperature. Isolation of the liquid or gas phase in a homogeneous state in an inclusion, from heterogeneous media of the L+G, B+L+G, B+L, and B+G fields, will enable us to determine the actual temperatures of crystallization by the method of homogenization. Fluid inclusions, captured from a homogeneous liquid, gaseous, or supercritical system, always give underestimated results. An analysis of sections $V_2$ and $V_6$ (route of homogenization 3-3'-3") has shown that if the homogeneous capture of L or G takes place from a heterogeneous B+L+G system, then the temperatures of disappearance of the gas bubble (or solution during homogenization

into the gas phase) and of the crystal of the solid phase (salts of the NaCl type), will be equal. As a consequence of this, it is possible in practice, in groups of different filling, to recognize inclusions of homogeneous origin, which are suitable for determining the true temperature values (isolation took place from a boiling solution). These inclusions will be homogenized into the liquid or gas phase as a result of the simultaneous disappearance of the solid and gas or liquid phases.

The demarcation of pneumatolytic, hydrothermal, and pneumatolytic-hydrothermal mineral-formation. Problems of segregation and clear division [p. 201] of fields of pneumatolytic and hydrothermal mineral-formation have interested many investigators. They have been reflected more completely (without considering inclusions of fluids) in the publications of Sobolev [174], Eliseev [59], Shternberg [203], and Govorov [34]. Inclusions were first studied for these purposes by Ermakov [63], who pointed out in this instance, that homogenization of inclusions into the liquid or gas phase indicates their hydrothermal or pneumatolytic origin. Methods of determining the aggregate state, and the temperatures and pressures of crystallization from heterogeneous (effervescing) solutions have been discussed by us, using the polymetallic veins of the Donbass as an example [83, 103]. In accordance with the conclusions of Smith [171] and Korzhinsky [109] about the state of a fluid in the supercritical field, we suggested the division of this area along the isochore of critical volume [88]. Such a conclusion was based to a marked degree on the theoretical constructions of P Niggli, I.A. Ostrovsky, and E.I. Vul'chin. Although these authors had also maintained the sense of separation of a special undifferentiated fluid (supercritical) area, their diagrams had in fact predetermined the rational nature of the division of this 'fluid' area.

On the sketch (Fig. 81), a more detailed subdivision of postmagmatic mineral-formation on PTV coordinates has been given for an aqueous fluid. The concept of recognizing intermediate fields of mineral-formation is to be found in Nikolaev[156], where, in emphasizing the indeterminate nature of the term 'fluid,' he suggested that supercritical fluids be divided into three groups: 1) true supercritical solutions, or fluids (T and P above the critical level); 2) gas solutions (T greater, and P lower than critical); and 3) compressed solutions (T lower, and P greater than critical). Eliseev [59] has also recognized pneumatolytic-magmatic and pneumatolytic-hydrothermal mineral-formation.

When one uses the diagrams, one of the coordinates of which is the composition or volume, the necessity arises for the recognition of three main cases, about which we have remarked above. For the A+(B) system as a whole, all the compositions that lie, on the basis of total specific volume, below $V_{cr}$ on the VTX diagram, will homogenize into the liquid phase, and those above $V_{cr}$, into the gas phase. In the case of inclusions, this is clearly reflected in the TV sections of this same diagram (Fig. 81).

In the cases of capture of inclusions by a rock-forming silicate from the medium A+(B), where A is $H_2O$, and B is a readily-soluble salt, the inclusions, finally homogenizing into the liquid phase, are assigned to the hydrothermal category, and those passing into the gas phase, into the pneumatolytic group. The critical volume $V_{cr}$ of the inclusions leads to homogenization into the critical state. Continuation of the $V_{cr}$ line (and for the entire VTX diagram, this is a cylindrical plane, normal to the coordinate plane XV) into the higher-temperature area makes it possible to divide the supercritical area according to the type of homogenization of the inclusions (Fig. 81). Here, we may recognize pre- and super-

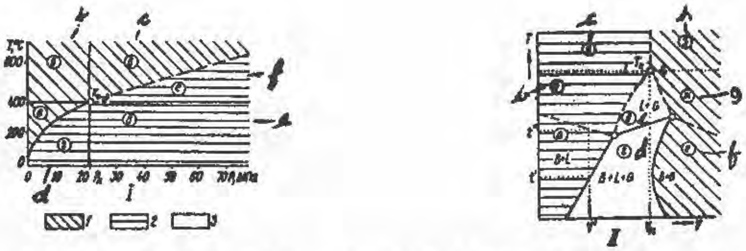


Fig. 81 [p. 200]. Sketch of aggregate state of medium of post-magmatic mineral-formation on PT (I) (for $H_2O$) and TV (II) coordinates (section of VTX diagram of binary system). Mineral-formation: 1) pneumatolytic, 2) hydrothermal, 3) pneumatolytic-hydrothermal. Shading corresponds to isochore of critical specific volume of $H_2O$. Fields of mineral-formation: I) pneumatolytic (a - pre-critical, b - thermo-supercritical, c - supercritical) and hydrothermal (d - pre-critical, e - baro-supercritical, f - supercritical); II) hydrothermal (a,b - pre-critical, c - supercritical), pneumatolytic-hydrothermal (c,d), and pneumatolytic (f,g - pre-critical, h - supercritical).

critical hydrothermal and pneumatolytic mineral-formation. We may also note that on the isochoric sections that pass through the line [p. 202] (plane) $V_{cr}$, separation of the field, based on final homogenization into a homogeneous liquid and a homogeneous gas, also takes place (see Fig. 77, section $V_4$). Incidentally, Vul'chin has, in this respect, constructed the section inaccurately (see Fig. 78B).

Below $V_{cr}$, the line (on PT coordinates) or area (on the TV section) of boiling solutions, separates the pneumatolytic and hydrothermal fields. As systematic studies have shown, the heterogeneous state, normal for almost all phases of postmagmatic mineral-formation, has relatively shallow depths. Therefore, in principle, the separation of pneumatolytic-hydrothermal crystallization is completely unjustified.

The route of homogenization, as is seen from the sections, may be extremely complicated. For instance, with V' sections x[sic] (see Fig. 81), $B+L+G \rightarrow B+L \rightarrow L$. In this case, if the solid phase B is poorly observed in the inclusion, the Th may be taken as temperature t', whereas the actual temperature should be t". A still greater complication arises during the capture of inclusions from a system of the $H_2O$-NaCl type (without silicate), because the precipitated solid phase may be masked by material from the crystal-host. The case of restoration of the aggregate state of a system based on inclusions, which arises in the fields of boiling solutions L+G and L+B+G, presents great difficulties. The type of homogenization of one or several inclusions from an insufficiently representative group of inclusions may, in such cases, lead to serious errors. Consequently, the principal requirement for the correct determination of the aggregate state (and other properties of the mineral-forming medium) is a close study of all the types of inclusions in a given sample with separation of syngenetic age groupings.

An approximate VTX diagram for the $H_2O$-NaCl system. The VTX diagram, considered above, represents a sketch of the changes in phase equilibria for the general volatile-nonvolatile system. NaCl occupies first place amongst the inclusions of predominant nonvolatile substances. Its content in solutions usually exceeds the total amount of all the remaining soluble components. The study of this salt and its aqueous solutions has turned out to be adequate for the construction of a diagram for the $H_2O$-NaCl system, close to reality [95].

The curve for the specific volumes of a saturated solution $V_L$ within the range of 0-200°C (Fig. 82) has been constructed from experimental data [175]; the $V_L$ of a melt of pure NaCl is accepted as 0.646 $cm^3/g$ (with T = 804°C). In the 200-804°C range, there are no data on volumes, but there are determinations of the composition of the solution (its values have been noted on the $V_L$ line with vertical shading) [175, 227, 251]. The specific volume of solid NaCl has been taken as 0.46 $cm^3/g$ [175].

The curve of specific volumes $V_G$ has been constructed from the results of indirect calculations, because at present there are no publications [p. 204] of direct determinations of $V_G$. For a vapor, saturated with NaCl, concentrations are known for given temperatures (350-700°C) and pressures [251], according to which the amount of the salt in vapors is negligible. Therefore, we have accepted that, at equal temperatures and pressures, the specific volumes of vapors of $H_2O$ ($V_1$) and $H_2O$-NaCl ($V_2$) are equal. The latter may be illustrated by the following transformation of the equation for ideal gases: $V_1 = T/P \cdot R_1$; $V_2 = T/P \cdot R_2$; and if $R_1 = R_2$, then $V_1 = V_2$.

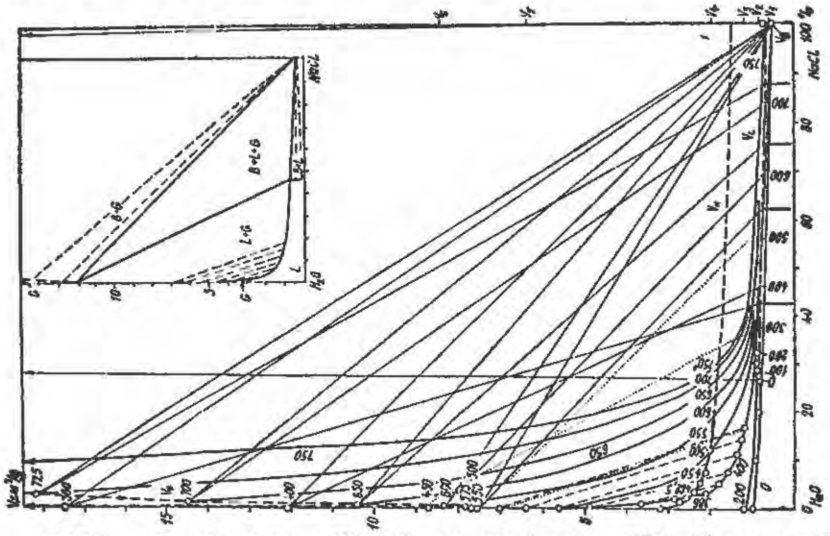


Fig. 82 [p. 203]. Projection XV of approximate VTX diagram for the $H_2O$-NaCl system: Projection of specific volumes: $V_B$) solid NaCl, $V_L$) saturated solution, $V_G$) gas; $V_K$) line of critical volumes; arrows indicate direction of lowering of temperature. Top right) isothermal section (phase triangle) at 400°C (explanation in text).

Using the detailed PT diagram with isochores for $H_2O$, constructed from known data [176], we have determined the corresponding [p. 205] values of $V_G$, which, in connection with the original assumptions, are not strictly accurate.

The points on the critical curve $V_{cr}$, corresponding to 386, 392, 402.5, and 417.5°C, have been taken from Khaibullin and Borisov's publication [186]; the end point for $H_2O$, $V_{cr} = 3.1$ $cm^3/g$; the values of V for 450 and 500°C have been obtained by a close extrapolation from the graph in [186]. The line $V_{cr}$ at T >500°C has been plotted approximately, taking account that $V_{cr}$ for pure NaCl may amount to 1.5-1.7 $cm^3/g$ (critical ratio of melt-gas volumes is about 2:3). On the $V_{cr}$ curve, vertical lines indicate the values of the composition [p. 206] of the fluid at 550, 600, 650, and 700°C, according to Sourirayan and Kennedy [251]; the points at 725 and 750°C have been obtained by extrapolation.

The isothermal section at 400°C, with lines joining the coexisting liquid and gas phases, has been constructed from data, obtained experimentally [186, 251]. The boundary lines of the fields of the remaining

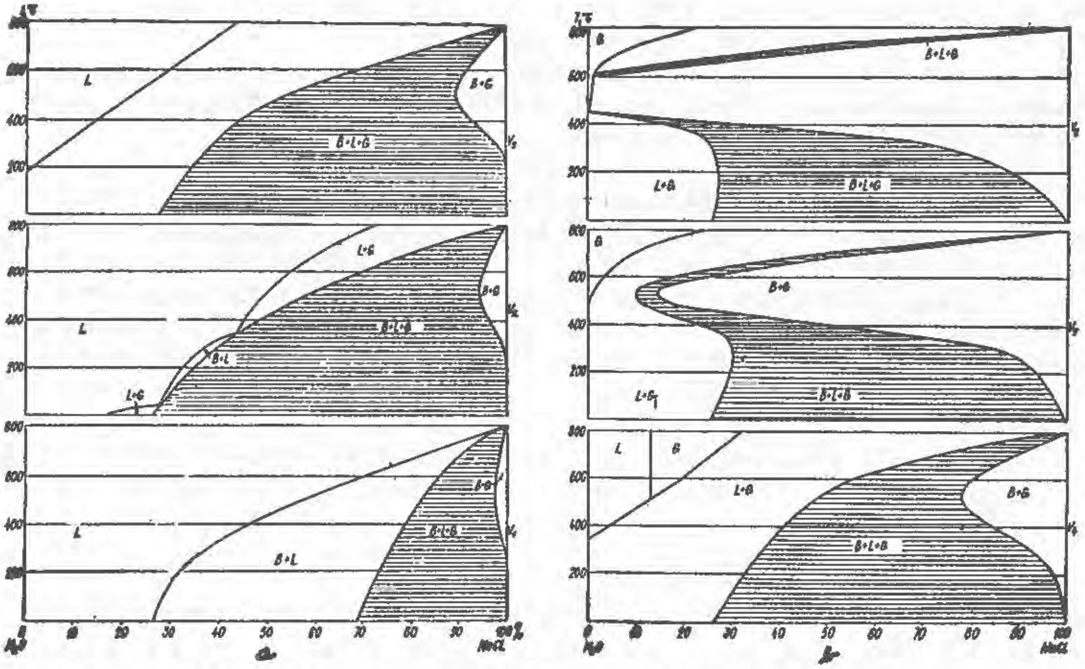


Fig. 83 [p. 204-205]. Isochoric TX sections of approximate VTX diagram for $H_2O$-NaCl system: A) with $V_1$-$V_3$ (respectively 0.6, 0.86, and 1.2 $cm^3/g$); B) with $V_4$-$V_6$ (respectively 2.0, 6.4, and 8.4 $cm^3/g$).

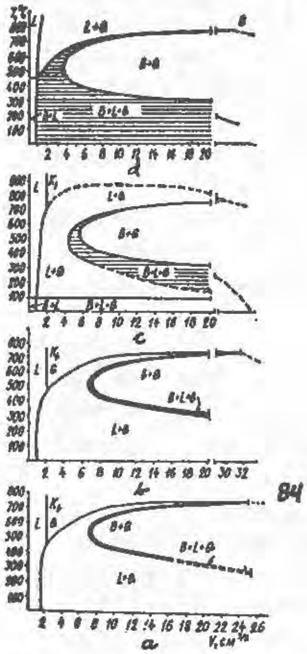


Fig. 84 [p. 206]. VT sections of the approximate VTX diagram (Fig. 82) for the $H_2O$-NaCl system with constant composition. X) concentration of NaCl, %: a) 5; b) 7; c) 28; d) 51.

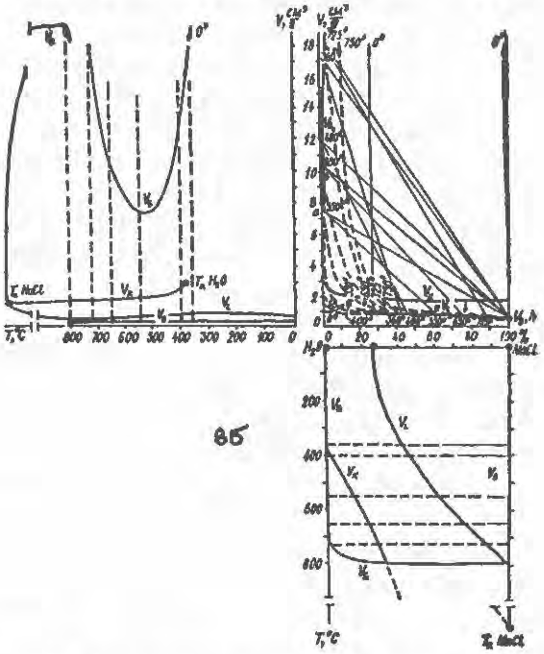


Fig. 85 [p. 207]. Projections of approximate VTX diagram for the $H_2O$-NaCl system on the VX, VT, and XT planes: $V_B$, $V_L$, $V_G$) lines of specific volumes of phases; $V_K$) line of critical volumes; $T_{cr}$) critical point; aah, bbh) isothermal sections.

isothermal sections (at 500, 600, 650, 700, 725, and 750°C) smoothly connect the corresponding $V_L$, $V_G$, and $V_{Cr}$ points.

The general form of the VTX diagram in three projections, has been presented in Figure 85. Sections of the diagram with constant V and X are illustrated in Figures 83 and 84.

This VTX diagram fundamentally corresponds to the earlier-discussed sketched diagram of the volatile-nonvolatile system, although in detail, it has substantial differences, important both for interpreting the results of measurements in inclusions, and also for revealing the patterns of phase changes in natural systems in general. This physicochemical model describes the behavior of the phases of the system on coordinates of actual values of the composition (bulk content, %), specific volume ($cm^3/g$), and temperature (0°C). With its aid, it is possible to set actual problems, and taking account of all the factors, accurately to solve them; without the diagram, this is essentially impracticable. The curve for the specific volumes of the liquid phase $V_L$ (in equilibrium with the gas G and solid B phases) has its maximum along the V axis. This extreme has been recorded for the first time; for $H_2O$-KCl, it is, for example, absent. As the composition of the gas phase at 0-725°C is strongly depleted in NaCl, the $V_G$ curve has been shifted towards the coordinate for pure $H_2O$. This, in the main, also determines the nature of the sections with constant V and X, and thus, the state of the inclusion systems during temperature changes.

The patterns for the $H_2O$-NaCl system, revealed with the aid of the VTX diagram, demonstrate the following:

1. During the homogeneous capture of inclusions from a heterogeneous medium, the nature of the penultimate phase change in the inclusions during their heating, indicates the aggregate state of the entire system of mineral origin (with respect to the phases of $H_2O$ and NaCl), that is, the origin of a particular inclusion; the nature of the final homogenization indicates the final aggregate state of the inclusion at the moment of isolation, that is, the state of its capture. For example, the inclusions that homogenize according to the scheme $B+L+G \rightarrow B+L \rightarrow L$, demonstrate that the mineral-forming system at the moment of isolation of the inclusions consisted of solution and NaCl crystals; their homogenization corresponds to the actual $T_C$.

2. For the conditions of an effervescing solution or during heterogeneous capture, [p. 208] it is possible, with the aid of the appropriate sections (Fig. 86; they are shown by dotted lines on the VTX diagram - see Fig. 82), to represent the properties of each inclusion in a family of mutually syngenetic inclusions by the actual parameters; this is also important for resolving the inverse problem: from the phase relations of a family of syngenetic inclusions, to determine the conditions of their capture or the presence of post-genetically transformed vacuoles amongst them. An analysis of the properties of syngenetic families of inclusions will permit us to separate from them those that developed through homogeneous capture, and thus, to determine the actual Tc.

3. The regime of homogenization of $H_2O$-NaCl inclusions into the gas phase is very complex in nature owing to a break for high values of V in the fields of solution and fusion; during heating, the following phase transitions are possible in such inclusions: $B+L+G \rightarrow L+G \rightarrow B+L+G \rightarrow B+G \rightarrow B+L+G \rightarrow L+G \rightarrow G$, and in this case, the liquid phase of the first three terms of the scheme is solution, and in the remainder, melt; an extreme point has been recognized, after which, as V diminishes, the solution-melt transition with rise in temperature is gradual. The melt-solution transition on the basis of temperature corresponds to a minimum on the $V_G$ curve;

it is marked by a bend in the line that separates the B+G and B+L+G fields on all the TX and TV sections, and is at approximately 525 ± 25°C. This temperature may be provisionally accepted for separating melt and solution within the B+L+G and L+G fields.

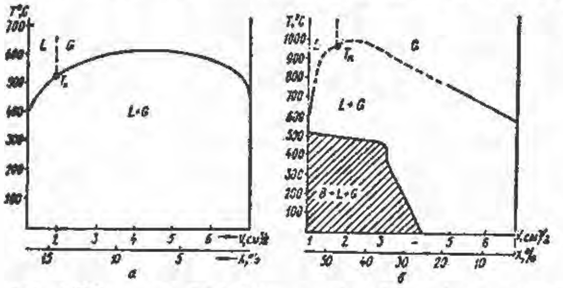


Fig. 86 [p. 208]. Sections of the approximate VTX diagram along nodal lines, joining corresponding liquid and gas phases at 400 (a) and 600°C (b) (on Fig. 82, they are marked by dotted lines). Intermediate values of V and X demonstrate possible characteristics of composition of inclusions, captured from a boiling medium at 400 and 600°C, and also temperatures of phase transitions.

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## [p. 209] PT-conditions of mineral genesis in the two-component system $H_2O$-$CO_2$ (problems of barometry).

Note: Questions of specific definitions of the terms used in this section (and variation in their usage) make it difficult to understand the author's true meaning without recourse to extensive consultations with author and translator. Dr. S.M. Sterner has very carefully reviewed this section and has summarized its salient features (as well as some confusing errors in some of the equations) in a letter which he has kindly given permission to me to distribute to interested individuals. (E.R.)

Among natural fluids other than $H_2O$, $CO_2$ is the most common. Conditions of its coexistence with water may be presented by a PTX-diagram and projections of the isothermic and isobaric cross-sections in the planes TX and PX (see Fig. 51). When compared with isochores of water, isochores of $CO_2$ in the fields L and G of the PT diagram have a steeper inclination to the pressure axis (see Fig. 22). This makes inclusions with $CO_2$ have low density, whose advantages in barometry are known. Moreover, a relatively extensive area of immiscibility of $CO_2$ and $H_2O$ allows use of inclusions from boiling (heterogeneous) fluids for relatively exact barometry. The range of P-T values obtained by this method for moderate-pressure processes may be significantly extended, if the upper T values of the combined PT parameters were determined not from Th of inclusions but by another, independent method. The aim of all the known methods of barometry is the determination of P (or P and T) in an inclusion: a) in the moment of homogenization (using inclusions of $H_2O + CO_2$ of heterogeneous origin, by a graphical method, with use of inclusion cryometry and decrepitation) and b) at the T determined indirectly or from the PT parameters of the two independent systems (from essentially G inclusions, from inclusions of high density-$CO_2$, $H_2O$ and $H_2O$ + NaCl, by the method of the commonly plotted PT diagrams [intersecting isochores?]).

Despite these numerous methods of finding of PT parameters, the single and most important condition of the correct solution of the question is the accuracy of determination of the phase state [in the Russian text: aggregate state] of the mineral-forming medium under the conditions of mineral crystallization. This may be achieved by earlier very thorough study of the families of syngenetic inclusions and selection of relics of authigenic trapping; the composition of these relics provides the correct selection of the PT diagram of the standard, experimentally studied analogous system.

## Determination of pressure from inclusions of $H_2O$-$CO_2$ of heterogeneous origin (homogeneous and heterogeneous trapping)

A.P. Karpinskiy [104] first used inclusions of $CO_2$ and P determinations. He accepted P of saturated $CO_2$ vapor at Th (+30.6°C) as equal P of amethyst formation (73 atm = 7.4 MPa) and from this he estimated the approximate depth (702 m) of formation of one of the deposits in the Urals.

R. Nacken [234] considered theoretically the problem of the possibility of determination of the conditions of origin by use of $H_2O$ and $CO_2$ inclusions. [p. 210] E.F. Holden [224] studied amethyst and smoky quartz from various deposits and he has noted the variability of the volume ratios of $CO_2$ and $H_2O$ solution in inclusions in the same specimen. This fact was explained by immiscibility of $H_2O$ and $CO_2$ under the conditions of mineral formation. This author calculated three isochores for $CO_2$ inclusions with various degrees of fill.

The present author's previous works ([83] and others) have proposed methods of P determination using inclusions with $LCO_2$ and plotting together PT diagrams of $H_2O$ and $CO_2$. Earlier there was an opinion about misuse of $LCO_2$-bearing inclusions for PT determinations. Usually R. Nacken [234] is quoted, although he has described quite completely the regularities of phase equilibria of the system $H_2O$-$CO_2$ applicable to fluid inclusions. But, despite the negative evaluation of the possibilities of the $CO_2$-filled inclusions in the determination of T (he considered that only "aqueous inclusions, in which G bubble disappears far below T critical, have here still properties of liquid and indicate the possibility of determination of T of formation of host mineral within narrow limits" [234, p. 16]), in his work there were well-founded observations and opinions, to which attention was not paid during the following years.

First, plotting on one PT diagram the state of every individual system $H_2O$ and $CO_2$, R. Nacken expressed the opinion on the possibility of determination of the true T from inclusions, formed contemporaneously by trapping in every vacuole separately pure $H_2O$ and $CO_2$. "In this case of very low probability (italicized by V.K.), one may receive the undoubtedly exact T of formation, because the point occurs on the crossing of both straight lines [op. cit.]. Second, the author presented schemes indicating the mechanism of trapping of $CO_2$ bubble by a crystal, and he found it possible to trap from heterogeneous solution separately pure G phase or with some admixture of liquid phase. However R. Nacken did not use his correct conclusions for determination of crystallization conditions. Most probably he could not solve this seeming contradiction only due to insufficient observations made directly in crystals. He has said that "conclusions, made on the basis of the individual experiments seem to be very ambiguous. Studies of numerous inclusions from one location probably may give more encouraging results" [234, p. 17].

Using material from Nagol'nyi region [83], the studied inclusions provided results which dispelled Nacken's doubts and gave a practical confirmation of the possibility of contemporaneous trapping of syngenetic inclusions of "pure" $CO_2$ and $H_2O$, i.e., that first proved the existence in nature of heterogeneous (boiling) mineral-forming solutions saturated with $CO_2$.

New and more complete data on mutual solubility and unlimited miscibility in the system $H_2O$-$CO_2$ [p. 211] at elevated P and T made it possible to move from the approximate and limited (for a given system) commonly plotted PT diagram (ideally usable only for independent phases) to a rational use of the regularities of the changing equilibrium between coexisting phases [88, p. 144]. Inclusions, formed due to trapping of individual homogeneous phases from heterogeneous solution, were proposed for determination of T ($H_2O$-filled inclusions of homogeneous trapping) and the linked P ($CO_2$-filled inclusions of homogeneous trapping). PT parameters in sealed vacuoles at the moment of homogenization should equal the true PT values, because P is the P of the saturated vapor (gas) at a given T. One also proposes a more complicated method of determination of P and T based on the mutual solubility of components, determined in inclusions, in agreement with the spatial model of the system within the PTX area.

The splitting of mineral-forming solution into two phases $H_2O$ and $CO_2$ is the basic condition of use of the $CO_2$ inclusions as geobarometers. For this reason the conditions of existence of such heterogeneous system determine the ranges of application and accuracy of this method. The space of heterogeneous equilibrium is limited by an irregular, dome-shaped surface (see cross-sections in Fig. 51).

Existence of a parent hydrothermal solution saturated with $CO_2$ and in heterogeneous state is evidenced not only by physico-chemical data of peculiarities of the system $H_2O$-$CO_2$, but also by facts of syngenetic formation of inclusions with various ratios of L phases. The immiscible state of the mineral-forming medium was found at numerous deposits in the USSR, especially for polymetallic ores of the Nagol'nyi area, rock-crystal-bearing provinces of Aldan and Polarnyi Ural, gold-ore veins of the Berezovskoe deposit, etc. Thermodynamic conditions of hydrothermal solution ascending from a magma chamber to the surface are characterized by gradual decrease of T and P. One may agree with V.A. Nikolaev that the process of distribution and condensation of the gas phase emanating from a magmatic melt "extends over certain P and T intervals with variable composition of G and L phase. Individual components of G mixture (e.g., $CO_2$) may remain in G state, dissolving partly and saturating under given conditions a condensing L solution or separating from it as a G phase on decrease of the external P, e.g., during ascending of solutions toward surface or during fracture formation in wall rocks" [156, p. 108]. Due to this the gas components ($CO_2$) may go upwards together with parent solution as an emulsion. Adhering to the crystal faces or forming directly on them, like $CO_2$ bubbles on the walls of a glass of soda-water, $CO_2$ can be [p. 212] trapped by a growing crystal. In the inclusion void the individual phases may occur in "pure" state ($H_2O$, $CO_2$) or both in various proportions.

According to the regularity of the heterogeneous equilibrium $H_2O$-$CO_2$ (Fig. 35) [sic], every liquid phase has the respective G phase of appropriate composition at a given T, i.e., they are in dynamic equilibrium. Thus in the L trapped by a crystal, on even a very small T decrease a G phase (bubble) appears due to decrease of P and solubility. For this reason T of disappearing of G phase during the laboratory heating of the inclusion will indicate the true T of inclusion trapping. Internal P at the moment of homogenization of such an inclusion also is equal P of mineral formation. But this P cannot be directly measured and one calculates it from the syngenetic inclusions of $CO_2$. In this procedure there is no necessity to use the common PT diagram. It is sufficient to find on a determined $CO_2$ isochore (Fig. 22) the point where T is equal Th of the $H_2O$-filled inclusion of homogeneous trapping.

Table 18. Filling and Th of $CO_2$-filled inclusions, characterized by isochores 0.08-0.95 g/cm$^3$ in Fig. 38 (calculated from data of [177, 211])

| Density, g/cm$^3$ | Filling with $LCO_2$ |  | Th, °C | Density g/cm$^3$ | Filling with $LCO_2$ |  | Th, °C |
|---|---|---|---|---|---|---|---|
|  | at 0°C | at 10°C |  |  | at 0°C | at 10°C |  |
| 0.08 | -- | -- | -5.9 | 0.55 | 55.3 | 57.6 | 30.6 |
| 0.12 | 2.9 | -- | 6.7 | 0.60 | 61.4 | 64.5 | 29.9 |
| 0.15 | 6.6 | 2.3 | 13.7 | 0.65 | 67.7 | 71.4 | 27.9 |
| 0.20 | 12.6 | 9.2 | 21.0 | 0.70 | 73.6 | 78.3 | 25.2 |
| 0.25 | 18.7 | 16.1 | 25.5 | 0.75 | 79.7 | 85.2 | 21.5 |
| 0.30 | 24.9 | 23.0 | 28.4 | 0.80 | 85.8 | 92.1 | 16.7 |
| 0.35 | 30.9 | 29.9 | 30.3 | 0.85 | 91.9 | 99.0 | 10.8 |
| 0.40 | 36.6 | 36.8 | 31.1 | 0.90 | 97.9 | -- | 3.1 |
| 0.45 | 43.1 | 43.7 | 31.3 | 0.95 | -- | -- | -5.2 |
| 0.50 | 49.2 | 50.7 | 31.2 |  |  |  |  |

Thus the P value will be P of trapping. The value of the partial pressure of aqueous vapor dissolved in $CO_2$ during trapping is to be added to this pressure. On the basis of the data [193] we can say that the total P in the inclusion slightly exceeds the obtained total. However, for most common conditions of hydrothermal mineral formation this difference does not exceed a few tens of atm.

Thus, for P determination it is necessary to know the Th of $H_2O$ inclusions from homogeneous trapping and density (specific volume) of $CO_2$ at the moment of inclusion trapping. [p. 213] Usually for $CO_2$ inclusions of homogeneous trapping the appropriate isochore on the PT diagram may be found from T of partial homogenization (Table 18), taking into account the volume of the condensed water solution. But if one uses $CO_2$ inclusions from heterogeneous trapping, the calculation of specific volume is significantly more complicated.

Let us consider the more general case of finding of the specific volume of $CO_2$ using inclusions from heterogeneous trapping[13].

By comparing of syngenetic inclusions from heterogeneous and homogeneous trapping, including also some experimental data for the system $H_2O$-$CO_2$, one may exclude the influence of water solution trapped by an inclusion together with G bubble of $CO_2$ at the moment of its sealing, i.e., by use of the appropriate corrections the composite inclusion [$CO_2$ + $H_2O$, A.K.] is reduced to an inclusion of $CO_2$ from homogeneous trapping. This problem is solved by consideration of the following factors, influencing the results of calculation to various degrees:

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[13] Calculation of the specific volume of $CO_2$ and determination of pressure from inclusions of heterogeneous trapping have essentially theoretical significance. It is necessary to write that a hydrothermal solution, depending on its concentration, may be more or less different than pure water. Thus the experimental data of the two-component system $H_2O$-$CO_2$ published by N.I. Khitarov and S.D. Malinin are not always close to the natural, more complex mineral-forming solutions. Taking all this into account, the mutual solubility of $H_2O$ and $CO_2$ can be better determined, when inclusions of homogeneous and heterogeneous trapping are compared. Such data for Donbass, however, almost did not differ from the experimental ones [83, 103].

1. Solubility of $CO_2$ in water during mineral formation and under conditions of equilibrium in an inclusion at room T. This is to be calculated by comparing inclusions of heterogeneous and homogeneous ($H_2O$) trapping.

2. Solubility of $H_2O$ in $LCO_2$ at room T; it is lower than 0.05% and it has no practical importance.

3. Solubility of $H_2O$ in $CO_2$ under conditions of mineral formation. The range of concentrations of $H_2O$ and $CO_2$ at elevated T and P is found during study of inclusions in minerals of the studied deposit. For instance, quartz from the Polyarnyi Urals contains inclusions of $CO_2$, which do not contain water solution at all. P from the calculations appears low, thus the miscibility of phases is also low. Minimum amounts of water solution in inclusions of $CO_2$ in minerals from the Nagol'nyi area are 2-3%. Thermodynamic conditions determined from these inclusions are: T 162-165°C, P 63-70 MPa. Thus, solubility of $H_2O$ in $CO_2$ under these conditions equals 2-3% of inclusion filling. According to studies of R.F. Sukhorskiy [178], inclusions in morion from Volyn', bearing 15% of $LCO_2$ and 5% of water solutions [p. 214] homogenized at 260°C, i.e., with this composition of G solution it is possible to dissolve in it 5% $H_2O$ at 260°C.

4. Concentration of the substance of host mineral in solution under conditions of mineral formation. Influence of this factor evidently is very low due to low solubility of minerals used commonly for geobarometry.

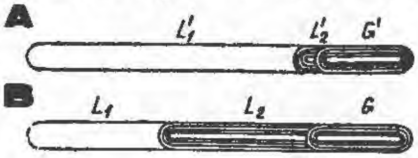

Fig. 87. Phase composition of syngenetic composite inclusions of $CO_2$ of homogeneous (A) and heterogeneous (B) trapping: $L'_1$, $L'_2$, $G'$ and $L_1$, $L_2$, $G$ - respectively volumes of water solution $LCO_2$ and gas.

Let us suppose that a mineral contains two tubular inclusions (Fig. 87), of syngenetic origin, trapped from a heterogeneous solution. Ratios of volumes of water solution, $LCO_2$ and G respectively $L'_1:L'_2:G'$ and $L_1:L_2:G$. For determination of $CO_2$ density at the moment of sealing of the inclusion from heterogeneous trapping ($dCO_2$), one should find its volume and mass ($dCO_2 = M:W$). Volume and mass of $CO_2$, observed in the inclusion at a given T are not equal to volume and mass of gas-like $CO_2$ under conditions of mineral formation. The following factors are essential for the calculations:

1. Volume of the $CO_2$ initially trapped by a mineral was lower than volume $L_2 + G$; the difference is equal thermal expansion of water solution $L_1$ proportionally to the phase ratio in inclusion A, i.e.:

$$\frac{L'_1}{L'_2 + G'} = \frac{L_1}{\Delta V'}; \qquad -\Delta V' = \frac{L_1(L'_2 + G'}{L'_1}.$$

2. Volume of the initially trapped $CO_2$ was higher than volume $L_2$ + G; the difference $\Delta L_1$ equals the volume of $H_2O$ dissolved in $CO_2$ under mineral-forming conditions. If the total $L_2 + G = 100\%$, we find $(+V") = \frac{\Delta L_1(L_2 + G)}{100}$.

3. Total mass of $CO_2$ initially trapped by a mineral was lower than its amount occurring at room T in the volume $L_2$ + G, because part of it was dissolved in water, as indicated by amount of $CO_2$ in inclusion of

water solution from homogeneous trapping. Let us call the amount of $CO_2$ occurring in solution in volumes $L'$, and $L_1$ as equal $l'$ and $l$. Thus total amount of $CO_2$ in inclusion A, if all values are expresed as volumes of $LCO_2$, will be equal $L_2 + \Delta L_2 + l'$, where $\Delta L'_2 = G\,d^G_{CO2} : d^L_{CO2}$. For both inclusions A and B the following proportion will be correct:

$$\frac{L'_1}{L'_2 + \Delta L'_2 + l'} = \frac{L_1}{\Delta V''' + l}, \text{ or } L_1 \Delta V''' + L'_1 l = L_1 L'_2 + L_1 \Delta L'_2 + L_1 l', \text{ but}$$

$L'_1 l$ and $L_1 l'$ are equal, since at a given T amounts of dissolved $CO_2$ are proportional to volumes of the taken solutions $l' : L'_1 = l : L_1$. Hence we obtain:

$$(\pm \Delta V''') = \frac{L_1 (L'_2 + \Delta L'_2)}{L'_1}.$$

[p. 215] The correction $\Delta V'''$ influences only the mass of $CO_2$ and it does not change the total volume of $CO_2$.

The correction calculations are approximate since phase volumes under the conditions of mineral formation in the first approximation are accepted as equal to those when observed under microscope. More exact results need the use of changes of volume to ΔV;, ΔV" and ΔV"'. When calculations are made with accuracy to 0.n, it is sufficient to make the double recalculation of corrections. Thus:

$$\Delta V_1 = \frac{(L_1 - \Delta V'')\ (L'_2 + G')}{L'_1};$$

$$\Delta V_2 = \frac{\Delta L_1\ (L_2 + G - \Delta V' + \Delta V'')}{100};$$

$$\Delta V_3 = \frac{(L_1 - \Delta V'')(L'_2 + \Delta L'_2)}{L'_1}.$$

Finally $CO_2$ density at the moment of trapping in inclusion can be calculated using the formula:

$$d_{CO_2} = \frac{M}{W} = \frac{L_2 d^L_{CO_2} + G d^G_{CO_2} - \Delta V_2 d^L_{CO_2}}{L_2 + G - \Delta V_1 + \Delta V_2}. \qquad (13)$$

Pressure determination by complex $CO_2$ inclusions from heterogeneous trapping. For more exact P determinations of mineral formation it is always best to use $CO_2$ inclusions of homogeneous origin. Such inclusions always can be detected during careful check of a preparation[sic]. Experiments made by M.O. Kliya and I.G. Sokolova [106] provide a confirmation that homogeneous trapping is very common in the formation of $CO_2$ inclusions. However, sometimes it is necessary to use inclusions from heterogeneous trapping. Moreover, the experience of determination of mineral-forming conditions by use of complex $CO_2$ inclusions provides a better understanding of a given method and the possibilities of its application.

Specimens of minerals bearing inclusions of L $CO_2$ are studied in detail under the microscope. The aim is to establish the phase composition of the parent solution (homo- or heterogeneous with respect to $CO_2$). Special attention should be paid to the post-genetic alteration of inclusions (necking-down, refilling, etc.). Such alterations may sometimes be interpreted as heterogeneous trapping.

After the reason for the various phase filling for syngenetic inclusions is established, in case of applicability of a given method, groups of inclusions are studied to determine the amount of water which was dissolved in the $CO_2$ under the conditions of mineral formation. The selected values may be corrected according to the tentative calculations of the approximate T and P of inclusion sealing. Finally the syngenetic inclusions for direct calculation of mineral-formation conditions should be selected -- inclusions of $CO_2$ of heterogeneous trapping and inclusions of $H_2O$ of homogeneous trapping.

Use of the formula (13) needs a direct measurement of the phase relations in both inclusions at the same (room) T. However, the measurement of the phase ratio is always of low accuracy and thus one should always (if possible) use a method where the number of measurements is small. Such a case occurs during heating up to T of partial homogenization of complex inclusions (L $CO_2$ + G $CO_2$). T may be measured relatively exactly. Thus, volumes of phases are measured usually at T of disappearance of G bubble in an inclusion of $CO_2$ from heterogeneous trapping. The cases when one measures phase volumes at T of disappearance (or of condensation) of L $CO_2$ in inclusion of $H_2O$ of homogeneous origin are much rarer.

For the first case the P calculation is a follows: T of partial homogenization of the complex inclusion $CO_2$ is measured with an accuracy ±0.5°C and from the table the respective density is found. At a given Th (partial) the percent ratio of phases is determined in both inclusions. Then the corrections $\Delta V'$, $\Delta V''$, $\Delta V'''$ and $\Delta V_1$, $\Delta V_2$, $\Delta V_3$ are calculated and the values found are put in formula (13), which, for the given case, will be as follows:

$$d_{CO2} = \frac{(L_2 - \Delta V_3) d^L_{CO2}}{L_2 - \Delta V_1 + \Delta V_2} \qquad (14)$$

The second case of $CO_2$ density calculation is typical of low P mineral formation, when complex inclusions may be formed, in which during laboratory heating all $CO_2$ goes to G phase (partial homogenization to G phase). It is reasonable that under such conditions L $CO_2$ in a syngenetic $H_2O$ inclusion of homogeneous trapping will evaporate to gas below the T of partial homogenization of the complex inclusion. In this case the phase ratio should be measured in both inclusions at Th (or at condensation) of $CO_2$ in the $H_2O$ inclusion from homogeneous trapping. The correction $\Delta V_3$ is determined similarly to the case described above and $\Delta V_1 = \Delta V_2 = \frac{G'(L_1 - \Delta V'')}{L'_1}$, if the amount of $CO_2$ dissolved in water under conditions of the inclusion sealing are expressed in units of its volume in the gas state.

Thus the general formula for calculation of $CO_2$ density under conditions of the mineral formation will be as follows:

$$d_{CO2} = \frac{L_2 d^L_{CO2} + (G - \Delta V_3) d^G_{CO2}}{L_2 + G - \Delta V_2 + \Delta V_2} .$$

**Determination of pressure using complex $CO_2$ inclusions from homogeneous trapping.** Preliminary studies of mineral specimens with $CO_2$ inclusions are performed as above. Finally for measurements those syngenetic inclusions are chosen, which have minimum and maximum amount of water solution, under the assumption that the first ones formed due to trapping of only "gas" phase ($CO_2$), and the second ones - only liquid solution. But frequently a certain amount of liquid water solution is trapped together with a homogeneous ("gaseous") phase. However, relatively small amounts of water solution trapped during sealing of the $CO_2$ bubble do not show any essential influence on the measurement results.

It was found, practically, that the upper limit for this "minimum amount" is 5% of water solution not including the $H_2O$ dissolved in $CO_2$ under the mineral-forming conditions.

Because of peculiarities of the use of this method and conditions of inclusion selection for calculation of P, the factors connected with the equilibrium of the components with limited miscibility practically have no significance. Such factors are a) solubility of $CO_2$ in $H_2O$ under conditions of mineral formation; b) solubility of $H_2O$ in L $CO_2$ at room T; c) solubility of $CO_2$ in $H_2O$ under conditions of equilibrium inside an inclusion at room T (the calculations indicate that for 4% [salt] water solution present in an inclusion, the dissolved $CO_2$ increases the final P value only of 0.n MPa, which may not be taken into account, and $CO_2$ solubility in $H_2O$ during mineral formation has the reverse influence).

Results of determinations mostly depend on the amount of water dissolved in compressed gas-like $CO_2$ under conditions of inclusion trapping ($\Delta L_1$). This value is determined by studies of phase relations in families of syngenetic inclusions and from the experimental data, similarly as is done during the selection of $CO_2$ inclusions from heterogeneous trapping.

The $CO_2$ density at the moment of inclusion sealing is found from the T of gas bubble disappearance in a $CO_2$ inclusion from homogeneous trapping. However, the correction for the volume of the water solution $\Delta L_1$ should be used; this refers to the water amount present in solution under the mineral-forming conditions. If partial homogenization occurs in the L phase, equation (13) is in this case as follows:

$$d_{CO2} = \frac{L_2}{L_2 + \Delta L_1} d^{L}_{CO2} ,$$

because $\Delta V_1 = 0$, $\Delta V_3 = 0$ and $\Delta V_2 = \frac{\Delta L_1(100 + 0)}{100} = \Delta L_1$. The value $d_{CO2}$ is found in the tables from the T of disappearance of the gas bubble.

If during heating the inclusion becomes partly homogenized due to the change L $CO_2$ → G $CO_2$, the calculations should be made from the following version of equation (13):

$$d_{CO2} = \frac{G}{G + \Delta L_1} d^{G}_{CO2},$$

because $\Delta V_1 = \Delta V_3 = 0$, and $\Delta V_2 = \Delta V_1$. The value $d^{G}_{CO2}$ is determined from tables on the basis of condensation of $CO_2$ in a $CO_2$ inclusion of homogeneous origin.

From the determined $d_{CO2}$ and Th of the $H_2O$-filled inclusion the appropriate isochore and the point on it are found, where P has the value to be determined. For exact determination of the isochore Table 19 is used. Partial pressure of the $H_2O$ vapor $\Delta P$ should be added to the found P value, which occurs in the mixture with $CO_2$ in the moment of inclusion sealing.

The method of P determination by use of $CO_2$ inclusions from homogeneous trapping gives results of satisfactory accuracy. Errors may occur essentially due to inaccuracy of Th measurements of the $H_2O$ inclusions, T of partial homogenization of the $CO_2$ inclusions and solubility of $H_2O$ in $CO_2$ at elevated P and T.

Errors of Th determinations for inclusions of aqueous solutions with use of a well-calibrated heating stage are not higher than ±1 to 2°C. According to the P-T plot, such an error may cause errors of P determination of tenths of MPa (few atm), and hence may be omitted.

More significant errors may appear due to inexact measurement of Th

Table 19. The saturation curve L - G for $CO_2$[211]

| Th, °C | Density of L $CO_2$, g/cm$^3$ | Density of G $CO_2$, g/cm$^3$ | Pressure | | Th, °C | Density of L $CO_2$, g/cm$^3$ | Density of G $CO_2$, g/cm$^3$ | Pressure | |
|---|---|---|---|---|---|---|---|---|---|
| | | | atm | MPa | | | | atm | MPa |
| 0 | 0.914 | 0.096 | 34.3 | 3.48 | 18 | 0.786 | 0.176 | 53.8 | 5.45 |
| 1 | 0.910 | 0.099 | 35.2 | 3.57 | 19 | 0.776 | 0.183 | 55.0 | 5.57 |
| 2 | 0.906 | 0.103 | 36.1 | 3.66 | 20 | 0.766 | 0.190 | 56.3 | 5.71 |
| 3 | 0.900 | 0.106 | 37.0 | 3.75 | 21 | 0.755 | 0.199 | 57.6 | 5.75 |
| 4 | 0.894 | 0.110 | 38.0 | 3.85 | 22 | 0.743 | 0.208 | 59.0 | 5.98 |
| 5 | 0.888 | 0.114 | 39.0 | 3.95 | 23 | 0.731 | 0.217 | 60.4 | 6.08 |
| 6 | 0.882 | 0.117 | 40.0 | 4.05 | 24 | 0.717 | 0.228 | 61.8 | 6.26 |
| 7 | 0.876 | 0.121 | 41.0 | 4.15 | 25 | 0.703 | 0.240 | 63.3 | 6.41 |
| 8 | 0.869 | 0.125 | 42.0 | 4.26 | 26 | 0.688 | 0.252 | 64.7 | 6.56 |
| 9 | 0.863 | 0.129 | 43.1 | 4.37 | 27 | 0.671 | 0.266 | 66.2 | 6.71 |
| 10 | 0.856 | 0.133 | 44.2 | 4.48 | 28 | 0.653 | 0.282 | 67.7 | 6.86 |
| 11 | 0.848 | 0.137 | 45.3 | 4.59 | 29 | 0.630 | 0.303 | 69.2 | 7.01 |
| 12 | 0.851* | 0.142 | 46.4 | 4.70 | 30 | 0.598 | 0.334 | 70.7 | 7.16 |
| 13 | 0.831 | 0.147 | 47.5 | 4.81 | 30.5 | 0.574 | 0.356 | 71.5 | 7.25 |
| 14 | 0.822 | 0.152 | 48.7 | 4.93 | 31.0 | 0.536 | 0.392 | 72.3 | 7.33 |
| 15 | 0.814 | 0.158 | 50.0 | 5.07 | 31.25 | 0.497 | 0.422 | 72.8 | 7.38 |
| 16 | 0.804 | 0.164 | 51.2 | 5.19 | 31.35 | 0.464 | 0.464 | 72.9 | 7.39 |
| 17 | 0.796 | 0.170 | 52.4 | 5.31 | -- | -- | -- | -- | -- |

*Sic - probably should be 0.841 (E.R.)

of the $CO_2$ inclusion. Analysis of the P-T plot up to 300°C and 100 MPa shows that a given value of error of Th of the $CO_2$ inclusion may cause various P errors. For the field of this plot limited with isochores starting from the phase equilibrium curve and branching to the right and to the left at T points 0-28°C, an error in Th measurement of 0.5°C leads to P errors of 2-3% of the estimated pressure. In the field between isochores starting from the phase equilibrium curve at 28-31.4°C the errors in P determinations become significant because small interval of Th (2-3°C) is pertinent to large field between the isochores. The P error may in this case be 10-15% per 0.5°C.

Inaccuracy of determination of the water solubility in gaseous supercritical $CO_2$ increases the error of P determination. It may achieve 3-5% if inclusions have Th <28°C and the accuracy of $H_2O$ solubility in $CO_2$ ±1%.

## Graphical method of pressure and temperature determination

Relation between pressure, temperature, composition and total specific volume of mixtures $H_2O + CO_2$ [193] and the mutual solubility of $H_2O$ and $CO_2$ under elevated P and T [136] permit a graphical method of finding of parameters of the homogeneous closed system (Ph and Th of inclusions in mineral) of known composition X and filling degree F. The construction of the plot F-Th for solutions of $CO_2$, in addition to theoretical importance, also has practical value, because Th of the most $CO_2$ inclusions cannot be measured by normal heating because of decrepitation of vacuoles before homogenization. From the phase relations in the inclusion (or in the autoclave) by use of the F-Th plot the values of Ph and Th can be determined without heating. The proposed method may be useful in experimental works with $CO_2$.

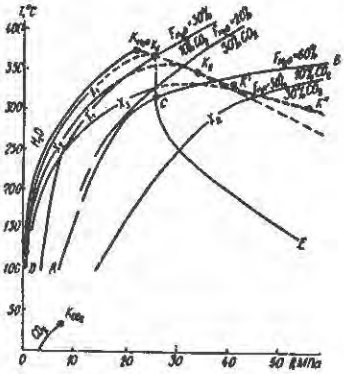

Fig. 88. Projection of the diagram PTX for $H_2O$-$CO_2$ on the plane PT, plotted on the basis of the data by N.I. Khitarov and S.D. Malinin [193, 194]: $X_1$, $X_2$, $X_3$ - projections of the sections of the constant total compositions of the system, pertinent to the mass relations of $H_2O$ and $CO_2$ (in wt. %): 90:10, 70:30, 50:50; $X_1'$, $X_1''$, $X_2'$, $X_3'$ - curves of pressure change during heating of the system $H_2O$-$CO_2$ of the various filling (above the line) and $CO_2$ content (under the line); AC-PT relation of the system before its homogenization, CB - the same after homogenization (in L or G phase); $H_2O$, $CO_2$, $K_{H2O}$, $K_{CO2}$ - curves of two-phase equilibrium of the pure components and their critical points; $K_{H2O}K''$ - critical points of mixtures of compositions $X_1$ and $X_2$; $K_1$, $K_2$ - critical points of mixtures of compositions $X_1$ and $X_2$; K', K'' - critical points of mixtures obtained from the PX plot of S.D. Malinin [136].

The closed autoclave system used in the experiments on studies of P-T relations [193] may be accepted as completely similar to the complex $CO_2$ inclusions with the same composition and filling. The P and T changes in such systems may be shown by the curve AB (Fig. 88); its lower part refers to the two-phase equilibrium liquid-gas, and the upper one - relations of the thermodynamic parameters in the one-phase medium. Point C separates the two branches of the curve and it indicates the conditions of homogenization of the system. In the case of a relatively high total density of the system the position of this point is fixed experimentally in a certain area of the bending of the curve AB. However, this area is relatively wide and indistinctly expressed, thus it is impossible to find a determined point of the homogenization moment. Solution of this problem is possible by graphical construction based on the data of solubility [136].

The P-T-X plot of the system $H_2O$-$CO_2$ with projections of the isothermal and isobaric sections is given in Fig. 51. For our purposes the sections of constant composition are important. One such PT section $X_1$ is shown in Fig. 88. The curve DE[14] indicates the section of the dome-shape surface of the two-phase equilibrium by the surface of constant composition $X_1$. The curve AB and the PT section are characterized by the same composition ($X_1 = 10\%\ CO_2$). Thus, the crossing point C of the curve AB and the line DE indicates the conditions of homogenization of the closed system (autoclave or an inclusion).

Every point on the curve of constant volume DE reflects the determined specific volume of the system (as is shown by its filling with L phase at a given T). Thus, within the composition ratio ($H_2O:CO_2$ = 90:10) it is possible to construct an infinite number of PT curves for various fillings and finding in their crossing points with the curve DE the respec-

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[14] The curve DE in the plot is the complex line $X_1'$, going through the points $DK_1CE$.

tive values of T and P of homogenization. In Fig. 88 only three P-T sections ($X_1$, $X_2$ and $X_3$) and certain of the PT relation curves ($X_1'$, $X_1''$, $X_2'$ and $X_3'$) are given for example.

According to the published results there were calculated F-Th curves (Fig. 89) for systems in which the $CO_2$ contents are equal (in %): 5 ($F_{H2O}$ = 50-60%), 10 (F = 20-60%), 15 (F = 50-60%), 20, 30 and 40 (F = 20-50%) and 50 ($F_{H2O}$ = 20-40%). The external dome-shaped curve and the plotted sections of the curves falling below it (dashed lines) show the relation F-Th respectively for pure water and the inclusions bearing various mass amounts of $CO_2$ (in %). $K_{H2O}$[sic; "K" on Fig. 89; E.R.] means Th of a $H_2O$ inclusion with critical filling. The curve going down from the point $K_{H2O}$ is the line of critical T and filling of homogenization of mixtures $H_2O + CO_2$. Thin continuous lines are isobars. For their construction the additional isobaric sections of the PTX diagram were used. Isobars were found by interpolation.

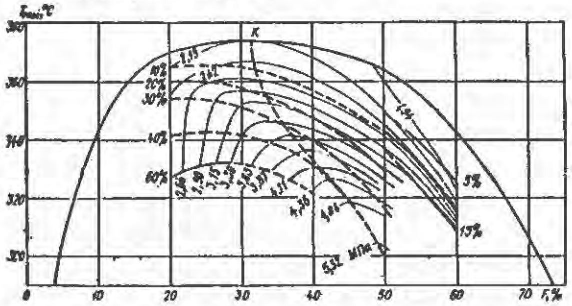

Fig. 89. Relation between Th of the complex $CO_2(H_2O + CO_2)$ inclusions and degree of water filling and $CO_2$ content.

[The plot F-Th is not complete due to the limited experimental data. Accuracy of the plotted curves is relatively low (errors of T are ca. ± 2 to 5°C, P 0.5 to 1.0 MPa, measurement errors omitted). The latter is caused by an insufficient number of solubility measurements, especially in the part of the bending of the dome-shaped surface, where interpolation is very difficult. More detailed and accurate experimental measurments would permit sufficiently precise determination of Ph and Th.]

Complex $CO_2$ inclusions contain the following phases: water solution ($L_1$), L $CO_2$ ($L_2$) and gas (G) in various volume ratios. From the amount of $CO_2$ one may calculate the total weight content of $CO_2$ (in %) in the vacuole. The latter is necessary for finding of Th and Ph from the plot F-Th. If one omits the very minor influence (at room T) of the volume effect of the $CO_2$ solubility, the amount of water in vapor phase and thermal expansion of L phase in T ranges 0-4 and 4-15°C, one may calculate for water solutions of $CO_2$ the volume ratios $L_1$:$L_2$:G according to the published results of O. Hähnel [222]. Fig. 90 shows the results of calculations for temperatures 0 and 15°C. Total content of $CO_2$ is determined by adding of its amounts in all phases of an inclusion at a given T and the internal P of G $CO_2$.

The diagram F-Th may be used for determination of Th and Ph of complex real $CO_2$ inclusions, if the salt concentration in inclusion solutions is insignificant. General regularities obtained for hypothetical $H_2O + CO_2$ inclusions, seemingly, are appropriate also for natural systems with higher salt content. Especially, they confirm the experimental data (obtained in heating stages) showing Th decrease for complex $CO_2$ inclusions in topaz from the Urals [63] and in quartz from Volyn' [178].

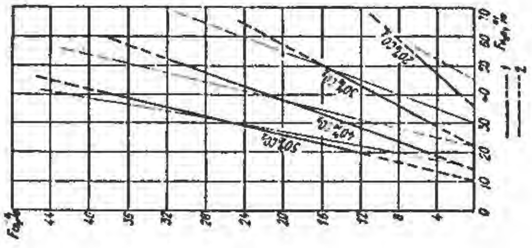

Fig. 90. Relation between the total $CO_2$ content in inclusions, filling with $H_2O$ and L $CO_2$; 1 - for 0°C; 2 - for 15°C; intermediate values of $CO_2$ should be found by interpolation.

The proposed graphical method of Th and Ph determination of the closed systems $H_2O$-$CO_2$ and the diagram F-Th for the complex $CO_2$ inclusions (within the filling limits from 20 to 40% and $CO_2$ content from 10 to 50%) permit the following conclusions:

1. Homogenization temperatures in L and G phases decrease with an increase of the $CO_2$ content.
2. Ph increases in such cases: a) with an increase of the $CO_2$ amount with constant filling; b) with an increase of the filling, when $CO_2$ concentration is constant, except of the systems containing less than 5% $CO_2$ and homogenizing in L phase (caused by the stronger influence of Th change than change of the absolute amount of $CO_2$).
3. Critical filling (similar to the system $H_2O$-NaCl) increases with increase of $CO_2$ content. With low $CO_2$ concentrations it is close to the critical F of water (31.3%); with high ones it approaches the critical F of $CO_2$ (45.0%).
4. Additional constructions of sections of the P-T-X diagram indicate that a) critical curve of the system $H_2O$-$CO_2$ in the isobaric sections takes (along the T axis) the highest position, and b) in the sections of constant composition the points of the critical curve occur below the maximum of the curves (along the T axis). This peculiarity is caused by the non-proportional distribution of $CO_2$ between L and G phases at various T. Due to this the F decrease of 5-15%, when compared with the critical F (at the constant $CO_2$ content), causes an increase of Th in G phase. Further F decrease is connected (similar to inclusions of pure water) with decrease of Th.

## Determination of pressure with use of thermometry, cryometry and decrepitometry

The possible modes of P calculation existing in inclusions at Th with use of the data of thermometric and cryometric analysis were discussed by Yu.A. Dolgov, L.Sh. Bazarov and I.T. Bakumenko [51]. The decrepitation method was used for barometric determinations by V.B. Naumov and S.D. Malinin [151]. The best objects for both methods are the complex $CO_2$ inclusions.

The publication [51] presents in detail, using real examples, the above methods of P calculation. For identification of the state of an inclusion with a well-studied system (in a P-T plot), satisfactory information on the inclusion composition is necessary. The more exact the [compositional] data, the more appropriate the system that may be applied and the more exact the obtained results. The authors find the total salt concentration (NaCl equiv.) and the ratio water (solution):$CO_2$ in inclusions using the well known methods of thermo- and cryometry. For P determination the constructed plots (from known experimental data) are used

[176, 251]. The proposed method may be improved during use by more exact methods of inclusion composition study.

Pressure at the moment of inclusion decrepitation during heating in heating stage does not equal the conditions of crystallization. Although the experimentally obtained P indicates an average value, its value may vary within very wide ranges, as indicated in [151]. Taking into account the indeterminate nature of this parameter and other errors of the measurements, seemingly this method of finding of P in the mineral-forming medium on the basis of the initial T of the abundant decrepitation is essentially limited in practical use.

## Pressure calculations from the upper limit of mineral-formation temperature

The state of the inclusion system may be extrapolated with use of a known standard diagram to high thermodynamic parameters, if one knows the composition of the inclusions. The data obtained indirectly and indicating the T of existence or crystallization of minerals with the studied inclusions permit the determination of the intra-vacuole pressure.

There are examples known of P determination by this method in inclusions filled by $CO_2$, $H_2O$, $CH_4$ and $H_2O$ plus NaCl. The method of the commonly plotted diagrams also may be included here.

P inside the essentially G inclusion at the moment of homogenization may be regarded as the minimum P of mineral formation. Maximum possible P may be calculated with respect to the upper limit of T of mineral formation. For instance, for pegmatites, the T limits may be Th of an inclusion and - on the other hand - either beginning of the pegmatite crystallization from melt (700°C after Fersman) or the α-β inversion of quartz (600-575°C).

However, P inside an inclusion at the moment of homogenization due to presence of water vapor and other G components is not always equal to the P of saturated vapor or solution at a given T. Presence of other G components well can be determined during the opening of inclusions in a liquid medium. The relative increase (or decrease) of G bubble permits an estimate of the total specific volume of the mixture and P under the given conditions. If P inside an inclusion, volume and T (room conditions) and at the moment of homogenization are respectively: $P_1$, $W_1$, $T_1$ and $P_2$, $W_2$, $T_2$, and after the inclusion opening - $P_3$, $W_3$, $T_3$, thus, according to the ideal gas law:

$$P_1W_1 = P_3W_3;$$
$$P_1V = RT_1;$$
$$P_2V = RT_2,$$

hence:

$$P_1 = \frac{W_3P_3}{W_1}; \qquad (15)$$

$$V = \frac{RT_1}{P_1};$$

$$P_2 = \frac{RT_2}{V}. \qquad (16)$$

Putting in the equations (15) and (16) the appropriate expressions for $P_1$ and V, we find:

$$P_2 = \frac{T_2W_3P_3}{T_1W_1}$$

Partial pressure of $H_2O$ vapor at a given T should be added to the value $P_2$, because of the presence of L phase in the inclusion: $P = P_2 + P_{H2O}$.

If the G composition in an inclusion is known, it is better to use the equation for real gases.

The calculation shows that errors of P measurements by this method reach ± 10 to ± 15%. This low accuracy is essentially caused by the low accuracy of the inclusion vacuole measurements (about ± 15%).

Similarly, inclusions with density close to 1 g/cm$^3$ may give information on P in fluid medium during metamorphism or mineral crystallization from melt. On the appropriate isochores extending to high PT parameters as straight lines, from an assumed or determined T one determines P. This way P was found for the crystallization of kyanite in metamorphic rocks and pegmatites of the E. Transbaikalia [52]. E. Roedder [241] calculated P in inclusions in olivine from nodules from basalts at T 1200°C as equal 250-500 MPa.

In the publications by V.B. Naumov [149] and other investigators the syngenetic inclusions of aqueous fluids and magmatic melts are used for barometry, as well as the presumably crystallized magmatic inclusions with a water solution phase. As in the method considered above, the isochore for the calculated density continues to the T of the beginning of melting or final crystallization of the inclusion filling; at this point the appropriate P is found.

The author does not reject the practical use of the above listed methods of barometry, but it is necessary to remark that the possible complication of the fluid composition due to easily water-soluble salts, dissolved at the time of fluid separation from melt, may change the proposed picture of the thermodynamic parameters of the essentially aqueous standard, especially at elevated T. Unambiguous evidence of the authigenic nature of phase composition of the used inclusions is [also] necessary.

Peculiarities of barometry of the mineral-forming process on the basis of NaCl-$H_2O$ inclusions were already discussed (see p. 189). Unfortunately, necessary experimental studies are absent for such inclusion systems, and their high density does not permit the use of the approximate relations of thermodynamic parameters.

The method of the joined P-T diagrams is essentially applicable practically, but depending on the degree of the mutual solubility of substances, it has limited ranges of use. This is pertinent also to some extent to the $H_2O + CO_2$ inclusions. It is important, however, not to overestimate their possibilities and to really evaluate the obtained parameters. For instance, the total absence of mutual solubility of aqueous solutions and $CO_2$ was supposed during P determinations for quartz crystallization (S. Urals) [122]. But the obtained results are very high (200-250 MPa and 470-550°C); they are too high for use of the model of complete immiscibility, if one takes into account the experimental data for the system $H_2O$-$CO_2$.

1. Alimarin, I.P., Petrikova, M.N. Inorganic ultramicroanalysis. - Moscow: Edition of AN SSSR, 1960, p.151.
2. Ansheles, O.M. Some studies of growth and dissolving of microscopical hyposulfate crystals. - In: Uchen. zap. Leningrad Univ. Seria geol.-pochv. nauk, 1939, No.5, v.21, p.1-10.
3. Arnautov, N.V., Nikitina, E.I. Application of microspectral analysis in the study of accessory minerals. - In: Mineral microinclusions, Moscow, Nauka, 1965, p.36-41.
4. Bazarov, L.Sh. Device for freezing of inclusions in minerals. - In: Materials on genetic and experimental mineralogy. Novosibirsk: Nauka, 1966, v.4, p.231-234.
5. Bazarov, L.Sh. Microthermostage for high-temperature investigations of inclusions in minerals. - Geologia i geofisika, 1968, No.8, p.140-142.
6. Bakumenko, I.T. On the determination of the indices of refraction of the fluid inclusions of minerals with the help of Fedorov's universal stage. - In: Materials on genetic and experimental mineralogy. Novosibirsk: Nauka, 1964, v.2, p.297-314.
7. Balitskii, V.S. Experimental study of geochemical conditions of formation of quartz crystals. - PhD dissertation in geol.-mineralogical sciences. Moscow, 1971, 50p.
8. Beliankin, D.S. Crystaloptics. - Moscow, Gosgeoizdat Edition, 1949, 126p.
9. Bershov, L.V. Atomic hydrogen and methane in some natural minerals. - Geochimia, 1970, No.10, p.1275-1278.
10. Betekhtin, A.G. Hydrothermal solutions, their nature and processes of ore formation. - In: Main problems in doctrine of magmatogenic ore deposits. Moscow, Edition of AN SSSR, 1955, p.125-278.
11. Borisenko, A.S. Determination of sodium carbonates and bicarbonates in solutions of gas-fluid inclusions by the method of cryometry. - In: Mineralogy of endogenous formations (by inclusions in minerals). Novosibirsk, Edition of Zap.-Sib. kn.izd-vo, 1975, p.98-104.
12. Bratus', M.D. Mineralogical-geochemical peculiarities of pegmatite formation of Korsun'-Novomirgorodski pluton (by gas-fluid inclusions) Candidate's dissertation in geol.-mineralogical sciences, L'vov, 1975, 24p.
13. Vargaftik, N.V. Reference book on thermophysical properties of gases and fluids. - Moscow, Nauka, 1972, 720p.
14. Vel'chev, V.N., Mel'nikov, F.P. An experience of application of a microscope with the Kofler heating/cooling stage for thermo-and cryometrical investigation of fluid inclusions in some minerals. - In: Mineralogical thermometry and barometry. Moscow: Nauka, 1965, p.123-128.
15. Vernadskii, V.I., Mineralogy, 3rd edition, Moscow, 1910, No.1, 344 p.
16. Vertushkov, G.N., Sokolov, Yu.A., Popov, V.A. Vein quartz of some gold-ore deposits of Urals. - Tr. Instituta geologii i geochimii Ural. fil. AN SSSR, 1970, No.86, p.38-43.
17. Voano, V.G. Modification of Ence's method of gas analysis, trapped in bubbles in glass. - Optico-mech. prom-st', 1937, No.2, p.38-45.
18. Vozniak, D.K. Physical-chemical characteristic of mineral-forming

solutions of the period of zanorysh-formation of Volynia pegmatites. Candidate's disseration in geol.-mineral sci., Kiev, 1971, 24p.

19. Vozniak, D.K., Galaburda, Yu.A. Device for cryometrical investigation of inclusions in minerals. - Mineral. sbornik L'vovsk. Universitet, 1977, No.31, issue 1, p.63-65.
20. Vozniak, D.K., Kalyuzhnyi, V.A. Reforming of inclusion forms in minerals of variable composition and its influence on composition of maternal solution in vacuoles (on the example of topaz from Volynia). Dokl. AN SSSR, 1973, No.5, v.212, p.1192-1195.
21. Vozniak, D.K., Kalyuzhnyi, V.A. Application of decrepitated inclusions for reconstruction of PT-conditions of mineral formation (on example of pegmatite quartz from Volynia). - Mineral sbornik/L'vovsk. universiteta, 1976, No.30, issue 2, p.41-54.
22. Vozniak, D.K., Kalyuzhnyi, V.A. Application of decrepitated inclusions for reconstruction of PT-conditions of mineral formation (on example of pegmatite quartz from Volynia). - Mineral sbornik/L'vovsk. universiteta, 1976, No.31, issue 1, p.22-30.
23. Vozniak, D.K., Lazarenko, E.K., Pavlishin, V.I. New genetic type of quartz-skeletal crystals with hydrocarbon inclusions. - In: Regional and genetic mineralogy. Kiev, Naukova Dumka, 1978, issue 2, p.15-26.
24. Volokhov, I.M. On the evaluation of precision of thermobarogeochemical reconstructions of magma-forming conditions and magmatic minerals. - Geologia i geofisika, 1975, No.1, p.12-19.
25. Vul'chin, E.I. Physical-chemical interpretation of thermometric measurements by the method of inclusion homogenisation. - Mineral.sbornik/L'vovsk. geolog. ob-vo, 1951, No.5, p.267-290.
26. Vul'chin, E.I., Yermakov, N.P. On the influence of solution salinity during thermometric determinations and on diagrams of VTX system of silicate-water. - In: Mineralogical thermometry and barometry. Moscow, Nauka, 1965, p.95-99.
27. Galaktionova, N.A. Hydrogen in metals. - Moscow, Metallurgia, 1967, 304p.
28. Gasoyan, M.S. IR-spectroscopy of vein quartz and its application for determination of formation conditions of tin-ore deposits. Candidate's dissertation in geol.-mineral sci., Moscow, 1971, 24p.
29. Geguzin, Ya.E. Mechanism and kinetics of formation of reformed inclusions in crystals. - In: Problems of modern crystallography, Moscow, Nauka, 1975, p.110-127.
30. Genkin, A.D., Koroliov, N.V. Determination of small grains of minerals in ores. - Geologia rudnikh mestorozhd. 1961, No.5, p.64-79.
31. Gigashvili, G.M. Primary gas-solid inclusions in quartzes of Volynia pegmatites. - Mineral.sbornik/L'vov. universiteta, 1969, No.23, issue 4, p.398-404.
32. Gigashvili, G.M. Determination of solution salinity of "honeycomb" inclusions in quartz of Ukraine pegmatites by cryometric, refractometric and calculation methods. - In: Abstracts of 4th regional conference on thermobarogeochemical processes of mineral formation. Rostov-on-Don: Edition of Rostov University, 1973, p.159-160.

33. Hirshfeld, D., Keroiss, I., and Bird, R. Molecular theory of gases and liquids. - Moscow, translation from English into Russian in the edition of Izdat. inostr. lit., 1961, 929p.
34. Govorov, I.N. Physical-chemical properties of water solutions under conditions of great depths and the pneumatolytic stage in ore-forming process. - In: Problems of postmagmatic ore formation. Prague, Edition of Czech. Acad. of Sci., 1965, v.2, p.512-517.
35. Golosov, S.I., Dolgov, Yu. A., Molchanov, V.I., and Shugurova, N.A. On emanation of hydrogen during the fine crushing of minerals. - In: Materials on genetic and experimental mineralogy, Novosibirsk, Ed. Nauka, 1966, p.220-226.
36. Goncharov, V.I. and Sidorov, A.A. Thermobarogeochemistry of volcanogenic ore formation. - Moscow, Ed., Nauka, 1979, 207p.
37. Grigoriev, D.P. On the issue of differentiation between primary and secondary liquid inclusions in minerals. - Mineral. sbornik/L'vov geol. o-vo, 1948, no.2, p.75-81.
38. Grigoriev, D.P. Some phenomena of mineral genesis in veins. - Zap. Vses. mineral. o-va, 1954, part 83, issue 3, p.177-197.
39. Grigoriev, D.P. Ontogeny of minerals, L'vov, Ed. of L'vov univers., 1961, 281p.
40. Grigoriev, D.P. Introduction - In: Genesis of mineral individuals and aggregates. - Moscow, Nauka Press, 1968, book 2, p.95-97.
41. Groshenko, A.R. Development of research technique for inclusions of mineral-forming media by the homogenization method. - In: Mineralogical thermometry and barometry. Moscow, Nauka Press, 1968, book 2, p.95-97.
42. Grushkin, G.G. Temperatures of quartz formation at Aurakhmat deposit. - Izv. AN Uzbek. SSR, 1948, v.2, p.36-46.
43. Grushkin, G.G. Some results of study of temperatures of quartz and fluorite formation. - Tr. In-ta geologii AN UzSSR, 1949, v.4, p.124-141.
44. Grushkin, G.G. Gas-liquid inclusions as a mineralogical barometer. - Zap. Vses. mineral. o-va, 1953, part 82, issue 2, p.125-137.
45. Grushkin, G.G. Some issues of mineral genesis. - Mineral sbornik/L'vov. geol. o-vo, 1960, no.4, p.71-81.
46. Grushkin, G.G. and Prikhod'ko, P.A. On the changing of chemical composition, concentration and pH of gas-liquid inclusions in successive fluorite generations. Zap.vses. mineral. o-va, 1952, p.81, issue 1, p.120-126.
47. Gryn'kiv, Z.S. and Kalyuzhnyi, V.A. Some methods of chemical analysis of liquid inclusions in minerals. - Tr. VNIISIMS, 1966, v.9, p.27-37.
48. Dobretsova, I.L. Determination of saline composition of liquid inclusions by the method of cryometry. - In: Mineralogical thermometry and barometry, Moscow, Nauka Dumka Press, 1968, book 2, p.64-69.
49. Dolgov, Yu. A. Genesis particularities of high temperature quartz. - Mineral sbornik/L'vov. geol. o-vo, 1955, no.9, p.85-89.
50. Dolgov, Yu.A. Thermodynamic peculiarities of granitic chamber pegmatite formation. - Doctoral dissertation in geol. mineral. sci., Moscow, 1968, 48p.
51. Dolgov, Yu.A., Bazarov, L.Sh., and Bakumenko, I.T. Method of pressure determination in inclusions by cooperative application of homogenization and cryometry. - In: Mineralogical thermometry and barometry. Moscow, Nauka Press, 1968, book 2, p.9-17.

52. Dolgov, Yu.A., Makagon, V.M., and Sobolev, V.S. Fluid inclusions in kyanite from metamorphic rocks and pegmatites of Mamskii region (North-East Transbaikalia). Dokl. AN SSSR, 1967, v.175, no.2, p.444-447.
53. Dolgov, Yu.A. and Simonov, V.A. Investigation of gas-liquid inclusions during heating above the homogenization temperatures. - In: Thermobarogeochemistry and genetic mineralogy, Novosibirsk, Nauka Press, 1975, p.121-123.
54. Dolgov, Yu.A. and Shugurova, N.A. Gas compositions in individual inclusions of various minerals. - In: Mineralogical thermometry and barometry, Moscow Nauka Press, 1968, book 1, p.290-298.
55. Dolgov, Yu.A. and Shugurova, N.A. Results of gas investigation in inclusions of Lunar glasses. - In: Lunar soil from the Sea of Abundance, Moscow, Nauka Press, 1974, p.356-362.
56. Dolomanova, E.I., Bershov, L.V., and Gasoyan, M.S. Isomorphic trace elements in vein quartz of tin-ore deposits of Transbaikalia. Izv. AN SSSR, ser. geol., 1972, no.6, p.68-74.
57. Dolomanova, E.I., Bogoyavlenskaya, I.V., Boyarskaya, R.V., and Loseva, T.I. On the question of physical-chemical conditions of formation of cassiterite-quartz type of deposits from the data of gas-liquid inclusions in minerals. New data on the minerals of the USSR, 1979, issue 28, p.58-78.
58. Druchok, L.P. and Kalyuzhnyi, V.A. Microspectral method of study of solid phase compositions in inclusions of minerals. - Abstracts of regional conference, L'vov., 1975, p.72-73.
59. Eliseev, N.A. On pneumatolytic crystallization of minerals. - Mineral sbornik/L'vov. geol. o-vo, 1948, no.2, p.53-73.
60. Ermakov, N.P. Temperatures of formation of hydrothermal optical minerals of Middle Asia. - Sov. geologia, 1944, no.1, p.28-45.
61. Ermakov, N.P. Origin and classification of fluid inclusions in minerals. - Mineral. sbornik/L'vov. geol. o-vo, 1948, no.2, p.53-73.
62. Ermakov, N.P. Criteria of mineral genesis, cognition, and the medium of mineral formation. - Mineral. sb./L'vov. geol. o-vo, 1949, no.3, Appendix 1, p.68.
63. Ermakov, N.P. Investigation of mineral forming solutions. - Khar'kov: Edition of Khar'kov University, 1950, 460p.
64. Ermakov, N.P. Inclusions of maternal solutions in minerals and their significance for theory and practice. - Tr.VNIIP, 1957, v.1, issue 2, p.173-175.
65. Ermakov, N.P. Microinclusions in minerals - a source of scientific information of physical-chemical conditions of deep ore formation. - In: Mineralogical thermometry and barometry. Moscow, Nauka Press, 1968, book 1, p.13-27.
66. Ermakov, N.P. Origin and genetic classification of normal and abnormal inclusions of solutions and melts in minerals. - In: Abstracts of the 3rd All Union Conference (9-15 Sept., 1968, Moscow). Moscow, Edition of VNIISIMS, 1968, p.19-21.
67. Ermakov, N.P. Geochemical systems of inclusions in minerals. - Moscow, Nedra Press, 1972, 375p.
68. Ermakov, N.P. Homogenization and decrepitation temperatures of inclusions in cognition of dynamics of processes of deep mineral formation. - In: Thermobarogeochemistry of mineral formation. Rostov-on-Don, Edition of Rostov University, 1976, p.5-13.
69. Ermakov, N.P. Methods of dynamic phasemetry of inclusions of mineral-forming media. - In: Methods and apparatus for the study of inclusions of mineral-forming media. Moscow, Nauka Press, 1980, p.5-11.

70. Ermakov, N.P. and Dolgov, Yu. A. Thermobarogeochemistry, Moscow, Nedra Press, 1979, 270p.
71. Ermakov, N.P. and Kalyuzhnyi, V.A. On the possibility of discovering the true temperatures of mineral-forming solutions. - Tr VNIISIMS, 1957, v.1, issue 2, p.41-51.
72. Zhovtulia, B.D. Investigation of inclusions in quartz of rhyolite tuffs of Beregovskoye Kholmogorie, Mineral. sb./L'vov. Univ., 1976, no.30, issue 1, p.60-64.
73. Zavaritskii, A.N. and Sobolev, V.S. Physical-chemical basis of petrography of igneous rocks. - Moscow, Gosgeolizdat Press, 1961, 383p.
74. Zakharchenko, A.I. Results of study of fluid inclusions in a rock crystal from Pamirs. - Mineral sb./L'vov. geol. o-vo, 1950, no.4, p.167-187.
75. Zakharchenko, A.I. On the issue of the nature of hydrothermal solutions. - Sov. geologia, 1953, no.1, p.73-76.
76. Zakharchenko, A.I. Mineral-forming solutions and genesis of quartz veins. - Moscow, Gosgeoltekhizdat Press, 1955, 105p.
77. Zakharchenko, A.I. and Moskalyuk, A.A. On chemical analysis of gas-liquid inclusions in minerals by the method of water extraction. - In: Mineralogical thermometry and barometry, Moscow, Nauka Press, 1968, book 1, 326-332.
78. Zatsikha, B.V. Postmagmatic mineralization in granites of "Kamenniye Mogily" massif (Priazovie). - In: Ore-forming medium studied by inclusions in minerals, Moscow, Nauka Press, 1972, p.178-184.
79. Ikornikova, N. Yu. Hydrothermal synthesis of crystals in chloride systems. Moscow, Nauka, 1975, 222p.
80. Ikorskii, S.V. Organic matter in minerals of igneous rocks, Leningrad, Nauka Press, 1967, 120p.
81. Ikorskii, S.V. and Evetskaya, E.A. On the sorbtion of $CO_2$ in extraction of gases from rocks and minerals in a vacuum mill. Geochimia, 1975, no.11, p.1712-1719.
82. Kalyuzhnyi, V.A. Measuring of refraction indexes of free liquids and maternal solutions, trapped in minerals on the Fedorov [i.e., universal] stage. - Mineral. sb./L'vov. geol. o-vo, 1954, no.8, p.315-344
83. Kalyuzhnyi, V.A. Liquid inclusions in minerals as a geological barometer. - Mineral sb./L'vov. geol. o-vo, 1955, no.9, p.64-84.
84. Kalyuzhnyi, V.A. On the practical control of precision of the method of measuring of light refraction properties of substances trapped in minerals with the help of Fedorov's [i.e., universal] stage. - Uchen. zap. L'vov. Univ., Ser. geol., 1955, v.35, issue 8, p.187-193.
85. Kalyuzhnyi, V.A. On the issue of hermetic properties of fluid inclusions. Tr. VNIIP, 1958, v.2, issue 2, p.113-117.
86. Kalyuzhnyi, V.A. On the study of composition of the "daughter"-minerals of polyphase inclusions. - Mineral. sb./L'vov. geol. o-vo, 1958, no.12, p.116-128.
87. Kalyuzhnyi, V.A. Improved microscope heating stage for analysis of fluid inclusions. - Tr. VNIIP, 1958, v.2, issue 2, p.43-47.
88. Kalyuzhnyi, V.A. Methods of study of polyphase inclusions in minerals. Kiev, Edition of Acad. Sci. of Ukrainian Soviet Republic, 1960, 168p. (In Ukrainian).
89. Kalyuzhnyi, V.A. Investigation of mineral-forming media by inclusions in minerals. - Materials of commission on mineralogy and geochemistry of Carpato-Balkan Geological Association, 1961, no.1, p.159-173.

90. Kalyuzhnyi, V.A. Optical and thermometric investigation of glass inclusions in phenocrysts of hyalodacites from Zacarpatia. - Dokl. An SSSR, 1965, v.160, no.2, p.438-441.
91. Kalyuzhnyi, V.A. Over-filled liquid inclusions in mineral and their genetic significance. - Mineral Yearbook (Sbornik) L'vov Univ., 1971, No. 25, v. 2, p. 124-131.
92. Kalyuzhnyi, V.A. New instruments for studying inclusions of mineral-forming fluids and principles of their working. - In Proc. 4th Regional Conf. on Thermobarogeochemistry of Mineral-Forming Processes. Publ. Rostov Univ., 1973, p. 285-286.
93. Kalyuzhnyi, V.A. Basis of information revealed by fluid inclusions on the genesis of minerals. - In "Problems of Genetic Information in Mineralogy" Syktivkar. Komfil. Publ., AN USSR, 1976, p. 69-70.
94. Kalyuzhnyi, V.A. The present status of knowledge on the problem "Carbon and its compounds in the endogeneous processes of mineral formation (based on the study of fluid inclusions in minerals)." - In: Carbon and its compounds in the endogeneous processes of mineral formation (based on the study of fluid inclusions in minerals). Kiev: Nauk. Dumka, 1978, p. 3-16.
95. Kalyuzhnyi, V.A. A schematic VTX-diagram of $H_2O$-NaCl system and its significance in the study of fluid inclusions. - Dokl. AN Ukrainian SSR, Ser. B, 1978, No. 4, p. 302-305 (in Ukrainian).
96. Kalyuzhnyi, V.A., Yorish, Z.I. On the X-ray studies of microquantities of minerals - Mineral. Mag. Geol. Soc. L'vov, 1962, No. 16, p. 403-407.
97. Kalyuzhnyi, V.A., Kovalishin, Z.I. On the factors governing distribution of carbon-gases in granites proximal to pegmatites and in quartz of zanorysh pegmatites of Ukrainian Shield. - In: Geochemical studies of deep-seated fluids based on the relicts of carbon-containing compounds and mineral paragenesis. Kiev, Nauk. Dumka, 1967, p. 5-21.
98. Kalyuzhnyi, V.A., Lyakhov, Yu.V. Cassiterite and fluorite inclusions in minerals of Volyny pegmatites. - Dokl. AN USSR, 1962, 143, No. 5, p. 1182-1185.
99. Kalyuzhnyi, V.A., Matvienko, A.D. Rapid method of analyzing bulk concentration of $CO_2$ in fluid inclusions and its practical application. - Mineral. Mag., L'vov Univ., 1975, No. 29, v. 3, p. 15-21.
100. Kalyuzhnyi, V.A., Mikalaichuk, N.A. Determination of the composition of solid phases of salts in the dry residue of solutions from fluid inclusions using scanning electron microscopy. - In: Mineralogical Thermometry and Barometry. Moscow, Nauka, 1976, v. 2, p. 72-75.
101. Kalyuzhnyi, V.A., Svoren, I.M. Basis of rational application of methods of analyzing gaseous components of fluid inclusions (problem of analyzing hydrogen). - Mineral. Mag., L'vov Univ., 1979, No. 33, v. 1, p. 35-41.
102. Kalyuzhnyi, V.A., Svoren, I.M., Platonova, E.L. Composition of gases in fluid inclusions and problem of detecting hydrogen (using mass-spectrometric method of chemical analysis). - Dokl. AN USSR, 1974, 219, No. 4, p. 973-976.
103. Kalyuzhnyi, V.A., Shiritsiya, O.S. Physico-chemical characteristics of $H_2O + CO_2$ fluids-fluid inclusions in polymetallic veins of Nagolnai Kryazhn (Donbas). - Geol. J., AN, Ukrainian SSR, 1962, 22, v. 2, p. 29-41 (in Ukrainian).
104. Karninski, A.P. On the presence of liquid carbon anhydride inclusions in minerals. - Mining J., 1880, 2, No. 4/5, p. 96-117.
105. Kliya, M.O., Lemmlein, G.G. On the theory of determining geological temperatures using method of decrepitating fluid inclusions in minerals. - Letters of Union Mineral. Soc., 1951, v. 80, No. 4, p. 315.

106. Kilya, M.O., Sokolova, I.G. Entrapment of emulsions by crystals growing from solutions. - Crystallography, 1958, 3, v. 2, p. 219-224.
107. Kovalishin, Z.I. The effect of host minerals on the gases released from inclusions by crushing. - In: Mineralogical Thermometry and Barometry. Moscow, Nauka, 1968, v. 2, p. 31-33.
108. Konev, A.A., Bekman, I.K. On the nature of gases released on heating of rocks (Nepheline syenites of Pribaikal). - Geokhimiya, 1978, No. 3, p. 390-397.
109. Korzhinski, D.S. General principles of postmagmatic processes. - In: Problems of Postmagmatic Ore Formation. Prague, Publ. Czechoslovakian Acad. Sci., 1965, v. 2, p. 305-313.
110. Kormyshin, V.A. Metrology of method of homogenization of gas-liquid inclusions. - Alma-Ata, Internal. Publ., Inst. Geol. AN Kaz. SSR, 1978, pp. 58.
111. Kuznetsov, V.D. Crystals and crystallization. - Moscow, Gostekhizdat, 1954, pp. 410.
112. Lazarenko, E.K., Kvasnitsa, V.N., Voznyak, D.K. and others. Characteristic features of morphology and conditions of formation of quartz crystals from hydrothermal veins of Donbas and Krivoy Rog. - In: Regional and Genetic Mineralogy. Kiev, Nauk, Dumka, 1978, v. 1, p. 3-26.
113. Lazarenko, E.K., Pavlishin, V.I., Latish, V.T., Sorokin, Yu.G. Mineralogy of Volyny chamber pegmatites. - L'vov, Vishaya Shkola [High School], 1973, pp. 358.
114. Lemmlein, G.G. Classification of liquid inclusions in minerals. - Letters of All Union Mineral. Soc., 1959, v. 88, No. 2, p. 137-143.
115. Lemmlein, G.G. Scar vicinal forms on amethyst crystals. - Trudy Lomonosov Inst., 1933, No. 6, p. 13-16.
116. Lemmlein, G.G. On the relation between the present and initial volumes of liquid inclusions in minerals. - Dokl. AN USSR, 1950, 72, No. 4, p. 775-778.
117. Lemmlein, G.G. The process of healing of fractures in crystals and the transformation of shapes of inclusion cavities of secondary inclusions. - Dokl., AN USSR, 1951, 78, No. 4, p. 685-688.
118. Lemmlein, G.G. On the theory of healing of fractures in crystals and the equilibrium shapes of negative crystals. - Dokl., AN USSR, 1953, No. 2, p. 283-286.
119. Lemmlein, G.G. Self-healing of fractures in crystals. - Trudy Inst. Crystal. AN USSR, 1954, 10, p. 158-160.
120. Lemmlein, G.G. Additions of national bibliography to the book by F.G. Smith "Geological thermometry based on inclusions in minerals." - Moscow, Publ. Inostr. Lit. (Foreign Literature), 1956, p. 124-163.
121. Lemmlein, G.G. Investigations on the genesis of liquid inclusions in crystals. - In: Problems of Geochemistry and Mineralogy, Moscow, Publ. AN USSR, 1956, p. 139-140.
122. Lemmlein, G.G. Morphology and genesis of crystals. - Moscow, Nauka, 1973, pp. 327.
123. Lemmlein, G.G., Klevtsov, P.V. Physico-chemical analysis of liquid inclusions in quartz, containing crystals of halite and sylvite. - Letters of All Union Mineral. Soc., 1955, v. 84, No. 1, p. 47-52.
124. Lemmlein, G.G., Klevtsov, P.V. The effect of concentration on the temperature of homogenization of systems composed of aqueous salt solutions. - Letters of All Union Mineral. Soc., 1955, v. 85, No. 3, p. 310-320.
125. Lemmlein, G.G., Kliya, M.O. The characteristics of healing of fractures in crystals during falling temperatures. - Dokl. AN USSR, 1952, 87, No. 6, p. 957-960.

126. Lemmlein, G.G., Kliya, M.O. Changes in liquid inclusions under the effect of local overheating of crystals. - Dokl. AN USSR, 195, 94, No. 2, p. 233-236.
127. Lemmlein, G.G., Kliya, M.O. Primary gas inclusions in crystals. - Letters All Union Mineral. Soc., 1961, v. 90, No. 3, p. 260-265.
128. Lemmlein, G.G., Kliya, M.O., Ostrovski, I.A. On the conditions of formation of pegmatite minerals based on the data from the study of primary inclusions in topaz. - Dokl. AN USSR, 1962, 142, No. 1, p. 81-83.
129. Lesnyak, V.F. Genesis of some ore deposits of N. Caucasus using thermometric analysis of inclusions in minerals. - Abstract, Dissertation for the degree of Candidate of Sci., L'vov Univ., 1952, pp. 24.
130. Lesnyak, V.F. Temperatures of formation of an ore deposit in N. Caucasus. - Mineral. Mag., Geol. Soc. L'vov, 1954, No. 8, p. 145-160.
131. Lomonosov, M.V. Layers of earth. - Moscow, Gostekhizdat, 1949, pp. 212.
132. Luskutov, A.V. Process of healing fractures in quartz crystals. - In: Mineralogy of Postmagmatic Processes. Leningrad, Publ. Leningrad Univ., 1959, p. 178-189.
133. Lyakhov, Yu.V. Mineral composition of polyphase inclusions in morion crystals from Volyny pegmatites. - Contributions of VNIISIMS (National Inst. Mineral Resources), 1966, 9, p. 92-100.
134. Lyakhov, Yu.V. Errors in the pressure estimation of mineral formation using halite bearing gas-liquid inclusions: Principles and methods of removing them. - Letters All Union Mineral. Soc., 1973, v. 102, No. 4, p. 385-393.
135. Magmatic crystallization based on the study of melt inclusions (editors: V.S. Sobolev and V.P. Kostyuk). - Novosibirsk, Nauka, 1975, pp. 232.
136. Malinin, S.D. $H_2O$-$CO_2$ system at high temperatures and pressures. - Geokhimiya, 1959, No. 3, p. 235-245.
137. Malinin, S.D., Saveleva, N.I. Experimental studies on the solubility of $CO_2$ in NaCl and $CaCl_2$ solutions at 25, 50 and 75°C and high pressures. - Geokhimiya, 1972, No. 12, p. 643-653.
138. Malishev, A.G. Pressure estimation using fluid inclusions with high-density gaseous phases. - Dokl. AN USSR, 1974, 216, No. 3, p. 625-627.
139. Mamchur, G.P., Matvienko, O.D., Yarinin, O.O. Genesis of Volyny pegmatites using $\delta^{13}C$. - Geol. J., 1975, 216, No. 3, p. 91-98.
140. Maslova, I.N. Investigations on the chemical composition of inclusions in fluorite using ultramicromethod. - Contributions of VNIIP (National Inst. Petrology), 1958, 2, p. 119-121.
141. Maslova, I.N. Ultramicrochemical studies on the composition of liquid and gaseous phases of biphase inclusions in Volyny quartz. - Geokhimiya, 1961, No. 2, p. 169-173.
142. Maslova, I.N., Esikova, A.D. Technology of electrometric methods in ultramicrochemical analysis. - Zavod. Lab., 1965, No. 10, p. 1270-1272.
143. Melancholin, N.M. Determination of the refractive indices of minerals under microscope using immersion method. - Moscow, Leningrad, Publ. AN USSR, 1949, pp. 100.
144. Melnikov, F.P. Cryometric studies of gas-liquid inclusions in minerals. - In: Methods and Apparatus for Studying Fluid Inclusions in Minerals, Moscow, Nauka, 1980, p. 70-79.
145. Mechanical and chemical phenomena during superfine grinding (editors: Klyarovski, V.M. and Molchanov, V.I.). - Novosibirsk, Publ. AN USSR, 1971, pp. 174.

146. Mineral forming fluids and mineral paragenesis in Zanorysh-type pegmatites of Ukrain (editor: Kalyuzhnyi, V.A.). - Kiev, Nauk. Dumka, 1971, pp. 215 (in Ukrainian).
147. Mikhailov, M.Yu., Shatski, V.S. Silicon carbide heater for high-temperature microscopic stage. - In: Mineralogy of Endogenous Formations, Novosibirsk, Nauka, 1974, p. 109-110.
148. Naumov, V.B. Results of thermometric measurements on fluid inclusions in standards of quartz conducted in the laboratories of USSR. - Geokhimiya, 1976, No. 7, p. 1109-1112.
149. Naumov, V.B. Estimation of concentration and pressure of volatile components in melts using fluid inclusions in minerals. - Geokhimiya, 1979, No. 7, 1979.
150. Naumov, V.B., Balitski, V.C., Khetchikov, L.N. On the relationship of temperature of formation and decrepitation of gas-liquid inclusions. - Dokl. AN USSR, 1966, 171, No. 1, p. 183-185.
151. Naumov, V.B., Malinin, S.D. New method of pressure estimation using fluid inclusions. - Geokhimiya, 1968, No. 4, p. 432-441.
152. Naumov, G.B., Dorofeeva, V.A. Chemical nature of the evolution of acidity of endogenous solutions. - Geokhimiya, 1975, No. 2, p. 248-258.
153. Naumov, G.B., Mironova, O.F., Naumov, V.B. Carbon compounds in the fluid inclusions in hydrothermal quartz. - Geokhimiya, 1976, No. 8, p. 1243-1251.
154. Nesis, E.I. Boiling of liquids. - Moscow, Nauka, 1973, pp. 280.
155. Niggli, P. Magma and its products. - Moscow, Gosgeoisdat., 1946, pp. 435.
156. Nikolaeev, V.A. On the problem of genesis of hydrothermal solutions during evolution of deep magmatic processes. - In: Basic Problems of Magmatogenic Ore Deposits. Moscow, Publ. AN USSR, 1955, p. 96-124.
157. Olshanski, Ya.I., Ivanenko, V.V. Transportation mechanisms of materials in the formation of hydrothermal sulfide deposits (Experimental studies). - Trudy IGEM, 1958, v. 16, pp. 76.
158. Ostrovski, I.A. VTX diagram for simple case in the system silicate-water. - Izvestia, AN USSR, Seria Geol., 1950, No. 5, p. 143-147.
159. Pashkov, Yu.N. Thermometry based on the study of fluid inclusions. - In: Methods and Apparatus of Studying Fluid Inclusions of Mineral-Forming Media. Moscow, Nauka, 1980, p. 12-30.
160. Pashkov, Yu.N., Piloyan, G.O. On the theory of decrepitation. - In: Proc. 4th Regional Conf. on Thermobarogeochemistry of Mineral-Forming Processes. Rostov-on-Don, Publ. Rostov-on-Don Univ., 1973, p. 292-293.
161. Petrichenko, O.I. Methods of studying inclusions in minerals of halide rocks. - Kiev, Nauk., Dumka, 1973, pp. 92 (in Ukrainian).
162. Piznur, A.V. Genetic relation of quartz vein with the granite intrusives in Barsukachi deposit based on the study of inclusions in minerals. - Trudy VNIIP, 1957, 1, v. 2, p. 135-143.
163. Piznur, A.V. Pressure during formation of Zhirekensk copper-molybdenum deposit (E. Transbaikal). - Dokl. AN USSR, 1968, 179, No. 5, p. 1186-1188.
164. Piznur, A.V. Fundamentals of Thermobarogeochemistry (Methods of Barometry). - L'vov, Publ. L'vov Univ., 1973, pp. 82.
165. Piznur, A.V. Fundamentals of Thermobarogeochemistry (Methods of Thermometry). - L'vov, Publ. L'vov Univ., 1973, pp. 106.
166. Polykovski, V.C., Roizenman, F.M., Maskareeva, T.C., Fokaev, V.M. Method of pressure estimation using fluid inclusions in quartz. - Trudy Moscow Geol. Explor. Inst., 1963, No. 39, p. 92-100.
167. Ryazhenko, B.N. Ion equilibrium in hydrothermal processes. - In:

Geochemical Investigations Under High Pressure and Temperature, Moscow, Nauka, 1965, p. 96-120.

168. Samoilovich, L.A. Dependence between pressure, temperature and density of aqueous saline solutions. - Moscow, Trudy VNIISIMS, 1969, pp. 36.

169. Slavyanski, V.T. Gases in glass. - Moscow, Oboronogiz 1957, pp. 142.

170. Slivko, M.M. Repulsion and entrapment of solid particles by growing crystals of tourmaline. - In: Genesis of Mineral Individual and Aggregates. Moscow, Nauka, 1966, p. 116-121.

171. Smith, F.G. Review of physico-chemical properties of supercritical fluids. - In: Experimental Investigations in Petrography and Ore Formation. Moscow, Publ., Inostrannaya Literatura, 1954, p. 459-489.

172. Smith, F.G. Geological Thermometry using Inclusions in Minerals. - Moscow, Publ., Inostrannaya Literatura, 156, p. 122.

173. Smith, F.G. Physical Geochemistry. - Moscow, Nedra, 1968, pp. 468.

174. Sobolev, V.S. Introduction to Mineralogy of Silicates. - L'vov, Publ. L'vov Univ., 1949, pp. 329.

175. Tables on the solubility of salt systems. - Leningrad, Goschimizdat., 1961, v. 3, p. 1275-2225.

176. Tables on the physical constants (properties) of rocks. - Moscow, Mir, 1969, pp. 543.

177. Tables for chemists. - Goschimizdat, 1951, v. 1, pp. 895.

178. Sukhorski, R.F. Effect of $CO_2$ on the homogenization temperatures of gaseous inclusions. - Mineral. Mag., L'vov Geol. Soc., 1953, No. 7, p. 271-280.

179. Sushchevskaya, T.M. Limitations of leachate analysis of inclusion composition. - In: Mineralogical Thermometry and Barometry, Moscow, Nauka, v. 2, p. 80-83.

180. Tugarinov, A.I., Naumov, V.B. Dependence of decrepitation temperature on the composition of gas-liquid inclusions and the strength of minerals. - Dokl., AN USSR, 1970, 195, No. 1 [pages not given].

181. Umova, M.A., Glebov, R.I., Shibanov, P.N. Chemical composition of gaseous inclusions in quartz from different deposits. - Dokl., AN USSR, 1957, 112, No. 3, p. 119-122.

182. Universal Stage of E.S. Fedorov. - Moscow, Publ., AN USSR, 1935, pp. 837.

183. Fersman, A.E. Achievements of Soviet Mineralogy and Geochemistry in Past Years (1929-1934). - Moscow, Leningrad, Publ. AN USSR, 1935, pp. 101.

184. Fersman, A.E. Selected works. - Pegmatites, v. 6, Moscow Publ. AN USSR, 1962, pp. 742.

185. Khaimov-Malkov, V.Ya. Growth conditions of minerals in contact with micro barriers. - In: Crystal Growth, Moscow, Publ., AN USSR, 1959, p. 5-39.

186. Khaibulin, I.Kh., Borisov, N.M. Experimental investigation of thermal properties of liquid and vapor solutions of sodium and potassium chlorides under equilibrium. - Thermophysics of High Temperatures, 1966, 4, No. 4, p. 518-523.

187. Khetchikov, L.N., Balitski, V.S., Gasparyants, N.P. On the possibility of determining chemical composition and concentration of mineral-forming solutions based on the chemical composition of gas-liquid inclusions in minerals. - Dokl., AN USSR, 1966, 168, No. 5, p. 1179-1182.

188. Khetchikov, L.N., Dorogovin, B.A., Samoilovich, L.A. Corrections to the homogenization and decrepitation temperatures of gas-liqud inclusions in minerals due to pressure, density and composition of solutions. - Geologiya Rudnikh Mestorozhdenii, 1968, No. 3, p. 87-97.

189. Khetchikov, L.N., Samoilovich, L.A. Experimental data on PFTX-relations in the water-salt and gas-water-salt systems. - In: Experiments in Mineralogy and Petrography, Moscow, Nauka, 1975, p. 112-120.
190. Khitarov, D.N. Some methodological problems in estimating chemical composition of gas-liquid inclusions using leachate. - In: Mineralogical Thermometry and Barometry, Moscow, Nauka, 1968, v. 2, p. 76-80.
191. Khitarov, D.N., Sushchevskaya, T.M. Analysis of chemical composition of liquid phase in inclusions in hydrothermal minerals. - In: Methods and Apparatus for Studying Inclusions of Mineral-Forming Media, Moscow, Nauka, 1980, p. 80-108.
192. Khitarov, D.N., Uchameishvili, N.E. Estimation of errors related to different methods of preparing aqueous leachates. - In: Theory and Practice of Thermobarogeochemistry, Moscow, Nauka, 1978, p. 229-236.
193. Khitarov, N.I., Malinin, S.D. Experimental characterization of the system $H_2O-CO_2$. - Geokhimiya, 1956, No. 3, p. 18-27.
194. Khitarov, N.I., Malinin, S.D. Equilibrium phase relations in the system $H_2O-CO_2$. - Geokhimiya, 1958, No. 7, p. 678-679.
195. Khitarov, N.I., Rentgarten, E.V., Lebedeev, N.E. Chemical composition of inclusions in Iceland-spar and problems of its genesis. - Geokhimiya, 1958, No. 3, p. 214-221.
196. Khodakovski, I.L. Characterization of hydrothermal solutions using data from the study of gas-liquid inclusions in minerals. - In: Mineralogical Thermometry and Barometry, Moscow, Nauka, 1965, p. 174-203.
197. Tsinzerling, E.V. Cracking of quartz plates at temperatures between 200 and 600°C. - Trudy Inst. Crystal. AN USSR, 1948, v. 4, p. 209-214.
198. Tsinzerling, E.V. Synthetic twinning in quartz. - Moscow, Publ., AN USSR, 1961, pp. 160.
199. Tsurinov, G.G., Volnova, V.A. Universal stage for microscopes for studies at high and low temperatures. - Zavod., Lab., 1952, No. 10, p. 1253-1255.
200. Chepurov, A.I., Pokhilenko, N.P. Heating stage with inert gas for high-temperature study of inclusions in minerals. - Geol. & Geophys., 1972, No. 6, p. 139-141.
201. Chupin, V.P. Errors in the measurements of homogenization temperatures and methods of their correction. - In: Mineralogy of Endogenous Formations. Novosibirsk, Inst. Geol. & Geophys., Soviet Br. AN, USSR, 1973, p. 137-146.
202. Sheftal, N.N. On the problem of real crystal-formation processes. - In: Crystal Growth, Moscow, Publ., AN, USSR, 1957, p. 5-31.
203. Sternberg, A.A. Properties of water in the supercritical region with reference to the problems of mineral formation at greater depths. - Geologiya Rudnikh Mestorozhdenii, 1962, No. 5, p. 13-19.
204. Shubnikov. A.V. How Crystals Grow. - Moscow, Publ., AN, USSR, 1935, pp. 128.
205. Elinson, M.M. Method of extraction and analysis of gas and liquid from inclusions in minerals. - In: Mineralogical Thermometry and Barometry, Moscow, Nauka, 1968, v. 2, p. 23-31.
206. Elinson, M.M., Polykovski, V.S. Study of gases in quartz crystals from Maidantaka. - Izvestia. Vuzov., Geolgia i Ravedka (Geol. & Explor.), 1961, No. 11, p. 26036.
207. Elinson, M.M., Chistyakov, F.M. Vacuum grinder for extracting gases from rocks and other porous material. - Zavod. Lab., 1949, No. 6, p. 749-751.

208. Ens, I. Gas analysis of bubbles in glass. - Optiko-mekha. Prom. (Optical-Mechanical Industry), 1935, No. 2, p. 126-132.
209. Yusupov, S.Sh., Dolgov, Yu.A. The effect of dikes on the formation of quartz in chamber pegmatites. - Dokl., AN, USSR, 1970, 190, No. 1, p. 191-194.
210. Yankovski, A.A. Pulse (voltage) discharge as a source of light for spectral analysis. - In: Proc. First Sci. Tech. Conf. on Spectral Analysis, Minsk, Publ., AN, BSSR, 1956, p. 34-39.
211. Amagat E.H. Sur la d'etermination de las densite des ligue'fies et de leurs vapeurs sature'es. Elements du point critique de l'acide carbonique. - C.R. Acad. Sci., 1892, 114, p. 1093-1098.
212. Barker C.G. The use of a mass spectrometer for analyzing the gases liberated by heating or crushing natural minerals. - In: Proc. First Symp. Applicat. A.E.I. MS 10 mass spectrometer. Manchester: Assoc. Elec. Industries Ltd., 1965, p. 85-95.
213. Breislak S. Institutions geologiques, 1. - Milan, 1818. - 468 p.
214. Brewster D. On the refractive power of the two new fluids on minerals, with additional observations on the nature and properties of these substances. - Trans. Roy. Soc. Edinburgh, 1826, 10, p. 407-427.
215. Chamberlin R.T. The gases in rocks. - Carnegie Inst. Washington, 1908, Publ. 106. - 80 p.
216. Chrustschoff K. von. Über secundäre Glaseinschlüsse in den Gemengtheilen gefritteter Gesteine. - Min. und Petrogr. Mitt., 1882, 4, S. 473-503.
217. Dewar J., Ansdell G. On the gaseous constituents of meteorites. - Proc. Roy. Soc. London, 1886, 40, p. 549-559.
218. Doelter C., Hussak E. Über die Einwirkung geschmolzener Magmen auf verschiedene Mineralien. - In: Neues Jahrbuch für Mineral., 1884, S. 18-44.
219. Forbes D. The microscope in geology. - Popular Sci. Rev., 1866, 6, p. 355-368.
220. Goguel R. Die chemische Zusammentsetzung der in den Mineralen einiger Granite und ihrer Pegmatite eingeschlossenen Gase und Flüssigkeiten. - Geochim. et cosmochim. acta, 1963, 27, N 2, p. 155-181.
221. Hartley W.H. Observations on fluid-cavities. - J. Chem. Soc., 1877, 31, p. 241-248.
222. Hähnel O. Über die Stärke der bei höheren Druck hergestellten wässrigen Kohlensäure. - Zbl. Mineral., 1920, 21, S. 25-32.
223. Hiemstra S.A. An easy method to obtain X-ray diffraction patterns of small amounts of mineral. - Amer. Miner., 1956, 41, N 5/6, p. 519-521.
224. Holden E.F. The cause of color in smoky quartz and amethyst. - Amer. Miner., 1925, 10, p. 203-252.
225. Hunt A.R. The evidence of the hydrothermal metamorphism of the schists of south Devon. - Brit. Assoc. Advanc. Sci., 1902. - 613 p.
226. Johnsen A. Über die Paragenese α-Quarz und Kohlensäure. - Sitz. Bayer Akad. Wissenschaften, Math.-Phys. Klasse, 1920, p. 321-328.
227. Keevil N.B. Vapor pressures of aqueous solutions at high temperatures. - Amer. Chem. Soc. J., 1942, 64, p. 841-850.
228. Keller W.D., Littlefield R.F. Inclusions in the quartz of igneous and metamorphic rocks. - J. Sed. Petrol., 1950, 20, p. 74-84.
229. Kennedy G.C., Wasserlung G.J., Heard H.C., Hewton R.C. The upper three-phase region in system $SiO_2$-$H_2O$. - Amer. J. Sci., 1962, 260, p. 501-521.
230. Kranz R. Organische Fluorverbindungen in den Gaseinschlüssen der Wölsendorfer Flusspäte. Deutsche Mineral. - Ges. Kurzreferate

Vortrage. Jahrestagung, 1965, 43, S. 13-14.
231. Kranz R. Organic amino compounds in the gas and liquid inclusions of uranium bearing minerals and their importance on transport reactions in hydrothermal solution. - In: Abstract in program, 4th international meeting on organic geochemistry, Amsterdam, 1968. Programme and Abs, 5, 1968. - 52 p.
232. Laemmlein G. Sekundäre Flüssigkeitseinschlüsse in Mineralien. - Z. Kryst. und Mineral., 1929, 71, S. 237-256.
233. Mackie W. The sands and sandstones of eastern Moray. - Trans. Edinburgh. Geol. Soc., 1896, 7, p. 148-172.
234. Nacken R. Welche Folgerungen ergeben sich aus dem Auftreten von Flüssigkeitseinschlüssen in Mineraline? - Centralblatt Min., etc., 1921, p. 12-20, 35-43.
235. Newhouse W.H. The temperature of formation of the Mississippi Valley lead-zinc deposits. - Econ. Geol., 1933, 28, 744-750.
236. Ölander A., Liander H. The phase diagram of sodium chloride and steam above the critical point. - Acta chem. scand., 1950, 4, p. 1437-1445.
237. Phillips J.A. Notes on the chemical geology of the goldfields of California. - Phil. Mag. Ser. 4, 1968, 36, p. 321-336.
238. Preisinger A., Huber W. Zur Bestimmung kleinster Gaseinschlüsse in Feldspaten. - Fortsch. Mineralogie, 1964, 41, N 2, p. 183.
239. Richter D.H., Ingerson E. Some considerations regarding liquid inclusions as geologic thermometers. - Econ. geol., 1954, 49, N 7, p. 786-789.
240. Roedder E. Technique for the extraction and partial chemical analysis of fluid-field [filled] inclusions from minerals. - Econ. Geol., 1958, 53, N 3, p. 235-269.
241. Roedder E. Studies of fluid inclusions. - I. Econ. Geol., 1962, 57, N 7, p. 1045-1061.
242. Roedder E. Studies of fluid inclusions. - I [II]. Econ. Geol., 1963, 58, N 2, p. 167-211.
243. Roedder E., Skinner B.J. Experimental evidence that fluid inclusions do not leak. - Econ. geol., 1968, 63, N 7, p. 715-730.
244. Roozeboom H.W. Die geterogene Gleichgewichte von Standpunkte d. Phasenlehre, 1904. - 363 S.
245. Skinner B.J. Some considerations regarding liquid inclusions as geologic thermometers. - Econ. geol., 1953, 48, N 7, p. 541-550.
246. Sorby H.C. On the microscopical structure of micaschist. - Brit. Assoc. Advanc. Sci., Sections, 1856, p. 78.
247. Sorby H.C. On some peculiarities in the microscopical structure of crystals, applicable to the determination of the aqueous or igneous origin of minerals and rocks. - Phil. Mag. Ser. 4, 1857, 15, p. 152-154.
248. Sorby H.C. On the microscopic structure of crystals, indicating the origin of minerals and rocks. - J. Geol. Soc. London, 1858, 14, pt. 1, p. 453-500.
249. Sorby H.C. On the structure and origin of non-calcareous stratified rocks. - Proc. Geol. Soc. London, 1880, 36, p. 46-92.
250. Sorby H.C., Butler P.J. On the structure of rubies, sapphires, diamonds and some other minerals. - Proc. Roy Soc. London, 1869, 17, p. 291-302.
251. Sourizajan S.[sic], Kennedy G.C. The system $H_2O$-NaCl at elevated temperatures and pressures. - Amer. J. Sci., 1962, 260, N 2, p. 115-141.
252. Takenouchi C., Kennedy G.C. The binary system $H_2O$-$CO_2$ at high temperatures and pressures. - Amer. J. Sci., 1964, 262, p. 1055-1074.
253. Touray J. Recherches geochimiques sur les inclusions a $CO_2$ liquide. -

Soc. Franc. minéral. et cristallogr. Bull., 1968, 91, p. 367-382.
254. Todheide K., Franck E.U. Das Zweiphasengebiet und die Kritische Kurve im System Kohlendioxyd-Wasser bis zu Drucken von 3500 bar. Z. Phys. Chemi. New. ser., 1963, 37, p. 387-401.
255. Twenhofel W.S. The temperature of crystallization of a fluorite crystal from Luna Country. New Mexico. - Econ. Geol., 1947, 42, p. 78-82.
256. Vogelsang H. Philosophie der Geologie und microskopische Gesteinsstudien. - Bonn, Cohen, 1867. - 197 S.
257. Zirkel F. Micromineralogische Mitteilungen. - In: Neues Jahrbuch Mineral. 1870, p. 801-806.
258. Zirkel F. Lehrbuch der Petrographie. - Engelmann: Leipzig, 1893, S. 166-192.

# 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.

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## LOCALITY INDEX

Notes: See page 535. 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* | |
|---|---|---|---|---|
| 18 | 482 | | 7 | Add p. 116 to Infrared spectroscopy. |
| 19 | 478 | 4 | | Item should be entered on p. 478 as item 2. |
| 19 | 489 | 2 | 12 | Delete period and add following: "rich in $CO_2$, polycomponent, and high in salinity.<br>(2) The boiling action of ideal fluid is an important mineralizing mechanism and is an important cause of forming high grade ores and of limiting them to certain locations.<br>(3) It is a necessary condition for cassiterite precipitation that fresh water infiltrated continually to dilute the mineralizing fluid.<br>According to [this] model, we predict high-grade ore in depth. |
| 20 | 193 | 2 | | Item should be entered on p. 390, under "van den KERKHOV." |
| 20 | 270 | 3 | | Move MONTENEGRO item to p. 271. |
| 20 | 270 | 4 | | Move MOROZOV item to p. 273. |
| 20 | 270 | 5 | | Duplication - combine lines 4 & 5 with item 2. |

†Partial items are also counted.

ISBN 0-472-02020-X

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