FLUID INCLUSION RESEARCH

Proceedings of COFFI

Edwin Roedder, *Editor*
Andrzej Kozlowski, *Associate Editor*

Volume 15

1982

Harvey Belkin

Fluid Inclusion Research

Volume 15

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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--Proceedings of COFFI. 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 either editor at the above addresses. We are acutely aware of the inadequate coverage in "COFFI" 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.

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ANN ARBOR

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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. Notices of past and future meetings and symposia are also published.

Most of the 336 items from Russian sources in this volume were translated or abstracted by Associate Editor Kozlowski; this represents an enormous contribution by Kozlowski toward achieving the aims of COFFI. Part of these abstracts are from several meetings in the Soviet Union, for which proceedings volumes have yet to be published. There are 650 items from other foreign language sources and English language literature for a total of 986 abstracts, citations, or annotated citations, plus subject and locality indices, and translations of six Russian papers

Some cited items are listed as "Indexed under fluid inclusions." These 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 data bases. Numerous persons and recent articles have suggested that with the rapid development of computerized data retrieval systems, bibliographical publications such as this one will soon be passé. While this 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 data base, and although the several extensive geological literature computer data bases have been consulted in assembling each of these volumes, none covers everything. Although each such search nets some items not previously found, most important, each produces only a small fraction of the entries that are eventually to be found in any given volume of COFFI. Second, and most important for a subject such as fluid inclusions, the data must be retrievable by applicable subject searches.

A data base is only as good as the indexing that went into the entries, and herein lies the problem. Until all journal editors insist on key word lists from their authors, and consider the careful evaluation of the adequacy of this listing to be a major responsibility for author and editor alike, the quality of computer retrieval will be limited by the knowledge and care of the indexers. One needs only to make various subject searches of a computer data base that should pull out items from his own personal bibliography to realize how inadequate this indexing of geological data bases has been in the past.

Although each abstract is duly credited, I wish to acknowledge considerable help from Dr. M. Fleischer. Chemical Abstracts, of Columbus, Ohio, has most graciously permitted the use of a limited number of their copyrighted abstracts, as indicated by a CA number in the abstract citations. Translations and other help have also been received from Drs. H.A. Stalder (Bern, Switz.); P. Lattanzi (Firenze, Italy); S.N. Grishina, Novosibirsk, USSR; C. Eastoe, Tucson, AZ; J.-C. Touray (Orleans, France); M.J. Logsdon (Denver, Colo.); and Huan-Zhang Lu (Guiyang, PRC). P.R. Bannes, Viburnum, MO, translated one Russian article. Many other individuals, too numerous to list here, have helped by sending books, reprints, references, and abstracts. I am also indebted to Prof. J. Guha (Chicoutimi, Quebec); and particularly to H.E. Belkin (U.S.G.S.) for extensive literature searches. I thank Nancy Teed (U.S.G.S.) for the excellent typography.

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, and indexing are strictly a result of lack of editorial time. The major shortcoming of this venture in the past has been the excessive lag time between the close of the literature year and publication. This can never be cut to zero, but has been greatly reduced with each recent volume; Vol. 14 was sent to press just 5-1/2 months after Volume 13, and the present volume (15) followed exactly 4 months after Volume 14.

I will be glad to learn of unpublished translations of Russian inclusion literature, and will also be glad to furnish photocopies of the original Russian 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.

March 22, 1985 Edwin Roedder, Editor

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Notices of Meetings and Symposia

Past Meetings

A joint meeting of the Mineral Deposits Studies Group and the Applied Mineralogy Group of the Mineralogical Society [G.B.] was held 14 May 1981. Fifteen papers were presented (see Fortey, 1982, this volume); those abstracts that are pertinent will be found in this volume of COFFI.

A symposium "Current Research on Fluid Inclusions" was held at Utrecht, The Netherlands, April 22-24, 1981. This symposium was the sixth in a series of informal symposia organized every other year, aimed at bringing European fluid inclusion workers together to discuss their results. Most of the abstracts for this meeting were published in COFFI, Vol. 13 (1981). Although some were published elsewhere, full papers for many of the presentations at that symposium were published in a special 214-page issue of Chemical Geology (see Kreulen and Touret, 1982, this volume of COFFI), and these papers are individually cited here.

A meeting was held 23 September, 1982, on Fluids in Metamorphism, at the Univ. of Glasgow, Scotland, convened by Prof. B.E. Leake. All ten papers presented are obviously pertinent to fluid inclusion studies and are abstracted in this volume of COFFI.

A workshop on Fluid Inclusion Studies was held 22-23 March, 1982, at the Indian Inst. of Technology, Bombay, convened by Prof. K.C. Sahu. Abstracts of these papers are in this volume of COFFI.

An International Conference on Mississippi Valley Type Lead-Zinc deposits was held October 11-14, 1982, at the University of Missouri-Rolla. A volume including a number of papers of pertinence to COFFI was published in 1983; abstracts of these papers will be found in Volume 16 of COFFI (1983).

The Sixth Symposium of the International Association on the Genesis of Ore Deposits (IAGOD) was held in Tbilisi, August 30 - September 17, 1982. The volume of Collected Abstracts from this meeting, edited by A.D. Shcheglov and V.I. Smirnov (Tbilisi, 334 pp., in English) contains many abstracts of pertinence to fluid inclusion study, particularly from the meeting of the Commission on Ore-Forming Fluids in Inclusions (COFFI), as well as from other sessions; these will be found in this volume of COFFI.

A meeting on Hydrothermal Phenomena Associated with Granitic Rocks of Europe, convened by Dr. A.H. Rankin and Prof. A. Weisbrod, was held in London, 27-28 May, 1982. Twenty-four papers were presented; many of these involve fluid inclusion studies, and will be found in this volume of COFFI.

A meeting on European Current Research on Fluid Inclusions ("ECRFI"), sponsored by the Soc. fr. Minéral. Cristallogr., was held at Univ. Orleâns, 6-8 April, 1983. Forty-six papers were presented (nine in a poster session). A short summary of the meeting, by J.-C. Touray, will be found in Bull. de Minéralogie. Supplement to Vol. 106, p. 55-56, 1983. Abstracts of the papers were published in Bull. de Minéralogie, Vol. 107, no. 2, and will be found in COFFI Vol. 16 (1983).

A meeting on Geothermometry and Geobarometry was held 13-19 January, 1983, at Aussois, Ecole D'Hiver, France, organized by the Soc. fr. Minéral. Cristallogr.

The Fourth International Symposium on Water-Rock Interaction was held August 29 - September 3, 1983, in Misasa, Japan, under the aegis of the Inst. for Thermal Spring Research, Okayama, Univ., and the International Association of Geochemistry and Cosmochemistry. A number of papers pertinent to fluid inclusion studies were presented. Abstracts of these will be found in Vol. 16 of COFFI (1983).

The Fifth New Zealand Geothermal Workshop was held in 1983 at Auckland, New Zealand, under the aegis of the Geothermal Institute, University of Auckland. Abstracts of pertinent papers will be found in Vol. 16 of COFFI (1983).

A meeting on Diagenesis and Metamorphism was held April 12-13, 1984, at the University of Bristol, England; pertinent abstracts will be found in Vol. 17 of COFFI (1984).

An Anniversary Meeting of the Mineralogical Society (G.B.) was held 12 January, 1984, at the Geological Society, Burlington House, London. Abstracts of the nine papers were published in 1983 and hence will be found in volume 16 of COFFI (1983).

The Seventh All-Union Conference on Thermobarogeochemistry had been tentatively scheduled for L'vov, in 1984, but apparently was postponed.

A meeting on Recent Advances in the Geochemistry of Ore Deposits, sponsored by the Mineral Exploration Research Institute (IREM-MERI), was held May 7-8, 1984, in Montreal, Quebec, Canada. Citations of the 11 review papers presented will be found in Vol. 17 of COFFI (1984).

A session on "Molten and gas-liquid microinclusions of mineral-forming substances" was held as a part of the International Geological Congress in Moscow in 1984. Abstracts will be found in COFFI, Vol. 17 (1984).

A National Seminar on Scientific and Industrial Applications of Fluid Inclusions in Minerals was held 21-22 October, 1984, at Dehra Dun, India, convened by Dr. R.R. Patil at the Wadia Institute of Himalayan Geology. Abstracts will be found in COFFI, Vol. 17 (1984).

Future Meetings

A meeting of European Current Research on Fluid Inclusions ("ECRFI") will be held 10-12 April, 1985, at the University of Göttingen, Göttingen, F.R.G., convened by Dr. E.E. Horn of the Geological Institute at the University of Göttingen.

A Conference on Stable Isotopes and Fluid Processes in Mineralization will be held 10-12 July, 1985, at the University of Queensland, St. Lucia, Brisbane, Australia.

A symposium on Occurrence and Genesis of Brines and Gases in Crystalline Rocks is being organized by P. Fritz and S.K. Frape, in connection with the GAC/MAC Joint Annual Meeting, 15-17 May, 1985, Frederickton, New Brunswick, Canada.

The Second International Symposium on Hydrothermal Reactions will be held August 12-14, 1985, at the Pennsylvania State University, University Park, Pennsylvania.

A symposium on Organics and Ore Deposits will be held April 25-26, 1985, in Denver, Colorado, under the auspices of the Denver Region Exploration Geologist Society; it will include organic fluid inclusion studies as one topic.

The Fourth Heidelberg Symposium on Ore Genesis will be held at the University of Heidelberg, F.R.G., February 14-15, 1985.

An international conference on Concentration Mechanisms of Uranium in Geological Environments will be held at Nancy, France, October 2-5, 1985.

The Seventh IAGOD Symposium will be held at Luleå, Sweden, August 18-22, 1986.

The Forteenth General Meeting of the International Mineralogical Association will be held 13-18 July, 1986, at Stanford University, Stanford, California, U.S.A.

The Fifth International Symposium on Water-Rock Interaction will be held in Reykjavik, Iceland, August 8-17, 1986.

Regional Representatives

The following series of Regional Representatives have been established to provide foci for coordination and exchange of information on COFFI 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.

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

ppb	parts per billion (10^9)	My	million (10^6) years
ppm	parts per million (10^6)	Ma	million (10^6) years
μg/g	parts per million (10^6)	mybp	million years before present
‰	parts per thousand	Ga	billion (10^9) years
ppt	parts per thousand	XCO_2	mole fraction CO_2
per mil	parts per thousand	K	temperature Kelvin
per mille	parts per thousand	mg	milligram (10^{-3} g)
%	parts per hundred	μg	microgram (10^{-6} g)
percent	parts per hundred	ng	nanogram (10^{-9} g)
Ky	thousand years	J	joule
Ka	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: one kPa = 0.1 kbar; one GPa = 10^8 bars = 10^5 kbar = 10^2 Mbar. 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.

Abstracts, Translated Abstracts, or Annotated Citations to World Literature, 1982

Note: Some items from previous years that were missed earlier are included, as are items for which a full English translation has become available, during the year, even if the item was previously abstracted from the original Russian. 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 the cyrillic names of Russian authors have resulted in different spellings of what is probably the same name (e.g., Petersil'e, Petersilie, and Petersilje). To avoid problems in the use of various bibliographic data bases, I have maintained such spellings as they appeared in the original publications.

AAGAARD, Per and HELGESON, H.C., 1982, Thermodynamic and kinetic constraints on reaction rates among minerals and aqueous soltuions. I. Theoretical considerations: Am. J. Sci., v. 282, no. 3, p. 237-257.

ABEBE, M., 1982, Composition of gases discharged from some thermal features of the Waiotapu geothermal field (abst.): Proc. Pacific Geothermal Conf. 1982 Part 1, Univ. Auckland Geothermal Inst., Auckland, NZ, p. 411.

ABRAMSON, B.S., PALIN, J.M., NOLL, M.R., EGGLESTON, Ted, NOVO-GRADAC, K.J. and NORMAN, D.L., 1982, Skarn formation and mineralization at the Continental mine, Central mining district, southwest New Mexico (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 429. Authors at Dept. Geosci., New Mexico Inst. Mining and Tech., Socorro, NM 87801.

A genetic model has been developed for the Continental Fe-Cu-(Zn) skarn deposit of southwest New Mexico. The deposit consists of Ca and Mg skarns and hornfels which replace Paleozoic and Mesozoic carbonates and shales adjacent to the Hanover-Fierro granodiorite stock. These are cut by later quartz-magnetite-sulfide veins.

Fluid inclusion studies indicate that two distinct fluids were responsible for skarn formation and mineralization. Inclusions in garnet, from the Ca skarn, have filling temperatures of 260-480°C (ave. 280-310°C), salinities of 4.5-19.0 eq. wt. % NaCl, and low XCO_2. Inclusions in quartz, from quartz-magnetite-sulfide veins, have filling temperatures of 265->600°C (ave. 410-480°C), salinities of 2.0-47.0 eq. wt. % NaCl, and high XCO_2.

Thermodynamic calculations, based on mineral assemblages and garnet fluid inclusion data, indicate the skarns and hornfels formed under thermal metamorphic conditions, probably involving only connate and metamorphically-derived fluids. In comparison, high temperatures and salinities of quartz fluid inclusions indicate that the fluid responsible for quartz-magnetite-sulfide mineralization had a significant magmatic component. Such a fluid could have been released late in the cooling history of the stock into the previously formed skarn. (Authors' abstract)

ADAR, F., ASHWAL, L.D., COLUCCI, M.T., BELKIN, H., ROEDDER, E., BERGMAN, S.C., GIBSON, E.K., HENRY, D.J., KOTRA, R.K. and WARNER, J.L., 1982, A progress report on fluid inclusions in meteorites: Meteoritics, v. 17, p. 178. First author at Instruments S.A., Metuchen, NJ.

Fluid inclusions, both primary and secondary, have been discoverd and studied in chondritic and achondritic meteorites. Fluid inclusions are important probes of the petrogenesis of natural rock systems because they yield direct information about the chemical nature of the fluid present in the system at some stage in its history, and place constraints on the rock's P-T history between formation and collection. Such data would be especially important in the study of meteorites because the lack of a geologic context for meteorites hampers inferences about their history.

At least seven meteorites (both falls and finds) are known to contain fluid inclusions: chondrites - Faith H5, Jilin H5, Bjurbole L4, Holbrook L6, Peetz L6, St. Severin LL6, and diogenite ALHA 77256. Surprisingly, fluids in chondrites have the same properties as those in the diogenite achondrite. These include: (1) shapes, sizes and occurrences: equant, rounded varieties, up to 20-30 μm, commonly along healed fractures and larger isolated irregular ones, up to 100 μm; (2) presence of both two phase (liquid + vapor) and three phase [liquid + vapor + glass(?)] inclusions; (3) a broad range in temperatures of homogenization (Th) of liquid + vapor to liquid from 30° to >220°C with no preferred temperature; (4) apparent difficulty in observing freezing phenomena, i.e., recognition of an observable crystalline phase at low (-180°C) temperatures; (5) increase* of vapor phase volume (V_v) on heating from -180°C; and (6) Raman vibration bands at 3200-3600 cm^{-1}. Properties (3) and (6) are characteristic of an aqueous fluid, but the fluid cannot be pure H_2O because of (4) and (5). If observations of change in vapor bubble morphology from deformed to spherical at -20° to -25°C are inferred to represent final melting, this would indicate large quantities of dissolved components, possibly salts. Laser Raman spectroscopy on many inclusions show no vibration bands characteristic of CO_2, CH_4, H_2, N_2, O_2 or S-bearing species. Our most recent Raman spectroscopic work resulted in precipitation of a dark solid phase, with vibration bands resembling graphite. This was observed for both ALHA 77256 and Jilin. In one inclusion in Jilin, we obtained a broad Raman signal between 2850 and 3000 cm^{-1}, which is characteristic of C-H stretching. This observation must be confirmed by further Raman studies.

In the chondrites, inclusions occur in olivine both inside chondrules and within chondrule fragments, aswell as in pyroxene (Jilin). In the diogenite, inclusions are only present in orthopyroxene. Occurrence of fluid inclusions with chondrules represents another factor which must be accounted for in any model of chondrule origin. Clearly, inferences about the origin of the fluids must await further characterization of their chemical composition. Morphologic, microthermometric, Raman spectroscopic studies along with direct analysis of trapped fluids using the laser microprobe/gas analysis technique are presently underway and the latest findings will be reported. (Authors' abstract)

See also Gibson et al., 1982, this volume. (E.R.)

*This is an unfortunate error that was missed by all in proofing the abstract. The vapor phase decreases on heating. (E.R.)

ADAR, Fran, LeCLERCQ, Michel and GRAYZEL, R.E., 1982, Industrial applications of micro Raman analysis: Am. Lab., p. 59-65.
A brief review (12 references). (E.R.)

AGAPOVA, G.F., SHMARYOVICH, Ye.M., VOROB'YEV, I.M., KHITAROV, D.N. and REKHARSKAYA, V.M., 1982, Experimental studies of conditions of precipitation of uranium from thermal sulfide-carbonate solutions: Geol. Rudn. Mest., v. 24, no. 1, p. 76-87 (in Russian).

AINES, R.D. and ROSSMAN, G.R., 1982, The hydrous component in garnets (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 430.

AKANDE, Samuel and ZENTILLI, Marcos, 1982, Genesis of the Gays River lead-zinc mineralization reconsidered in the light of geologic and fluid inclusion studies (abst.): Geol. Assoc. Canada/Min. Assoc. Canada Program with Abstracts, v. 7, . 35. Authors at Dept. Geol., Dalhousie Univ., Halifax, Nova Scotia, Canada, B3H-3J5.

The Gays River lead-zinc deposit in central mainland Nova Scotia is hosted in a Mississippian carbonate reef complex. Lead-zinc ores are distributed in stratiform bodies and discordant vein systems within a dolomitic reef overlain by Mississippian gypsum and anhydrite. The stratiform ores are generally concordant open-space filling distributed in highly porous, structurally controlled erosional channels separating knobs and ridges of the Lower Palaeozoic quartz metawacke basement. Sphalerite, galena, marcasite, pyrite, chalcopyrite, calcite, fluorite, and barite occupy both primary and secondary porosities of the microdolomitic host rock. Massive stratiform ores occur locally along the evaporite-dolomite contact. Discordant vein systems of N/S, NNE, and E/W orientations, mapped underground, have the largest concentrations of massive sphalerite and galena, with minor chalcopyrite, pyrite, calcite and barite. Localized brecciation, and intense post-ore dedolomitization are spatially related to faults adjacent to the veins. Fluid inclusions in sphalerite homogenize at 215°C, ore-stage calcite at 173°C, post-ore calcite at 142°C, fluorite at 142°C and barite at 137°C, before pressure corrections. Salinity is approximately 20.4 equivalent weight percent NaCl in post-ore fluorite and calcite. Our present geologic and fluid inclusion evidence discounts the possibility of the lead-zinc ores being an early diagenetic cement as previously considered, and places the Gays River ores in the high temperature group of MVTD. Contact relationships and remarkable similarities between the stratiform and vein ores suggest that the discordant veins were feeders to epigenetic conformable mineralization. A model involving deeply circulating brines released during dolomitization and gypsum dewatering best explains the metal leaching, transportation and subsequent deposition of lead and zinc ores as replacements and open-space fillings within the dolomitic reef. (Authors' abstract)

ALDERTON, D.H.M., THOMPSON Michael, RANKIN, A.H. and CHRYSSOULIS S.L., 1982, Developments of the ICP-linked decrepitation technique for the analysis of fluid inclusions in quartz, in R. Kreulen and J. Touret (guest eds.), Current Research on Fluid Inclusions: Chem. Geol., v. 37, p. 203-213. First author at Dept. Geol., Chelsea College, 552 King's Road, London SW 10 OUA.

Further developments in the analysis of fluid inclusion decrepitates by inductively-coupled plasma emission spectroscopy (ICP) are outlined. Decrepitates from samples of quartz have been analyzed and give useful results. As several mechanisms of transfer of material into the plasma are feasible it is important that the temperature of heating should be restricted to the temperature range of decrepitation. However, contamination by silicate phases in the quartz appears to be of little significance. Reproducibility in our analyses is usually better than 30% (relative standard deviation, RSD) and most of this appears to be due to heterogeneity in the abundance of fluid inclusions. We have been able to estimate the ore metal content of some hydrothermal fluids from SW England and have obtained values in the range one hundred to a few thousand parts per million for some elements (Cu, Pb, Zn, Sn and B). Because of the sensitivity of the method we feel that its greatest potential is in the field of routine mineral exploration, and we have had considerable success in this application. (Authors' abstract)

ALEKSANDROVA, E.S., BANNIKOVA, L.A. and SUSHCHEVSKAYA, T.M., 1980, Errors in gas analysis in thermal explosion of inclusions: Geokhimiya, no. 11, p. 1710-1716 (in Russian; translated in Geochem. Int'l., v. 17 no. 6, p. 66-71, 1982).

Abstract in Fluid Inclusion Research--Proceedings of COFFI v. 13, p. 3, 1980. (E.R.)

AL'MUKHAMEDOV, A.I. and MEDVEDEV, A.Ya., 1982, Geochemistry of sulfur in processes of basic magma evolution: "Nauka," Moscow, 148 pp., 700 copies printed, price 1 rbl. 90 kopecks (in Russian).

The book presents a petrologic model of sulfur behavior in pre-chamber and intrachamber magmatic differentiation and results of experimental studies of the role of sulfur in silicate systems, essentially of basic composition. (A.K.)

AMIRZHANOV, A.A. and VORONTSOV, A.Ye., 1982, Petrochemical peculiarities of the liquation processes in alkaline basaltoids from diatremes of the Southen Siberian Platform: Geokhimiya, no. 10, p. 1510-1516 (in Russian).

AMSTUTZ, G.C., EL GORESY, A., FRENZEL, G., KLUTH, C., MOH, G., WAUSCHKUHN, A. and ZIMMERMAN, R.A., eds., 1982, Ore genesis: the state of the art, Society of Geology Applied to Ore Deposits Spec. Pub. 2, 804 pp., pub. Springer-Verlag, New York: Econ. Geol., v. 77, p. 1956-1962.

Consists of 74 papers by various authors, mostly favoring syngenetic origins for the deposits, and hence frequently in conflict with the data from fluid inclusion studies, unless one assumes that most syngenetic ores have been recrystallized by later, non-ore-forming hydrothermal fluids. The more pertinent papers are abstracted in this volume. (E.R.)

ANANTHASWAMY, J. and ATKINSON, G., 1982, Thermodynamics of concentrated electrolyte mixtures. I. Activity coefficients in aqueous NaCl-$CaCl_2$ at 25°C: J. Solution Chem., v. 11, no. 7, p. 509-527.

ANDERSON, A.T., Jr., 1982, Sources of volatiles in subduction zone magmas (abst.): EOS, Trans. Am. Geophys. Union, v. 63, p. 449. Author at Dept. Geophy. Sci., The Univ. Chicago, Chicago, IL 60637.

Both juvenile and recycled sources of volatiles are possible for subduction zone magmas. Such sources include crustal aquifers and rocks as well as subducted rocks and unmodified mantle. Similar ratios of Cl/K_2O near 0.08 in high-alumina basaltic liquids from diverse regions suggest a uniform volatile source of plausible subcrustal origin. Large and variable Cl/K_2O in basaltic liquids from the Shasta region appear to be related to dehydrated ultramafic xenoliths of crustal origin. Variably large Cl/K_2O at Asama may reflect crustal contamination. The estimated amount of Cl brought to the crust by subduction zone magmatism is about the same as the estimated amount subducted as amphibolitic oceanic crust, consistent with a deep, subduction-recycled source for Cl. The amount of H_2O brought to the crust by subduction zone magmatism is still uncertain but appears to be less than the amount subducted. Consequently most subduction zone basaltic magmas probably do not have major sources of H_2O from both the mantle and crust. The unusually large concentrations of H_2O in some Shasta basaltic liquids may reflect an additional input of crustal H_2O because of the association with the dehydrated xenoliths. Some subduction zone high-alumina basaltic liquids are sulfide saturated and most have about as much dissolved sulfur as other basaltic liquids, suggesting unexceptional redox conditions, possibly inherited from an unexceptional mantle environment. Present data are consistent with subduction-recycled sources of Cl, H_2O and S in subduction zone high-alumina basaltic liquids, but local crustal additions are likely and juvenile sources cannot be ruled out. (Author's abstract)

ANDERSON, G.M. and BURNHAM, C.W., 1982, Feldspar solubility and the transport of aluminum under metamorphic conditions (abst.): Geol. Assoc. Canada/Min. Assoc. Canada Program with Abstracts, v. 7, p. 36. First author at Dept. Geol. Univ. Toronto, M5S 1A1, Canada.

Na and K complex with Al in aqueous solutions at high P and T to an extent that varies with temperature. This explains why feldspars dissolve incongruently under these conditions, giving micas at some temperatures and feldspathoids at higher temperatures. Comparison of aqueous SiO_2 values in equilibrium with feldspar with quartz solubilities shows that aqueous SiO_2 is at least partly in a form other than H_4SiO_4. Since Al does not dissolve unless complexed by alkalies, the simplest interpretation of the solubility data is that the dominant solute produced by feldspar dissolution (at $P > 2$ Kb) has the feldspar stoichiometry. The transport of Al in hydrothermal solutions depends on how much alkali is available, i.e. not tied up with other ligands such as chloride. Experimental data show that in the low Cl^- solutions, aqueous Al contents are quite high. (Authors' abstract)

ANDREWS, A.J., OWSIACKI, Leo, KERRICH, R.W. and STRONG, D.F., 1982, No. 32 Petrology, stable isotopes, and fluid inclusions of the Ag-Co-Ni arsenide vein deposits near Cobalt and Gowganda, Ontario, in Summary of Field Work, 1982, by the Ontario Geol. Survey, J. Wood et al., eds.: Ontario Geol. Survey Miscellaneous Paper 106, p. 207-209. First author at Geol. Mineral Deposits Sec., Ontario Geol. Survey, Toronto, Canada.

Fluid inclusion studies will be made. (E.R.)

ANTONIU, N.K., SEVRYUKOV, N.N. and DOLGANEV, V.P., 1982, The system $NaBr-Na_2CO_3-H_2O$ at 50°C: Zhurn. Neorg. Khimii, v. 27, no. 5, p. 1333-1335 (in Russian). Authors address not given.

Solubility isotherm 50°C and composition of crystal phases in equilibrium with solution are given. (A.K.)

APLONOV, V.S. and SOKOLOV, S.V., 1982, Evaluation of suitability of minerals with perfect cleavage for decrepitation analysis, in Use of methods of thermobarogeochemistry during prospecting and studies of ore deposits, N.P. Laverov, ed.: Moscow, "Nedra" Publ. House, p. 175-184 (in Russian).

A large number of minerals with perfect cleavage and of various origins was described and it was shown that their decrepitation is caused by inclusions of mineral-forming media. This supposition is proved by: 1) significant variation of T of decrepitation beginning and end, 2) decrease of Td for a sequence of generations of one mineral, 3) similarity of Th and Td, 4) confirmation of T intervals of mass decrepitation by visual observations of T of leakage of inclusions. The conclusion is that decrepitation may be used for minerals with perfect cleavage. (Authors' abstract translated by A.K.)

AREVADZE, D.V. and YAROSHEVICH, V.Z., 1982, The origin and sources of substances of some volcanogenic deposits in the USSR (abst): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 9-10. Authors at Caucasian Inst. Min. Resources, Tbilisi, USSR.

The methods of thermobarogeochemistry and isotope geochemistry were used for investigations of the ore deposits within the areas of present-day and recent volcanism (The Mutskovskoje deposit on the peninsula Kamchatka, the Valentina and Nazarovskoje deposits on the island Kunashir, the Kolyma ore deposits, Madneuli, David-Gareji, Tsiteli-Sopeli deposits in the Lesser Caucasus).

The ore deposits of the Lesser Caucasus and Kunashir reveal vertical zoning of ores - from pyrite and copper-pyrite to polymetallic and barite-polymetallic ores. The lode deposits of Kamchatka and Kolyma seem to be polyascendent ones.

In the ore deposits under study the temperature of ore-formation changed from 400 to 350°C at early stages and from 250 to 180°C at later stages, only the monomineral barite ores of the Lesser Caucasus revealed warm-water primary inclusions (120-60°C). The pressure did not seem to exceed 500 bars. Occasionally boiling of fluids was observed at the productive stage of ore deposition.

The fluids in the most of the ore deposits were chloridic and weakly concentrated (3-10 weight per cent of NaCl equiv.). Besides the chloride, the fluids of gold-silver deposits contain a sulphate-ion, while their concentration reaches 30 weight % NaCl equivalent. Although being a predominant gaseous component, the carbon dioxide does not make up a separate phase in the inclusions.

In most cases the sulphide sulphur has nearly standard values of $\delta^{34}S$ from +4 to -4‰. Sulphur becomes lighter from the early to late sulphide generations in the copper-pyrite and barite-polymetallic deposits of the Lesser Caucasus. A similar change of the isotope composition is observed in barites ($\delta^{34}S$ from +20 to +12‰), which is indicative of sulphate-ion formation caused by partial oxidation of the sulphide sulphur in the fluid. The fluid of the gold-silver deposit contains predominantly an oxidized form of sulphur ($SO_4^{=}$) with the calculated value of $\delta^{34}S \approx +1$‰.

The values of the carbon isotopes of the carbonates ($\delta^{13}C$ from -4.7 to -9.8‰) are close to those of the deep-seated CO_2.

The isotope content of the water hydrogen is close to the δD values of the regional meteoric waters both in the primary and in the secondary fluid inclusions of the minerals in the studied deposits; however, a number of samples from the Lesser Caucasus and Kolyma demonstrated a near-juvenile isotope composition of the water, which is indicative of a possible existance of magmatic liquids in the hydrothermal solutions.

The isotope content of hydrogen and oxygen in the present-day geothermal waters of the Kuryly-Kamchatka volcanic arc proves their essentially meteoric source, while in the fumaroles of a number of volcanoes (Mutnovski, Avachi, Mendeleev, Tjati, Ebeko) anomalous values of δD and $\delta^{18}O$ are observed, which does not rule out presence of a considerable portion of the magmatic component.

It is thus concluded that despite of the fact that deposits under discussion belong to different ore formations, they were originated from similar hydrotherms in the same P-T-X-conditions. The water source in such systems is a polygenic one with an obvious prevalence of the meteoric component, while the sulphur and carbon dioxide are of a deep-seated origin. Thus the diversity of ore deposits of volcanic belts was evidently caused by metal sources and actual geological conditions of hydrothermal discharge. (Authors' abstact).

ARKHANGEL'SKAYA, V.V., 1982, Geology and conditions of formation of lead ore mineralization at the Mountain Bol'shoe Bogdo in the Pricaspian depression: Izvestiya Akad. Nauk SSSR - Ser. Geol., no. 8, p. 108-121 (in Russian). Author at IGEM of the Acad. Sci. of USSR, Moscow.

Ores of the Bol'shoe Bogdo Mt. formed in limestones from epigenetic hydrotherms. Th of inclusions in analcite from ores were 150-220°C, sometimes to 260°C, Td up to 300°C. (A.K.)

ÁRMANNSSON, H., GÍSLASON, G. and HAUKSSON, T., 1982, Magmatic gases in well fluids aid the mapping of the flow pattern in a geothermal system: Geochimica et Cosmo. Acta, v. 46, p. 167-177. First author at National Energy Authority, Geothermal Div., Reykjavik, Iceland.

Gas composition and silica concentrations of well fluids are used in conjunction with pressure, temperature and enthalpy data to obtain a model of the drilled part of the Krafla geothermal field (Northeast Iceland).

A magma chamber is located at 3-8 km depth under the field. Magmatic gases emanate from the chamber and travel via a channel reaching the surface at the Hveragil eruptive fissure. The composition of the gases is apparently modified on the way, in that sulphur, which presumably is in the form of sulphur dioxide to begin with, is removed on the way, and what remains is in the form of hydrogen sulphide at the end. It is suggested that the major removal mechanism is the deposition of pyrite and pyrrhotite during the passage of the gases through the hydrothermal system.

The hydrothermal system is divided into a lower part whose temperature exceeds 300°C and whose fluids are to a varying extent affected by the magmatic gases, and an upper part whose temperature is ca 200°C. This upper part is a run-off from the lower part but the magmatic effects have mostly disappeared there. (Authors' abstract)

ARMBRUSTER, Thomas and BLOSS, F.D., 1982, Orientation and effects of channel H_2O and CO_2 in cordierite: Am. Min., v. 67, p. 284-291. First author at Lab. Chem. and Mineral. Crystal., Univ. Bern, Freiestrasse 3, CH-3012, Bern, Switzerland.

Channel CO_2 and H_2O were reintroduced into a channel evacuated Mg-cordierite and the changes in properties noted. (E.R.)

ARNDT, N.T. and NISBET, E.G., eds., 1982, Komatiites: London, George Allen and Unwin, 526 pp. First author at Max-Planck-Institut für Chemie, Mainz.

Of pertinence to the study of the silicate melt inclusions found in typical pyroxene and olivine crystals in komatiites. (E.R.)

ARNÓRSSON, Stefán, SIGURDSSON, Sven and SVAVARSSON, Hördur, 1982, The chemistry of geothermal waters in Iceland. I. Calculation of aqueous speciation from 0° to 370°C: Geochimica Cosmo. Acta, v. 46, p. 1513-1532. First author at Sci. Inst., Univ. Iceland, Dunhagi 3, Reykjavik, Iceland.

A computer program has been developed to calculate the composition and aqueous speciation of geothermal reservoir waters including pH, redox potential and gas partial pressures. The program is specifically suited to handle geochemical data from wet-steam wells, hot-water wells and boiling hot springs, but it may also be used for non-thermal waters. Solubility data for selected geothermal minerals are incorporated to facilitate the study of solution/mineral equilibria. The program may also be used to study chemical changes in water chemistry accompanying boiling, variable degassing and cooling, and how these changes disturb solution/mineral equilibria. (Authors' abstract)

ASHWAL, L.D., COLUCCI, M.T., LAMBERT, P., HENRY, D.J. and GIBSON, E.K., Jr., 1982, Fluid inclusions in meteorites: direct samples extraterrestrial volatiles: LPI Conf. on Planetary Volatiles, Alexandria, Minnesota, Program Oct. 9-12, 1982 (unpaginated). First author at Lunar and Planetary Inst., Houston, TX.

A longer (two-page) version similar to Adar et al. (1982; this volume). (E.R.)

ATKINSON, P., MOORE, J.McM. and EVANS, A.M., 1982, The Pennine orefields of England with special reference to recent structural and fluid inclusion investigations: Bull. BRGM, Sec. II, v. 2, no. 2, p. 149-156. First author at Dept. Geol., Leicester Univ., England.

Thermometric fluid inclusion measurements on quartz, fluorite, baryte and calcite from the Alston Block show a decreasing depositional temperature sequence. Fluid inclusion homogenization measurements on fluorite from the Askrigg Block and the Southern Pennine Orefield indicate lower temperatures of mineralization. In the Alston Block thermal gradients in the proximity of vein intersection feeder zones are high whilst the other two mineralized areas have poorly defined lateral gradients even in their fluorite zones. (From the authors' abstract)

ATKINSON, P., MOORE, J.M.M. and EVANS, A.M., 1982, The Pennine orefields of England with special reference to recent structural and fluid inclusion investigations: Bull. BRGM, Sec. II, v. 2, no. 2, p. 149-156 (in French, English abstract). First author at Dept. Geol., Leicester Univ., England.

The lead-zinc-baryte-fluorite mineralization of the Pennine Orefields occurs in veins and metasomatic replacements in Lower Carboniferous rocks. Recent studies have shown that the vein systems formed as a result of combinations of wrench and extensional mechanisms. Stratigraphical variation in the structural style of the veins includes en echelon, extensional and splayed fissures with small normal horizontal and oblique slip displacements. The systems of vein fissures with minor wrench movements correspond in geometry to the Riedel shear fracture groups obtained in deformation experiments.

The Lower Carboniferous strata is draped over tilted, partly fault bounded blocks of Lower Palaeozoic Caledonian "basement." Vein swarms in the Northern Pennine Orefield tend to lie above Caledonian granite cupolas in the basement. The Southern Pennine Orefield consists of a mineralized belt trending NW-SE whose vein system has a dominantly E-W strike. The important veins formed by incipient wrench faulting appear to be Riedel shear fractures created as the Carboniferous cover strata ruptured in response to reactivation of basement faults under simple shearing stress conditions.

Thermometric fluid inclusion measurements on quartz, fluorite, baryte and calcite from the Alston Block show a decreasing depositional temperature sequence. Fluid inclusion homogenization measurements on fluorite from the Askrigg Block and the Southern Pennine Orefield indicate lower temperatures of mineralization. In the Alston Block thermal gradients in the proximity of vein intersection feeder zones are high whilst the other two mineralized areas have poorly defined lateral gradients even in their fluorite zones.

Theories of ore genesis are discussed briefly. (Authors' abstract)

BERDNIKOV, N.V. and KARSAKOV, L.P., 1982, Fluid inclusions in minerals of the rocks of the Belomorian complex: Akad. Nauk SSSR Doklady, v. 266, no. 6, p. 1440-1443 (in Russian; see Translations).

BABURIN, L.M., VIKULOVA, L.P., DEMIN, B.G., ERMAKOV, N.P., LEVITSKY, V.V., POPIVNYAK, I.V., RAZVOZZHAEVA, E.A. and KHRENOV, P.M., 1982, Geochemical parameters and physico-chemical conditions of hydrothermal system formation (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 10-11. Authors at East-Siberian Res. Inst. Geol., Geoph. & Min. Resources, Irkutsk, USSR.

1. The T, P, V and the chemical and isotopic compositions of the gaseous, liquid and solid phases of the ore-forming hydrothermal systems have been studied.

2. Quartz veins are developed in the upper parts of the systems in which the solutions passed in unconfined cavities, while zones of streaky-impregnated essentially sulphide mineralization occur in their lower parts where the solutions circulate along confined paths and where filtration-diffusion mass-transfer was predominant.

3. The temperature range in the vein zones is 500-50°C; the tourmaline-quartz complex is formed at 500-350°C; the pyrite-quartz complex at 460-310°C; the gold-pyrite-polymetallic-quartz complex at 300-170°C; and the quartz-carbonate complex at 160-50°C. The temperature gradients in the vein zones and in the impregnated zones are 15-20°C and 3-5°C per 100 m, respectively.

4. The pressure in the mineral-forming system was above 2000 atm. at early stages of the process, and 600-800 atm. at ore stages.

5. In the course of mineral formation the minerals consisting of elements with lower atomic weight are successively substituted for the minerals consisting of elements with higher atomic weight, i.e., sulphides and sulpharsenides of Fe, Co, Ni, for Co and Zn sulphides, Co selenides, Pb and Bi sulphides, Co, Bi and Sb; Au, Ag and Pb tellurides for free Au, Ag, Pt. A similar substitution of anions with a high atomic weight is observed: S-As-Se-Sb-Te.

6. Hydrocarbons appeared to reduce stage-by-stage in the gaseous phase of the quartz and sulphides, while carbon dioxide increased from pre-ore to ore stages: CO_2/CH_4 increases from 3-5 to 50-100, the atomic ratio H:C:N:O changed from 1:3:5:6 to 1:200:20:300, the gas-saturation value grew from 10-50 to 100-250 cm^3/kg. In Au CO_2 = 90-75%; C_1 = 0.1-3%; C_2-C_5 = 0.1-0.01%.

7. The availability of hydrocarbons in gold, and of bitumens and asphaltenes in quartz and sulphides, the data on the metal evacuation in magmatic gases, comparison with series of ligand effects of the metal-organic compounds, and observation of high Au concentrations in the ore insoluble organic matters, in asphaltenes and asphaltogenic acids suggest that the elements migrate in the ore-magmatic systems as complex metalsulphurorganic compounds like $C_2H_2C = CAu\ NH_3$, $(CH_3)_2Au \cdot TeS \cdot CN \cdot Pb_3$, cis-$PbAuCl_2S \cdot Pr$, etc.[sic] In the beginning of the process within the ore-formation boundaries occurs oxidation of hydrogen, carbon and hydrocarbons;

halogens react with sodium, potassium; transition metals with sulphur, arsenic, antimony, selenium, and heavy metals react with tellurium and organic ligands to form metallorganic compounds. Within the boundaries of the ore-lode systems the P and T drop causes boiling, and degasification of solutions, decay of metallorganic compounds, precipitation of sulphides, selenides, tellurides from the solutions, and reduction of free Au and Ag. Most part of the hydrocarbon radicals are oxidized. However, the metallorganic compounds do not destroy completely which is proved by the presence of groups with strong double and triple bonds in the minerals.

8. The C, O, S, Pb, He, Sr isotopic data and availability of intermetallic compounds of tellurium in the ores speak for the crustal-mantle nature of the ore-matter and, especially, the crustal origin of the ore-forming solutions.

9. The polygenic ore matter is distributed in the thermal systems under certain physical and chemical conditions (T = 300-170°C P = 800-600 atm., CO_2 in gases = 80-95%, hydrocarbon = 0.1-2.0%, N^2 = 5-15%, $Na^+ > K^+$, $Cl^- > F^-$, Pb>Zn, Co<Ni). Its distribution is defined by the initial metal concentation in the deep-seated and magmatic fluids, by structural and compositional peculiarities of the host medium, by the duration of certain undisturbed physico-chemical conditions of the hydrothermal systems, by the metallorganic compound concentration in the fluids, the ligands of the compounds predetermining mobility of the metals and kinetic characteristics of substitution and exchange reactions of the complexes. (Authors' abstract)

BACK, William and LÉTOLLE, René, eds., 1982, Symposium on Geochemistry of Groundwater: 26th Int'l. Geol. Congress, Paris, 1980, reprinted from J. Hydrology, v. 54, no. 1/3, 1981: Amsterdam, Elsevier Sci. Pub. Co.

Includes sections on geochemistry of brines and deep aquifers, isotopes in groundwater, etc. (E.R.)

BAILEY, D.K., 1982, Kimberlite: "the mantle sample" formed by ultrametasomatism (abst.): Terra Cognita, v. 2, p. 232.

BAKER, M.B. and GROVE, T.L., 1982, The importance of H_2O in controlling textural development during dynamic crystallization (abst.): EOS, Trans. Am. Geophys. Union, v. 63, p. 451.

BAKUMENKO, I.T., 1982, Accompanying, combined and anomalous inclusions, criteria for their recognition and possibilities of use, in Use of methods of thermobarogeochemistry during prospecting and studies of ore deposits, N.P. Laverov, ed.: Moscow, "Nedra" Publ. House, p. 126-140 (in Russian).

Originally homogeneous inclusions are usually called normal. Moreover, various inclusions that originally were not homogeneous or that were epigenetically altered, used to be called anomalous. Those that were trapped as mineral-forming medium and another phase (G, L or Xl), are called combined inclusions. Only some anomalous inclusions are able to provide limited information. Anomalous inclusions should be distinguished from normal ones. Xenogenic trapped phases are called accompanying phases. Especially interesting are syngenetic accompanying inclusions of boiling solutions and melts, because together with normal inclusions they may provide valuable information about composition, phase state, and density of boiling products and give true T of crystallization without Th correction. The paper gives also 32 drawings of various "anomalous" inclusions. (Abstract by A.K.)

BAKUMENKO, I.T., KOSUKHIN, O.N. and CHUPIN, V.P., 1982, Conditions of crystallization of pegmatite-bearing and ore-bearing granites (with reference to investigation data of inclusions) (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 195-196. Authors at Inst. Geol. & Geophy., Novosibirsk, USSR.

Temperatures of crystallization and conditions of enrichment of granitic magmas with volatile components have been found with the help of melt inclusion study in quartz and other minerals. Significant variations of the initial temperatures of magmatic crystallization have been determined; the temperatures appeared to be sometimes higher than 1000-1200°C for some massifs of quartz porphyries, granite-porphyries and granodiorite-porphyries with which polymetal and rare-metallic mineralization is associated (Salair, Eastern Zabaikalje, Mongolia, Armenia, Uzbekistan); sometimes they are higher than 800°C for a number of pegmatite- and ore-bearing granite massifs (Volyn, Buryatiya, Eastern Kazakhstan, Eastern Zabaikalje).

A sharp drop of crystallization temperature of the granite melts is connected with increasing content of water (water is frequently found as a separate phase in the fluid part of the melt inclusions). For instance, impregnations of quartz in some ore-bearing quartz porphyries of Zabaikalje began to crystallize from "dry" high-temperature (above 1000°C) melts, while their external zones and the basic mass crystallized from water-containing melts at much lower temperatures (below 700°C). The early phases of multiphase granite massifs are usually more high-temperature and formed from "drier" magmas than later phases (Korosten pluton, Vyborg massif, Khan-Bogdin massif in Mongolia, etc.). In the Korosten rapakivis considerably lower temperatures have been observed: from 830-790°C at early phases to 630°C at later phases, with a rare-metal ore formation occurring at low temperatures.

Accumulation of water in granite magmas contributes as well to formation of residual pegmatite melts, therefore, magmatic crystallization of pegmatites occurs at lower temperatures and from melts which contain more water than their host granites (sometimes even below 600°C). Pegmatite melts may have been formed in migmatite-gneiss series as a direct consequence of anatexis. The anatectic ceramic pegmatites of the Aldan Shield crystallized at 830-760°C, the muscovite pegmatites of the Mama districts - at 650°C.

Fe, B, Li - saturated granite magmas crystallize at lower temperatures. Water significantly increases the fluxing effect of these components (the Vyborg rapakivis of late phases, the Ukrainian granites with zinnvaldite and topaz, the Bukhaingol massif granites in Mongolia, chamber pegmatites of different regions formed as low as 600-540°C).

An integrated study of melt inclusions and syngenetic fluid inclusions in quartz has provided an estimation of fluid composition and pressure, as well as of saturation and boiling temperatures of acid magma. The boiling events are especially characteristic of pegmatite melts. The carbon-dioxide-water fluid pressure was not high (about 1 kbr) in high-temperature pegmatites, while the water pressure was higher (reaching 3-5 kbar) in lower-temperature fluids. Boiling was observed also in anatectic magmas of the granulite facies (890-860°C at 5-6 kbar; the isolating fluid rich in CO_2) and in allochthone granites (particularly, at later stages of their magmatic crystallization, e.g., for the rapakivi it took place at less than 600°C and at 3-4 kbar; the fluid being rich in water). Isolation of large fluid masses enhances concentration of the ore matter evacuated from the melts and/or its extraction from its host rocks. (Authors' abstract)

BALASUBRAMANIAM, K.S., 1982, Usefulness of healed surface fluid inclusion data in the evaluation of low temperature ore deposits (abst.): [Proceedings & Abstracts], National Workshop on Fluid Inclusion Studies, 22-23 March, 1982, Indian Inst. Tech., Bombay, p. 44-46 (unpaginated). Author at Indian Inst. Tech., Bombay.

Inclusions in healed fractures in minerals from the large fluorite deposit related to carbonatite at Amba Dongar have been studied with the 'CHAIXMECA' unit. Heating has been done at the rate of 1°C per minute and freezing measurements were carried out before the determination of homogenization temperature. Two ranges of Tt were recognized: (1) 150°C - 215°C for early fluorites and (2) 74°C - 140°C for later fluorites. REE and other geochemical studies also show two generations of fluorites, one associated with radioactive minerals and the other associated with sulphide minerals. Further, earlier fluorites contain mainly primary fluid inclusions, whereas the later fluorites carry secondary inclusions. These deposits are formed at low temperatures, from low salinity fluid; both dropped considerably during successive stages of mineralization. (From the author's abstract)

BALITSKIY, V.S., 1982, Credibility of results of thermobarogeochemical studies on the basis of inclusions in minerals, in Use of methods of thermobarogeochemistry during prospecting and studies of ore deposits, N.P. Laverov, ed.: Moscow, "Nedra" Publ. House, p. 198-208 (in Russian).

The credibility of results of inclusion studies is still debatable, because all methods of study were (and are) developed through use of natural minerals, i.e. by reconstructions and suppositions. Comparative material simply does not exist. Recently the homogenization method was verified and proven by studies of synthetic crystals. Gas analysis of individual inclusions in synthetic quartz, calcite and phlogopite proved that the inclusion gases qualitatively correlate with gases present in autoclaves, but quantitative data are not sufficiently exact. Analyses of water leachates from synthetic quartz also differ both from the autoclave solution before and after the runs (analyzed components Li, Na, Cl, S, SiO_2). Special studies should be performed for verification of the methods presently used by means of synthetic minerals. (Abstract by A.K.)

BALL, T.K., FORTEY, H.J. and SHEPHERD T.J., 1982 Wallrock alteration profiles around the Harding and Smith veins, Carrock Fell mine, Cumbria (abst.): J. geol. Soc. London, v. 139, p. 98-99.

Studies of the detailed geochemistry and petrography of the granitic host rock surrounding the Smith and Harding veins were presented. Two related processes affecting the geochemical distribution were noted. One is related to the greisening of the wallrock, resulting in the breakdown of feldspar, the other to the introduction of ore mineral-forming elements. These processes are related in turn to the fluids present or introduced into the wallrock at the time of emplacement of the lodes. (Authors' abstract)

BANDY, A.R., MAROULIS, P.J. and WILNER, L.A. and TORRES, A.L., 1982, Estimates of the fluxes of NO, SO_2, H_2S, CS_2 and OCS from Mt. St. Helens deduced from in situ plume concentration measurements: Geoph. Res. Letters, v. 9, no. 9., p. 1097-1100. First author at Chem. Dept., Drexel Univ., Philadelphia, PA 19104.

Measurements of the concentrations of NO, SO_2, H_2S, CS_2, and OCS were made in the Mt. St. Helens plume September 22, 1980. In this study the NO, SO_2 and H_2S concentrations were in the range 20-314 pptv, 0-438 ppbv and 0-54 ppbv respectively. The concentrations of CS_2 and OCS were below our lower limit of detection of 10 ppbv. Ratios of the concentrations of NO and SO_2 and H_2S and SO_2 were found to be 1.3×10^{-3} and 0.13 respectively. Fluxes of 65 and 1.1 tons per day were estimated for H_2S and NO respectively. The fluxes of CS_2 and OCS were found to be less than 20 tons per day. (Authors' abstract)

BANNIKOVA, L.A., BARSUKOV, V.L., GRIGORYAN, S.S. and VOLKOV, V.V., 1982, Effect of carbon-involved redox reactions on the formation of a gold-ore deposit in Armenian SSR: Geokhimiya, no. 7, p. 961-970 (in Russian, English abstract). First author at Inst. Geochem. and Anal. Chem., Moscow, USSR.

The paper refers to fluid inclusion data from the literature mostly from the earlier publications of the same authors. (A.K.)

BANNIKOVA, L.A., BELYI, V.M. and NAUMOV, V.B., 1982, Peculiarities of formation of stratiform copper ores of Dzhezkazgan on the basis of the isotope data and results of fluid inclusion studies: Geokhimiya, no. 2, p. 198-208 (in Russian). Authors at Inst. Geochem. and Anal. Chem., Moscow, USSR.

Dzhezkazgan deposit of Cu and Cu-Pb, Central Kazakhstan, occurs in reddish detrital beds of Middle and Upper Carboniferous. Ores disseminated in sediments occur together with veins consisting of calcite, quartz, barite, celestite, gypsum, chalcocite, bornite, chalcopyrite, galena and other sulfides. Almost all P and PS inclusions in barren minerals are G/L (two-phase); only one specimen bears one-phase L inclusions. All inclusions homogenized in L phase, some specimens yielded Th 192°C, but mostly Th were in ranges 50-150°C; Te = -43 to -52°C, Tm of last ice crystal -10 to -25°C, total salt concentration should be in ranges 15-25 wt.%, with density at 100-190°C about 1.1-1.2 g/cm^3. (Abstract by A.K.)

BARANOVA, N.N. and RYZHENKO, B.N., 1981, Computer simulation of the Au-Cl-S-Na-H_2O system in relation to the transport and deposition of gold hydrothermal processes: Geokhimiya, no. 7, p. 989-1001 (in Russian; translated in Geochem. Int'l., v. 18, no. 4, p. 46-60, 1982).

Abstract in Fluid Inclusion Research--Proceedings of COFFI, v. 14, p. 11. (E.R.)

BARGAR, K.E. and MUFFLER, L.J.P., 1982, Hydrothermal alteration in research drill hole Y-11 from a vapor-dominated geothermal system at Mud Volcano, Yellowstone National Park, Wyoming, in S.G. Reid and D.J. Foote, eds., 33rd Annual Field Conf., Wyoming Geol. Assoc. Guidebook 1982, Mammoth Hot Springs, WY, Sept. 15-18, 1982, p. 139-152. Authors at U.S. Geol. Survey, 345 Middlefield Road, Menlo Park, CA 94025.

U.S. Geological Survey research diamond-drill hole Y-11 in the Mud Volcano area of Yellowstone National Park was drilled to a depth of 105.7 m. The hole penetrated about 2.1 m of Holocene fluvial sedimentry deposits, 13.1 m of glacio-sedimentary deposits associated with the Pinedale Glaciation (≥45,000-14,000 yr B.P.), approximately 4.3 m of tuff beds of the Upper Basin Member of the Plateau Rhyolite (~265,000 yr B.P.), and 86.2 m of a 600,000 year-old ash-flow tuff (the Lava Creek Tuff of the Yellowstone Group). Cavities in the welded ash-flow tuff contain abundant sanidine and tridymite from vapor-phase crystallization during cooling of the flow. The rhyolitic glassy groundmass had undergone extensive devitrification to form alkali feldspar and alpha-cristobalite before hydrothermal alteration.

Hydrothermal alteration in drill core Y-11 was produced by an early chloride-rich near-neutral hot-water system and a later vapor-dominated system. The hot-water system precipitated minerals such as chalcedony, quartz, septechlorite, calcite, rhodochrosite, bastnaesite, mordenite, fluorite, and some beta-cristobalite, pyrite, and montmorillonite. These minerals cannot have been deposited from the steam and bicarbonate-sulfate condensate found in the present geothermal system. Later minerals related to the current vapor-dominated regime include opal, kaolinite, halloysite, alunite, and some beta-cristobalite, pyrite, and montomorillionite. These yonger minerals are, in part, superimposed on the earlier formed minerals. Relations between the two generations of hydrothermal minerals are best observed in the drill core within the later cross-cutting fractures at 74.6-77.6 m, where later fracture fillings of kaolinite and pyrite cut across earlier chalcedony fracture fillings. (Authors' abstract)

BARGER, J.E., et al., eds., 1982, Special issue - polymetallic sulfides: Marine Tech. Soc. J., v. 16, no. 3, p. 1-92.

Contains 14 articles on various aspects of the occurrence, origin, and hydrology of seafloor sulfide deposits of interest to all studies of the inclusions from such vent materials. The most pertinent are abstracted in this volume. (E.R.)

BARKER, D.S., 1982, Magnetite-apatite veins in quartz monzonite, Iron Springs district, Utah: a revised model (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 439. Author at Univ. Texas at Austin, Austin, TX 78712.

Magnetite-apatite veins fill radial subvertical joints in three of four shallow plutons of Miocene quartz monzonite. Joints formed where concordant intrusive contacts have radii of curvature less than 2 km. Ore bodies of magnetite replace limestone only next to those parts of plutons cut by magnetite-apatite veins. Previously the veins were considered conduits through which iron-bearing fluid escaped from deuterically altering quartz monzonite to form replacement ore. New data suggest that vein fillings formed later than the metasomatic bodies, as CO_2- and Cl-rich fluid migrated back into quartz monzonite through joints which earlier had been avenues for escape of aqueous fluid.

"Bleached" selvages, richer in clinopyroxene and albite, locally vesiculated, and containing highly altered biotite and no surviving amphibole, abut the joints and formed at high temperature as the fractures opened. Selvages alone were inadequate sources for iron in veins and replacement ore; probably iron was extracted from the entire mass of altering quartz monzonite and migrated through joints into limestone. Subsequently, magnetite and apatite precipitated in the joints, forming inward-younging comb structure. Ti and V in vein magnetite decrease toward the centers of veins. Vein apatite has higher Cl/F (increasing toward centers of veins) and higher halogen/hydroxyl ratios, than apatite in quartz monzonite.

A fourth pluton, containing disseminated hematite but no veins or replacement ore, was emplaced at shallower depth into clastic sedimentary rocks. XCO_2 in hydrothermal fluid appears to have exerted decisive control on formation of metasomatic and vein magnetite bodies. (Author's abstract)

BARNES, H.L., 1982, A genetic model for Mississippi Valley-type ore deposits (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 439. Author at The Pennsylvania State Univ., 235 Deike Bldg., University Park, PA 16802.

Diagenesis and burial metamorphism in miogeosynclines releases water equivalent to roughly 1/3 the initial sediment volume. For basins within 30° latitude of the equator, often present in the section are the evaporites, high organic contents, and bacterially produced sulfides necessary for this released water to form a potential ore solution. Complexes of Pb and Zn with soluble organic ligands, stable to at least 200°C, must account for transport rather than inorganic complexes which provide at 150°C solubilities only 10^{-2} to 10^{-4} times the minimum 10 ppm required.

Episodic dewatering of this solution along growth faults from below about 3 km depth, corresponding to a minimum of 150°C, may follow 3 different paths, depending on shale-limiting permeability. (1) Permeable growth faults may allow ebulition to the basin floor to form a syngenetic, bedded deposit, such as Bleiberg, Austria. (2) Similar flow into the hinge zone at the basin margin may produce both epigenetic and syngenetic ore in pinnacle or barrier reefs, such as Pine Point, N.W.T. (Due to the tectonics of basin margins, (1) and (2) are often strongly faulted.) (3) Alternatively, impermeable growth faults may divert flow through extrabasinal aquifers to deposit epigenetic ores in cratonal carbonates or sandstones, such as in S-W Wisconsin or Laisvall, Sweden. All three subtypes show high organic contents. (Author's abstract)

BARNES, S.J., COATS, C.J.A. and NALDRETT, A.J., 1982, Petrogenesis of a Proterozoic nickel sulfide-komatiite association: the Katiniq sill, Ungava, Quebec: Econ. Geol., v. 77, p. 413-429. First author at Dept. Geol., Univ. Toronto, Toronto, Ontario M5S 1A1, Canada.

Concentrations of precious metals, particularly Pt and Pd, are unusually high in the Katiniq sulfides; this may be partially due to higher concentrations of these elements in the parent silicate magma but is thought to be largely the consequence of equilibration of the sulfide liquid with very large volumes of silicate magma. Accumulation of immiscible sulfide liquid droplets in the sill probably occurred over a period of time when large volumes of silicate magma were flowing through the sill and subsequently on toward the surface. (From the authors' abstract)

BAROSS, J.A., LILLEY, M.D. and GORDON, L.I., 1982, Is the CH_4, H_2 and CO venting from submarine hydrothermal systems produced by thermophilic bacteria?: Nature, v. 298, p. 366-368.

BARRETT, T.J. and ANDERSON, G.M., 1982, The solubility of sphalerite and galena in NaCl brines: Econ. Geol., v. 77, p. 1923-1933. Authors at Dept. Geol., Univ. Toronto, Toronto, Ontario M5S 1A1, Canada.

If chloride complexes are the dominant form of Pb and Zn in ore-forming solutions, it is unlikely that 3 m NaCl solutions below 150°C could carry sufficient quantities of metal(s) and reduced sulfur to form an ore deposit. (From the authors' abstract)

BARSUKOV, V.L. and BORISOV, M.V., 1982, Simulating the geochemical consequences of hydrothermal solution automixing. Part 2. Mass transfer in areas of contraction of hydrothermal flow: Geokhimiya, no. 9, p. 1244-1256 (in Russian).

BARTON, M.D., 1982a The fluorine-rich skarn at McCullough Butte, Eureka Co., NV: Geol. Assoc. Canada/Min. Assoc. Canada Program with Abstracts, v. 7, p. 38. Author at Geophys. Lab., 2801 Upton St., NW, Washington, DC 20008, USA.

Geologic mapping SW of Eureka, Nevada reveals that fluorine-rich alteration underlies >3 square miles near McCullough Butte. The Ordovician host rocks are Pogonip Gr. limestone, Eureka Quartzite, and Hanson Creek Fm. dolomite. Structure in the area is broadly simple: NNW-trending folds, but with abundant low-angle faults (related to the Mississippian age Roberts Mtn. thrust), and later Basin and Range faults.

The 84±3 m.y. stockwork skarn has ubiquitous fluorite and is apparently related to two-mica granite porphyries which are very poorly exposed. Alteration in carbonate hosts can be divided on the basis of vein and vein envelope mineralogies into (from early to late): 1) garnet-pyroxene veins and skarn; 2) plagioclase veins and amphibole skarn envelopes; 3) mica-fluorite veins with mica skarn; and 4) quartz/carbonate veins. Dominant sulfides are sphalerite, pyrrhotite, and lesser pyrite; silicates are low-iron with more iron in the clinopyroxene than in the garnet. Locally pervasive dolomitization of Pogonip limestone preceded the skarn-forming event but is not quite coincident with it. In the quartzite quartz veins dominate except near carbonate contacts where tremolitic zones are common. Quartz veins with greisen envelopes occur in the porphyry dikes.

Geochemical data indicate low aO_2, aS_2, aCO_2, total Fe, Cu, and Pb and high F, $^{87}Sr/^{86}Sr$, Zn, and Be with anomalous W, Sn, and Mo. Various data suggest a low-temperature, low-pressure origin by reaction of the carbonates with acid, fluorine-rich fluids derived from a local granitic body. The skarn resembles other low-sulfide, fluorine-rich skarns associated with typical greisens. (Author's abstract)

BARTON, M.D., 1982b The thermodynamic properties of topaz solid solutions and some petrologic applications: Am. Min., v. 67, p. 956-974. Author at Geoph. Lab., Carnegie Inst. of Washington, 2801 Upton St., NW, Washington, DC 20008.

Hydroxyl-topaz contents of topaz coexisting with other aluminous phases increases with increasing pressure and decreasing temperature. With decreasing temperature at constant composition topaz removes HF from a water-rich fluid. (From the author's abstract)

BARTON, M.D., RUIZ, Joaquin and ITO, Emi, 1982, Preliminary tracer studies of the fluorine-rich skarn at McCullough Butte, Eureka Co., Nevada (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 440. First author at Geophys. Lab., 2801 Upton St., NW, Washington, DC 20008.

The REE and isotopes of C, O, and Sr have been studied to trace the sources of components in a multiple-stage, fluorine-rich skarn associated with two-mica granite porphyries, as well as in nearby quartz+carbonate+Ag veins. The C/O results on carbonates from the different rock types show that the Ag veins are strongly depleted in ^{18}O and that the fluorite-associated alteration is depleted in ^{18}O and ^{13}C relative to the host carbonates. Initial $^{87}Sr/^{86}Sr$ is 0.7087-0.7105 in the host carbonates and 0.7117 in the granite, with intermediate values in the alteration. The REE in the alteration resemble the host REE.

The C/O results are compatible with a meteoric fluid for the Ag veins, and a magmatic (±meteoric) fluid ± the effect of decarbonation for the F-rich alteration. The Sr results support a magmatic source for the F-rich alteration, whereas the local sources of the REE are consistent with published, high mineral/fluid K_D's. (Authors' abstract)

BARTON, P.B., Jr., 1982, The many roles of organic matter in the genesis of mineral deposits (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 440. Author at U.S. Geol. Survey, 959 National Center, Reston, VA 22092.

Organic matter and the vital functions of organisms have many roles in geochemical processes related to mineral deposits. Among these are:

1) catalyzing of reactions, such as the reduction of sulfate or the oxidation of sulfide; 2) mobilization of elements, such as by chelation or complex formation; 3) immobilization of elements, such as by sorption or precipitation; 4) modifying chemical environments, such as by changing oxidation potential or pH; and 5) serving as a reducing or oxidizing agent, such as in the precipitation of pitchblende in sandstones.

Organic matter plays two other roles of which the first already is, and the second may prove to be, of considerable importance in mineral exploration: 1) Living plant matter often accumulates elements that are present in soils or ground water, thereby providing a sampling medium for geochemical exploration. 2) Dead organic matter undergoes a complex series of maturation reactions, the rates of which are strong functions of temperature; thus examination of the maturation state of organic matter can distinguish regions that have, form those that have not, been heated. It would appear to be a potential prospecting guide for Mississippi Valley-type Pb-Zn deposits, "no-see-'em" Au ores, and other epigenetic deposits.

As a reductant/oxidant, organic matter may function right up into the magmatic range, but most other roles are limited to less than perhaps 200°C. The temperature of 200° marks a fuzzy division (for sulfide ores) between high-temperature deposits that form by processes that are in principle reversible and the low-temperature deposits for which disequilibrium may be essential. (Author's abstract)

BASSETT, A., DEICHA, G. and PROUVOST, J., 1982, Crystallogenetic disequilibrium in ore veins as indicated by hydrothermal fluid inclusions, in G.C. Amstutz et al., eds., Ore Genesis; The State of the Art, p.737-741. First author at Dept. Min. Cristallog., Univ. Pierre et Marie Curie, Tour 16 (2 E), 4 place Jussieu, 75230 Paris Cedex 05, France.

The presence and nature of inclusions in quartz as revealed by SEM studies of broken surfaces is used to suggest the degree of supersaturation of the depositing fluids. (E.R.)

BATARD, F., BAUBRON, J.C., BOSCH, B., MARCE, A. and RISLER, J.J., 1982, Isotopic identification of gases of a deep origin in French thermomineral waters: J. Hydrology, v. 56, no. 1-2, p. 1-22.

BATSANOV, S.S., 1982, Temperatures of formation of solid solutions of alkaline metal halides: Zhurn. Neorg. Khimii, v. 27, no. 8, p. 2145-2146 (in Russian). Authors address not given.

The paper presents equation for calculation of temperature of solid solution formation for structures of the NaCl type (Li, Na, K, Rb, Cs vs F, U, Br, I), that may help in interpretation of dms in inclusions. (A.K.)

BAUMER, Alain, KLEE, Wilfid, LAPRAZ, Dominique, MULLIS, Josef and OBERHÄNSLI, Roland, 1982, Crystal chemical studies on an apatite from an alpine fissure (La Fibbia, St. Gotthard-massif, Switzerland): Schweiz. Mineral. Petrogr. Mitt., v. 62, p. 353-363 (in French). First author at Lab. Géol. & Géochimie, E.R.A. 888 Transfert de Matière, Parc Valrose, F-06034 Nice Cedex.

An apatite from an alpine cavity at La Fibbia (St. Gothard, Switzerland) was examined by microthermometry, with an electron microprobe, by X-ray diffraction and by infrared spectroscopy. The mineral is a fluorapatite with some replacement of fluoride by hydroxyl and of phosphate by carbonate ions. The apatite is thermoluminescent, the effect being mainly due to the presence of Mn^{2+}. A consideration of the parageneses and a study of the fluid inclusions showed that the mineral was formed at temperatures between 380 and 420°C and at pressures between 1.5 and $2.0 \cdot 10^8$ N/m^2. From the crystal form and other observations it can be deduced that the growth rate was low. It appears that the supersaturation was the result of a steady decrease in pressure. (Authors' abstract) (The fluid inclusion study was by J. Mullis.)

BAZAROVA, T.Yu., KOSTYUK, V.P. and KUZNETSOVA, I.K., 1982, Composition of differentiation products of alkaline basaltoid melts: Geologiya i Geofizika, no. 10, p. 73-77 (in Russian; English abstract). First author at Inst. Geol. Geophys. of Siberian Branch of Acad. Sci. USSR, Novosibirsk.

Melt inclusions in clinopyroxene of composition of alkaline basalt were submitted to partial melt crystallization. Three stages of experiment were controlled by electron microprobe analysis of glass composition: stage I - fresh melt, stage II - initial recrystallization, stage III - remnant glass after melt crystallization (see Figure). Comparison of composition of remnant glass in pyroxenes from alkaline basalts from various petrographic provinces shows the complete similarity of course of the differentiation process: decrease of FeO, MgO and CaO contents and accumulation of SiO_2, Al_2O_3 and K_2O plus essentially constant Na_2O content. SiO_2 content increase reaches 10-12%, K_2O 6-7%, Al_2O_3 6-10%. This proves the possibility of formation of e.g. potassium-high syenites by magma differentiation process. (Abstract by A.K.)

Figure. Stages of change of inclusion melt composition during its crystallization: 1-alkaline basalt, 2-stage I, 3-stage II, 4-stage III.

BEANE, R.E., 1982a, Evolution of hydrothermal minerals and related fluid characteristics in some porphyry copper deposits of the southwestern United States of America (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 12-13. Author at AMAX Explor., Inc., Tucson, AZ, USA.

Paragenetic relations among vein-related hydrothermal mineral assemblages and accompanying fluid inclusions reveal a systematic pattern to development of alteration and mineralization in a group of porphyry copper deposits of southern Arizona and New Mexico, U.S.A. In the central porphyritic intrusion, three classes of hydrothermal fluids can be recognized, based on differences in temperature and salinity. These groups exhibit a common order of appearances in the deposits studied. The earliest fluids had high salinities, on the order of 45-70% NaCl equivalent, and inclusions homogenize at temperatures in excess of 750°C; these fluids deposited quartz, K-feldspar, biotite, and magnetite, which have oxygen isotope ratios characteristic of a magmatic source. Inclusions of such fluids are absent at most porphyry copper deposits studied. The succeeding class of fluids has inclusion homogenization temperatures generally less than 500°C, but salinities remain high, normally in the range 36-60 wt% NaCl equivalent; attendant alteration is the same as that with higher temperature hypersaline fluids. The last type of fluids recognized has salinities normally less than about 15 wt% NaCl, and inclusions homogenize most commonly between 250° and 400°C. These late fluids are seen with alteration mineral assemblages which progress from K-feldspar + magnetite or hematite to K-feldspar + chlorite + epidote + chalcopyrite + pyrite ± magnetite and finally to quartz + sericite + pyrite. Oxygen-hydrogen isotope studies have led to the supposition that the dilute fluids were derived from a dominantly meteoric source.

Available evidence indicates that the progression from original potassic alteration produced by hypersaline magmatic fluids to propylitic and then phyllic alteration minerals during circulation of low-salinity fluids occurs under near-isothermal conditions. In all of the deposits studied, deposition of copper sulphides commenced with formation of the quartz + epidote + chlorite ± orthoclase alteration assemblage, although chalcopyrite may be spatially related to earlier potassic minerals undergoing propylitization. The silicate mineral sequence defines a systematic decrease in the activity quotients $(K^+)/(H^+)$ and $(Fe^{2+})/(H^+)^2$ in the hydrothermal fluid, which can be interpreted to result from increasing amounts of meteoric fluids flowing through, and reacting with, rocks initially altered to the potassic assemblage. The accompanying sequence of opaque minerals; magnetite, then chalcopyrite + pyrite, and finally pyrite with changing silicate altertion is interpreted to be a result of the decreasing aqueous $(Fe^{2+})/(H^+)^2$ caused by reactions between various silicate minerals and the hydrothermal fluid.

Studies of the porphyry copper deposits show that as time progressed, the location and intensity of fracturing of the rock volume changed. Early fracturing occurred throughout the central intrusion and to a short distance into adjacent wall rocks, but as time evolved, fracturing became more intense and was concentrated toward the margins of the intrusive. Thus a volume of unfractured rock expanded outward from the center of the porphyritic intrusion over older fractured material. Because fracturing controlled fluid flow and attendant alteration, successively younger hydrothermal mineral assemblages were overprinted on older assemblages from the center toward the margins of the intrusion. The final result is the zoned porphyry copper deposit consisting of an old, central potassic core, an adjacent shell of K-feldspar + chlorite + epidote containing hypogene mineralization, and a young phyllic zone focused on the margins of the porphyritic intrusion. (Author's abstract)

BEANE, R.E., 1982, Hydrothermal alteration in silicate rocks: southwestern North America, in S.R. Titley, ed., Advances in Geology of the Porphyry Copper Deposits, Southeastern North America, p. 117-137.

Includes reference to pertinent fluid inclusion studies from the literature. (E.R.)

BEATY, D.W. and TAYLOR, H.P., Jr., 1982, Some petrologic and oxygen isotopic relationships in the Amulet mine, Noranda, Quebec, and their bearing on the origin of Archean massive sulfide deposits: Econ. Geol., v. 77, p. 95-108. First author at Noranda Exploration, 12640 W. Cedar Dr., P.O. Box 15638, Denver, CO 80215.

Whole-rock $\delta^{18}O$ values decrease from about 6 to 10 in most of the Abitibi belt to 5 to 7 in the country rocks surrounding the ore deposit, to values as low as 3.6 in the core of the dalmatianite zone. This oxygen isotopic zoning must have been produced by the hydrothermal activity, because the dehydration reactions associated with contact metamorphism cannot have affected $\delta^{18}O$ by more than 0.5 per mil. Assuming an alteration temperature of 300° ± 50°C and a water/rock ratio greater than two, the hydrothermal fluid must have had $\delta^{18}O = 0.5 \pm 1.0$. This indicates that the Amulet ore deposit formed from a hydrothermal fluid that had a $\delta^{18}O$ value similar both to modern seawater and to the fluids which formed the Phanerozoic massive sulfide deposits of the Kuroko and Cyprus types. The apparent constancy of $\delta^{18}O$ of seawater during the Precambrian and the continued importance of seawater hydrothermal processes are important constraints which must be considered in developing models of the history of the earth. (From the authors' abstract)

BEHR, H.J. and HORN, E.E., 1982, Fluid inclusion systems in metaplaya deposits and their relationships to mineralization and tectonics, in R. Kreulen and J. Touret (guest eds.), Current Research on Fluid Inclusions: Chem. Geol., v. 37, p. 173-189. Authors at Geol.-Paläontol. Inst., Univ. Göttingen, D-3400 Göttingen, FDG.

Fluid inclusions have been analyzed along traverses through the Upper Proterozoic Damara Orogen, South West Africa/Namibia. Two genetically different fluid systems of regional importance could be distinguished: (1) a fluid system with 25-50% gross salinity (NaCl-KCl-$CaCl_2$), source: continental evaporitic sequences; and (2) another fluid system with 4-16% gross salinity (NaCl), source; metamorphic fluids derived from pelitic geosynclinal sediments.

Further fluid systems of local importance are bound to numerous late-tectonic granite and alaskite intrusions.

Residual hypersaline solutions caused mineralization of stratiform Cu deposits and numerous giant quartz reefs.

The two fluid systems have played an important role in the development of thrusts and nappes. (Authors' abstract)

BEIN, Amos and LAND, L.S., 1982, San Andres carbonates in the Texas Panhandle: sedimentation and diagenesis associated with magnesium-calcium-chloride brines: Bureau Econ. Geol, The Univ. Texas at Austin, Austin, TX, Report of Investigations No. 121, 48 pp.

Includes a gas chromatographic study of organic matter in carbonates, Br in halite, Sr in anhydrite, various elements in whole-rock carbonates and 5 analyses for Na, Ca, Mg, Cl, HCO_3 and SO_4 in water leachates. (E.R.)

BELEVTSEV, Y.N., 1982, Ore-forming metamorphogenic systems (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 14-15. Author at Inst. Geochem. & Physics of Min., Kiev, USSR.

Three groups of metamorphogenic deposits are distinguished according to the formation temperatures of ore paragenesis: (1) one corresponding to low-temperature facies (100-120 to 550°C); (2) the other describing to average temperature facies (500 to 650°C); and (3) the third group of high temperature facies (650 to 1000°C).

The pressures of ore-formation were found considering the carbon-dioxide content in the fluid inclusions of the minerals. They were 1.5-2.5 kbar for the first-group deposits, 2-3 kbar for the second-group and 4-5 kbar for the third-group. (From the author's abstract)

BELEVTSEV, Ya.N., BUKHAREV, V.P., NAUMENKO, V.V., GONCHARUK, A.F., POPOV, B.A., STEPANOV, V.A. and USENKO, A.I., 1982, Volcanic-sedimentary origin of magnetite ores ion the Urals: Geol. Rudn. Mest., v. 24, no. 1, p. 53-66 (in Russian). Authors at Inst. Geochem. and Physics of Minerals of Acad. Sci. of Ukr. SSR, Kiev, Ukrainian SSR.

The mineral associations in the Blagodat' Mt. ore field formed at the following temperatures (Th and Td): 1) ≥670°C - pyroxene+scapolite+garnet+magnetite; 2) 480-560°C - pyroxene+zoned garnet+(amphibole, biotite)+magnetite+epidote; 3) 380-480°C - epidote+magnetite+sulfides; 4) 180-260°C - apatite+chlorite+albite+analcite+calcite. (A.K.)

BELOVA, L.L., KRICHEVETS, G.N. and SHMARIOVICH, E.M., 1982, On the hydrodynamic conditions of epigenetic mineralization formation under the interaction of stratal waters and ascending fissure-vein solutions: Akad. Nauk SSSR, Dokl., v. 265, no. 2, p. 393-396 (in Russian).

BENDER, J.F., HANSON, G.N. and BENCE, A.E., 1982, The Cortlandt complex - evidence for large-scale liquid immiscibility involving granodiorite and diorite magmas: Earth and Planet. Sci. Letters, v. 58, no. 3, p. 330-344.

BENY, C., GUILHAUMOU, N. and TOURAY, J.-C., 1982, Native-sulphur-bearing fluid inclusions in the CO_2-H_2S-H_2O-S system - microthermometry and Raman microprobe (MOLE) analysis - thermochemical interpretations, in R. Kreulen and J. Touret (guest eds.), Current Research on Fluid Inclusions: Chem. Geol., v. 37, p. 113-127. First author at B.R.G.M. , Dept. M.G.A., 45060 Orléans Cedex, France.

Fluorite and quartz samples from Oseja (Oviédo, Spain) and Sierra de Lujar (Granada, Spain) contain multiphase fluid inclusions with two immiscible liquids, as gas and a solid phase at room temperature. Studies by Raman scattering microspectrometry permitted:

(a) An unambiguous identification of native sulphur dxl.

(b) Determination of CO_2/H_2S molar ratios in the gas phase and in the two liquids (aqueous solution and a mixture of liquefied CO_2 and H_2S).

(c) In H_2S-rich inclusions, identification of a H_2S hydrate (probably the clathrate $H_2S \cdot 5.75\ H_2O$), observed at low temperature.

A check of internal consistency is given by the comparison of the theoretical $(CO_2/H_2S)_{gas}/(CO_2/H_2S)_{water}$ ratio (value = 3) and the observed ratio (mean value = 3.3).

Homogenization of the gas and (CO_2+H_2S) liquid occurs generally in the liquid phase. In the Lujar samples it occurs between +24°C and 38°C and there is a fair correlation with H_2S content. In the Oseja samples it occurs between +27°C and +48°C, and the trend with composition is not clear. H_2S hydrate was observed during some freezing runs in fluorite from Oseja and CO_2 hydrate in samples from Sierra de Lujar.

Because of decrepitation, total homogenization was observed only in small inclusions of the quartz from Lujar at above 300°C. The temperature of total homogenization corresponds to the vanishing of the sulphur droplet, which determines the paleofugacity of S_2 in the fluid ($10^{-3.6}$ bar).

The main equilibria describing the composition of the fluid inclusions before total homogenization are the following:

(a) $2S \rightleftharpoons S_2$ (buffering fS_2)

(b) $H_2S + 1/2O_2 \rightleftharpoons H_2O + 1/2S_2$ (buffering fO_2).

An example of calculation is given at +250°C. One may see that inclusions are just outside the graphite field and that CH_4/CO_2 is very low which explains that methane was not detected by Raman scattering microspectrometry. (Authors' abstract)

BERDNIKOV, N.V. and KARSAKOV, L.P., 1982, Fluid inclusions in minerals of rocks of the Belomorie complex: Akad. Nauk SSSR Doklady, v. 266, no. 6, p. 1440-1443 (in Russian). Authors at Inst. of Tectonics and Geophysics of Far-East Sci. Center of Acad. Sci. of USSR, Khabarovsk. See also Translations.

Quartz and kyanite from garnet-kyanite-biotite gneisses outcropping on the side of Ryabina River bear LCO_2 inclusions with Th from -54 to +15°C. Three inclusions of superdense CO_2 were found that did not heterogenize on freezing but at -70°C convert to CO_2 solid with formation of a contraction cavity that disappears on melting. The minerals bear also PS and S inclusions of LCO_2. Inclusions of LCO_2 bear frequently trapped graphite crystals. The pressure reaches 8.1×10^8 Pa. (Abstract by A.K.)

BERGER, B.R. and EIMON, P., 1982, Comparative genetic model characteristics of epithermal gold-silver deposits: AIME 111th Annual Meeting, Dallas, TX, Feb. 14-18, 1982, Program, p. 27. First author at U.S. Geol. Survey, Denver, CO.

In paper presented at meeting, the importance of boiling was stressed, and fluid inclusion evidence for it was discussed. (E.R.)

BERGMAN, S.C., 1982, Petrogenetic aspects of the alkali basaltic lavas and included megacrysts and nodules from the Lunar Crater Volcanic Field, Nevada, USA: Ph.D. dissertation, Princeton Univ., Princeton, NJ, 432 pp.

This study integrates major and trace element and Sr-isotopic data on the alkali basaltic lavas and included megacrysts and nodules from the Lunar Crater Volcanic Field (LCVF) with the purpose of understanding the origin and evolution of each group. CO_2-rich fluid inclusions (<12 mole% CO), abundant in all nodules, have compositions and densities indicating relatively oxidized fluids were entrapped at moderate to high pressures. Volatile saturation via primary and/or retrograde boiling of basaltic magmas in the lower crust and upper mantle generated most of these fluids. (From the author's abstract)

BERGMAN, S.C. and DUBESSY, Jean, 1982, Carbon dioxide-carbon monoxide fluids in a veined nodule from the Lunar Crater Volcanic Field (LCVF), Nevada: implications for oxygen barometry (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 443. First author at ARCO Oil and Gas Co., R&D, Box 2819, Dallas, TX 75221.

A wehrlite nodule from the Marcath flow, a late Cenozoic alkali basalt of the LCVF, contains a 1 cm wide vein (80% amph, 15% fspar (An50), and 3% ilm) which chemically resembles an alkali basalt. The vein has been interpreted to result from the intrusion and subsequent crystallization of a relatively primitive alkali basaltic magma into a wehrlite mass in the upper mantle or lower crust (Bergman et al., 1981, EPSL, 56, 343). CO_2-rich fluid inclusions occur in fspar, cpx, ol, and amph in both the vein and host wehrlite. Laser-Raman spectroscopic data indicate that the fluids in the vein consist of 8-12 mole % CO in CO_2, whereas, those in the host wehrlite are >99.5 mole % CO_2; H_2, CH_4, N_2, SO_2, and H_2S, if present all, occur in concentrations less than 0.5 mole %. Using the CO-CO_2 fluid compositions and fugacities, oxidation states (when corrected for P and T) of the fluid inclusions in the vein phases are near QFM (log $fO_2 \cong -9$ at 1200°C), whereas, those in the host wehrlite are significantly more oxidized (log $fO_2 \cong -5$ at 1200°C). On cooling below ~1000°C, the CO-CO_2 fluids possess predicted oxidation states in the graphite stability field.

The fO_2 of the vein fluid is in the range reported for basaltic extrusives and suggests that the vein's parental magma had an oxidation state at depth similar to surficial basaltic lavas. Fluids within the wehrlite are compositionally different from those in the vein and suggest that (a) these two fluid generations did not equilibrate over the scale of <5 mm and (b) prior to the intrusion of the QFM-oxidation-state-basalt to form the vein, the CO_2-rich fluids in the wehrlite were significantly more oxidized. (Authors' abstract)

BERGMAN, S.C., WARNER, J.L., HENRY, D.J., ASHWAL, L.D., LEE-BERMAN, R. and GIBSON, E.K., Jr., 1982, Fluid inclusions in diogenite ALHA-77256: Lunar & Planetary Sci. XIII, The Lunar & Planetary Inst., Houston, p. 35-36.

See Adar et al., 1982, this volume. (E.R.)

BERKEBILE, C.A. and DOWTY, Eric, 1982, Nucleation in laboratory charges of basaltic composition: Am. Mineralogist, v. 67, p. 886-899. First author at Dept. Marine Geol., Corpus Christi State Univ., Corpus Christi, TX 78411.

Homogeneous nucleation probably never occurs in the laboratory or in nature in basaltic compositions. The principal question concerning natural basaltic rocks is whether nucleation in each case was internal, on suspended crystals, or external, on wall rocks or other surfaces. (From the authors' abstract)

BERZENIN, B.Z., BOBROV, A.B. and KICHURCHAK, V.M., 1981, Physico-chemical conditions of formation of rare-metal pegmatites in the middle Pridneprov'ye: Geokhimiya i rudoobrazovaniye, v. 9, p. 63-66 (in Russian). Authors at Novomoskovskaya Geol.-Prosp. Expedition of the Trust "Ukryuzhgeologiya."

Precambrian rare-metal pegmatites in the central part of the Ukrainian Shield, Komendantovskaya zone, occur in amphibolite-facies metamorphic rocks and aplite-pegmatoid granites of the marginal zone of the oldest block of Ukrainian Shield. Three pegmatite types are distinguished: microcline, microcline-oligoclase and albite. Following P inclusions were found in albite: G + L + 45-50% of crystal phases (salts and silicates); G dissolves in LH_2O (280-370°C), and next crystals start to dissolve with complete homogenization at 540-620°C. Some inclusions decrepitated at >600°C before homogenization. Similar inclusions but with a little different phase ratios homogenized at 470-500°C. Numerous S inclusions homogenized at 200-310°C. Thus, pegmatites formed under action of magmatic melts-solutions rich in Rb and Cs. (Abstract by A.K.)

BEZVERKHNYI, M.P. and GRIGORCHUK, G.Yu., 1982, Certain geochemical peculiarities of endogene mineralization of various structural-formation zones in Transbaikalia: Mineralog. Sbornik, v. 36, no. 1, p. 49-59 (in Russian; English abstract). Authors at L'vov Univ., L'vov, Ukrainian SSR.

In the Darasun-Mogocha zone molybdenite-quartz complex formed at 550-290°C, quartz-tourmaline - 420-280°C, bismuthinite-quartz - 400-270°C, gold-quartz-pyrite-chalcopyrite - 440-260°C, gold-quartz-polysulfide - 330-310°C, quartz-carbonate-antimonite - 210-180°C; in the Ingoda-Shilka zone quartz complex with scheelite - 350-280°C, gold-quartz-pyrite-arsenopyrite - 390-250°C, gold-bismuthinite-quartz - 380-270°C, quartz-tourmaline - 370-250°C, gold-sphalerite-sulfoantimonite-quartz - 320-230°C, quartz-carbonate-antimonite - 270-100°C; in the Unda-Zol zone quartz-tourmaline complex - 440-290°C, quartz-magnetite - 450-330°C, molybdenite-quartz - 490-300°C, quartz-arsenopyrite-pyrite - 310-200°C, quartz-polymetal - 330-240°C, gold-pyrite-quartz - 300-220°C, quartz-carbonate - 130-30°C. (A.K.)

BIBBY, D.M., 1982, Impurities in natural diamond, in Chemistry and Physics of Carbon, a series of advances, P.A. Thrower, ed., v. 18, p. 1-91. Author at DSIR, Petone, New Zealand.

A very extensive review (91 pp., 223 references) including studies of the gases and other materials in diamond. (E.R.)

BIJAK, M.K. and NORMAN, D.I., 1982, Mineralization of the Bunker Hill mine, Coeur d'Alene district, Idaho, in light of fluid inclusion studies (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 443. Authors at Dept. Geosci., New Mexico Inst. Mining and Tech., Socorro, NM 87801.

The Bunker Hill mine is a Pb-Zn-Ag vein and replacement deposit in the Revett Fm. of the Belt Supergroup. A generalized paragenesis is siderite/sphalerite-sulfosalts-chalcopyrite-quartz/quartz-galena.

Fluid inclusions in sphalerite have homogenization temperatures of 350-320°C and those in quartz, 320-250°C. In inclusions from both minerals, salinities are 10-12 eq. wt. % NaCl, boiling is indicated and an immiscible liquid phase is observed. Gas analysis of inclusions in quartz indicates 2.5 wt. % gases with roughly equal amounts of N_2 and CO_2, and lesser H_2, CH_4, C_nH_n and Ar. Hydrogen sulfide is 10^{-2} to 10^{-3}m.

Boiling by N_2 effervescence is indicated at a calculated pressure of about 500 bars and fN_2 = 300-400 bars. The observed immiscible liquid is suggested to be $NaCl-H_2O-CO_2$ resulting in part from high, internal inclusion-pressures. High nitrogen fluids suggests derivation from a sedimentary environment. We suggest that the mineralizing fluids were derived from the Belt Supergroup and mineralization was at a depth of 1.5 to 5 km. (Authors' abstract)

BILGRAM, J.H., 1982, Kinetics of freezing: Die Naturwissenschaften, v. 69, no. 10, p. 472-478 (in German).

BLATTNER, P., 1982, Synopsis of oxygen isotopes in geothermal solids and fluids of New Zealand - the Ngawha problem: Proc. Pacific Geothermal Conf. 1982 Part 1, Univ. Auckland Geothermal Inst., Auckland, NZ, p. 39-44. Author at N.Z. Geol. Survey and Inst. Nuclear Sci., DSIR, Lower Hutt.

Geothermal minerals serve as downhole probes of oxygen isotope compositions and thus of parameters of geothermal hydrology. "Deep" wells (2500 m) in New Zealand show no sign of $\delta^{18}O$ values 'bottoming out.' Ngawha differs from other systems both in the level and profile details of $\delta^{18}O$ values. The reservoir fluid at Ngawha may largely be of magmatic origin and Ngawha hydrogeology may or may not be suited for development of a high-throughput surface recharge system. (Author's abstract)

BLOKH, A.M., 1982, Matter mobilization in a highly concentrated solution as a result of dissipative state of water in the Earth's interior microspaces (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 15-16. Author at Min. Geol. USSR, Moscow, USSR.

Resorts to the long-since discredited "dense water" studies of Deriagin (see Derjaguin, 1973, Fluid Inclusion Research--Proceedings of COFFI, v. 6, p. 34, 1973) to obtain "melt-solutions" of high silica concentrations. (E.R.)

BOCTOR, N.Z. and FRANTZ, J.D., 1982, Solubilities and thermodynamic properties of $MnCl_2°$ in the system $MnSiO_2-SiO_2-HCl-H_2O$: Carnegie Inst. Wash. Year Book 81, p. 371-374.

BOGDANOV, B., 1982, Hydrothermal systems of pyrite, porphyry copper and copper lode deposits in the Srednegorie zone of Bulgaria (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 17-18.

BOGDANOV, B.D., 1982 Copper-porphyry deposits in Bulgaria: Izvestiya Vyssh. Uchebn. Zaved.-Geologiya i Razvedka, no. 6, p. 37-52 (in Russian). Author at High Mining-Metallurgic Inst., Sofia, Bulgaria.

Th found for ore associations at the Medet deposit are as follows: quartz-pyrite-chalcopyrite-molybdenite veinlets 320-350°C, quartz-molybdenite veinlets 300-320°C, quartz-pyrite 280-310°C, quartz-sphalerite-galena 240°C, quartz-calcite veinlets 200-240°C; Asarel deposit: secondary quartzites 230-213°C, quartz-chalcopyrite-pyrite ores 311-294°C, quartz-sphalerite-galena 230-215°C, quartz-pyrite veins 192-152°C; Prokhorovo deposit: quartz-molybdenite, quartz-chalcopyrite-pyrite and quartz-pyrite veinlets 320-340°C, quartz-sphalerite-galena veinlets 250-270°C; Plana deposit formed at 200-250°C. (A.K.)

BOGOYAVLENSKAYA, I.V., 1982, Studies of inclusions of mineral-forming media abroad (1976-1978) - scientific report, in N.P. Ermakov, ed., Thermobarogeochemistry in Geology - Materials of the Sixth All-Union Symposium on Thermobarogeochemistry: Vladivostok, Far East Sci. Center, Acad. Sci. USSR Pub. House, p. 170-178 (in Russian).

A review. (A.K.)

BOHLEN, S.R., BOETTCHER, A.L. and WALL, V.J., 1982, The system albite-H_2O-CO_2: a model for melting and activities of water at high pressures: Am. Mineralogist, v. 67, p. 451-462. First author at Inst. Geophysics and Planet. Physics, Univ. California, Los Angeles, Los Angeles, CA 90024.

The melting of albite in the presence of H_2O-CO_2 vapor has been determined in piston-cylinder apparatus from 5 to 25 kbar for mole fractions of H_2O in the vapor (X_{H_2O}) from 1.0 to 0.0. Albite in the presence of CO_2-rich vapor melts as much as 150-300°C lower than indicated by previous theoretical and experimental studies. The albite-CO_2 melting curve is indistinguishable from the vapor-absent melting curve up to 15 kbar, but it is significantly lower above 15 kbar as a result of a substantial increase in the solubility of CO_2 in the liquid. Calculated activity coefficients (γ) for water in H_2O-CO_2 vapor in the range 700-1000°C, 5-15 kbar are everywhere greater than unity and increase isobarically and isothermally toward CO_2-rich compositions. For $X_{H_2O}<0.3$ calculated γ_{H_2O} are significantly greater than those predicted by the modified Redlich-Kwong equation. (Authors' abstract)

BOI, M., MAXIA, M., BROTZU, P., MACCIONI, L., SALVADORI, I and VALERA, R., 1982, The vein deposit of Monte Genis (SE Sardinia) in the framework of Sardinian F-Ba mineralizations. Bull. BRGM, sec. II, v. 2, no. 3, p. 303-307. First author at Progemisa S.p.A., Cagliari, Italy.

The Monte Genis vein deposit occurs in a leucogranitic cupola. Two main minerogenetic processes are recognized: I Phase: Ba-F paragenesis, referred to the last magmatic activity. II Phase: F-Ba paragenesis, referred to repeated mobilizations and depositions. (From the authors' abstract)

Fluid inclusions in fluorite 1 have Th 160-190 (banded) to 240-250°C (massive); dm NaCl and liquid CO_2 rare.

Inclusions in fluorite 2 have Th 110-140°C and rare NaCl dm. (E.R.)

BOKIY, G.B., NIKITIN, A.V. and PEPIN, S.V., 1982, Chemical transport of carbon by nitrogen-containing "intermediates" in natural diamond synthesis: Dokl. Akad. Nauk SSSR, v. 266, no. 3, p. 711-714 (in Russian).

BOLIVAR, S.L., 1982, Kimberlite of Elliott County, Kentucky. Kentucky Geol. Survey, Ser. XI, 1982, 37 p.

Kimberlites of Elliott County were emplaced in a series of pulses as a mush magma of suspended cyrstals and xenoliths. A CO_2- and H_2O-rich gas provided a fluidization agent for the mush. The pipes are possibly Early Permian in age. (From the authors abstract)

BONEV, I., 1982, Mechanisms of the hydrothermal ore deposition in the Madan lead-zinc deposits, central Rhodopes, Bulgaria (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 18-

19. Author at Geol. Inst., Bulgarian Acad. Sci., Sofia, Bulgaria.

The study of fluid inclusions shows that the hydrothermal solutions, which deposited the main sulphide assemblages, were high-temperature ones (330-300°C) of low concentrations (4-5% total salinity), Cl-Na-K composition and acid character. No sulphur components (SO_4^{2-}, HS^-, S^{2-}) were detected (sensitivity limit 0.007 g/l). The gas phase consists of CO_2 and water vapor. The preore skarn-forming solutions were of analogous temperature but of about 2 times higher concentration and of alkaline character.

The ore metals were transported in complex, probably chloride forms, while the sulphide deposition was the result of physico-chemical changes in the solutions during their advance and interaction with the geological environment. The neutralization (the lowering of acidity) of the fluids plays a decisive role.

Three concrete mechanisms are found to cause such changes in the solutions: 1) interaction with the pyroxene skarns and sometimes with marbles, 2) interaction with the associated gneiss rocks, 3) boiling of the solutions. (From the author's abstract)

BORISENKO, A.S., 1982, Analysis of salt composition of gas-liquid inclusions in minerals by cryometry method, in Use of methods of thermobarogeochemistry during prospecting and studies of ore deposits, N.P. Laverov, ed.: Moscow, "Nedra" Publ. House, p. 37-47 (in Russian).

The paper presents Te and eutectic compositions of 39 salt-water systems important for inclusion studies and refractive indices, crystal habits, T coefficients of salt dissolution and T interval of salt existence for halite, sylvite, carobbiite [KF], villiaumite, ice, hydrohalite, mirabilite, potassium sulfate, $MgCl_2 \cdot 12H_2O$, borax, bischofite, soda, trona and nahcolite as crystals formed in inclusions on freezing. The course of freezing runs is also shown. Solutions may be divided into five groups on the basis of Te: 1. LiCl and $CaBr_2$ solutions (Te -83.0 to -74.8°C); 2. $CaCl_2$ solutions (Te -49.8 to -55.0°C); 3. $MgCl_2$, $FeCl_2$ and $FeCl_3$ solutions (Te -33 to -38°C); 4. NaCl solutions (Te -21.2 to -23.5°C); 5. sulfate and carbonate solutions (Te -1.2 to -5.0°C). KCl and $KHCO_3$ solutions have separate Te (-10.6 and -6.0°C). Also imperfections and difficulties in cryometric studies are described. (Abstract by A.K.)

BORISENKO, L.F. and KURILENKO, N.M., 1982, Primary magmatic sulfide mineralization in ore-bearing troctolites of the gabbro-anorthosite formation: Akad. Nauk SSSR Doklady, v. 262, no. 1., p. 186-189 (in Russian). Authors at Inst. Mineral., Geochem. and Crystallochem. of Rare Elements, Moscow, USSR.

Troctolites of the Chepoviche gabbro-anorthosite massif (Korosten pluton, Ukrainian shield) bear ilmenite with globular inclusions consisting of pyrrhotite+chalcopyrite or pyrrhotite+silicates that are interpreted as evidence of magmatic (melt) origin of ilmenite. (A.K.)

BORODAEV, Yu.S., MOZGOVA, N.N., OZEROVA, N.A., BORTNIKOV, N.S., PASHKOV, Yu.N., OJVANEN, P. and ILITUJNEN, A., 1982, Mineralogical-geochemical peculiarities of ore region Seinäjoki (Finland), p. 160-206, in Geochemistry of ore-formation processes: "Nauka," Moscow, 272 pp., 900 copies printed, price 3 rbls 50 kopecks (in Russian).

Studies of G/L inclusions in quartz were performed for two sulfide-As-Sb deposits: Tervasmäki and Kalliosalo (Finnland). Three types of inclusions were found: 1. G and essentially G (with LCO_2), Th 320-360°C; 2. Polyphase inclusions LH_2O + LCO_2 + G + solids (ore mineral and halite dm), Th 240-290°C, NaCl concentration 34 wt.%; P 0.5-0.6 kbar; 3. Two-phase G/L inclusions, Th 140-150°C. (A.K.)

BORODAYEV, Y.S., MOZGOVA, N.N., OZEROVA, N.A., BORTNIKOV, N.S., PASHKOV, Y.N., OYVANEN, P. and ILITUYNEN, A., 1982, III, Mercury and antimony; mineralogic-geochemical characteristics of the Seinajoki ore district, Finland, in The Geochemistry of Ore-Forming Processes, Fedorchuk, V.P., ed.: Izd. Nauka, Moscow, USSR, p. 160-206 (in Russian).
Indexed under fluid inclusions. (E.R.)

BORODZICH, E.V., KOROBEYNIK, V.M., SNEZHKINA, Ye.Ye., SOZINOVA, T.V. and YANITSKIY, I.N., 1982, Certain peculiarities of fluid dynamics of the Earth: Akad. Nauk SSSR Doklady, v. 262, no. 3, p. 565-568 (in Russian). Authors at All-Union Sci.-Research Inst. of Mineral Raw Materials, Moscow.
General review of activity of liquids and gases in the Earth's crust and subcrustal zone. (A.K.)

BOW, C., WOLFGRAM, D., TURNER, A., BARNES, S., EVANS, J., ZDEPSKI, M. and BOUDREAU, A., 1982, Investigations of the Howland reef of the Stillwater complex, Minneapolis adit area: stratigraphy, structure, and mineralization: Econ. Geol., v. 77, p. 1481-1492. Authors at Anaconda Copper Co., 555 17th St., Denver, CO 80217.
Consistent relationships between sulfide morphologies and the phase assemblages of host silicates provide convincing evidence that the immiscible sulfide droplets formed concurrently with olivine during the earliest stages of reef genesis. (From the authors' abstract)

BOWERS, T.S., 1982, Calculation of the thermodynamic and geochemical consequences of nonideal mixing in the system H_2O-CO_2-NaCl on phase relations in geologic systems: PhD dissertation, Univ. California, Berkeley, California, 142 pp.
Indexed under Fluid Inclusions. (E.R.)

BOYLE, R.W., 1982, Geochemical prospecting for thorium and uranium deposits: Dev. in Econ. Geol., v. 16: Amsterdam, Elsevier Sci. Pub. Co. Author at Geol. Survey of Canada, Ottawa, Ontario, Canada.
Includes one paragraph (p.363) on liquid inclusion methods. (E.R.)

BRAND, Uwe, 1982, Chemistry of the ore-forming fluids of the Polaris and Abbott River deposits, Cornwallis lead-zinc district, Arctic Canada: host-rock calculations, in Studies in Sedimentary Processes No. 2, Brock Univ. Dept. of Geol. Sci., Research Report Series No. 26, 23 pp.
Isotopically there is little difference between the host and vug liner dolomite of the material from the Polaris and Abbott River West deposits. However, oxygen isotopes are useful in distinguishing between the different carbonates around a lead-zinc deposit.
Elemental and isotopic calculations suggest that the ore-forming brines at Polaris and Abbott River West were chemically analogous to formation water. The Polaris chemical values fall into the optimal range observed for fluid inclusions in Mississippi Valley-type deposits. In contrast, the Abbott River values are at the low end of the optimal range of ore-forming brines. (Author's abstract)

BRATUS', M.D. and POGREBNYAK, I.N., 1982, Genetic peculiarities of crystallization of rock crystal from Bol'shoi Balkhan: Akad. Nauk SSSR Doklady, v. 262, no. 1, p. 189-194 (in Russian). First author at Inst.

Geol. Geochem. of Mineral Fuels of Acad. Sci. of Ukrainian SSR, L'vov.

The studied rock crystal occurrences developed in W. Turkmenia in the junction zone of the Epihercynian platform (Turan plate) with the alpine folded area (Kopetdag), in the area Karachagyl and Karashumt. Rock crystal veins occur in Bajocian black argillites. Rock crystal forms with calcite; calcite is intergrown with milky quartz crystals and colorless transparent quartz occurs in vugs in the central parts of the veins. P inclusions in quartz are connected with rhombohedron and prism faces and they consist of: essentially G (LH_2O up to 10% by vol.), G/L (LH_2O 40-60%) and essentially L (LH_2O 90-98%). G inclusions reach 0.5-1.0 mm, vacuoles are frequently decrepitated. On cooling L, separates that freezes at -181°C with earlier formation of feathery crystals, probably of heavy hydrocarbons. Feathery crystals dissolve on heating at -108.0 to -100.5°C, homogenization of L_1 in G at -71°C or in L[sic] at -76°C. Critical phenomena were observed at -70°C. Phase changes indicate that L_1 is methane with admixture of heavier hydrocarbons. Estimated density of L_1 at -71°C is 0.11 g/cm^3 and at -76°C - 0.26 g/cm^3. Since Th of G/L inclusions are 165-135°C, P should be at Th equal from 920-850 bars to 240-200 bars (Th in external zones 135-90°C). By mass spectrometry gases in mechanically crushed quartz and calcite consist of (in vol. %) CO_2 nil-3.80, N_2 nil-1.52, CH_4 92.94-99.35, C_2H_6 nil-1.74, C_3H_8 nil-0.04 (six analyses). Ions in quartz and calcite by water leachate method (in mg-equiv.) Na 0.012-0.14, K 0.002-0.007, Ca 0.023-0.066, Mg 0.016-0.034, Cl 0.007-0.045, SO_4 nil-0.036, HCO_3 0.037-0.088. CO_2 in inclusions in rock crystal has $\delta^{13}C$ -19.1‰ (PBD standard), same for CH_4 -20.5‰. The value $\delta^{13}C$ sharply differs from methane in sedimentary rocks but it is close to abiogenic methane in inclusions in minerals. (Abstract by A.K.)

BREITSCHMID, Alfred, 1982, Very low-grade regional Alpine metamorphism of sediments in the external part of the Swiss Alps (Vierwaldstatter See, Urirotstock): Eclogae Geol. Helv., v. 75, no. 2, p. 331-380 (in German). Author at Geol. Inst. Univ., Baltzerstrasse 1, CH-3012, Bern.

Very low-grade regional Alpine metamorphism of sediments from the Helvetic zone and the Pennine Klippen-nappe has been studied in a cross section through the external part of the Swiss Alps, along the Basel-Chiasso geotraverse.

The following methods were used:

1. X-ray diffraction and optical analyses (380 samples ranging in age from Triassic to Eocene).
2. Determination of illite crystallinity (IC) (364 samples).
3. Coal rank determination (Rm) (41 samples).
4. Fluid inclusion analyses in fissure quartz (14 samples).

Fluid inclusion analyses show a fluid field of higher hydrocarbons in the zone of diagenesis, while the transition to the methane-fluid field takes place in the border area of diagenesis/anchizone at about 200°C. Finally, the transition to the water fluid field occurs at the beginning of the higher anchizone at around 270°C. (The fluid inclusion analyses reported in Frey, M. et al. (1980, see COFFI, Vol. 13, p. 74) are given here in a new context.)

These studies were used to construct a model in order to demonstrate the geological history of the Helvetic zone including flysch sedimentation, nappe movements, metamorphism and molasse sedimentation. (From the author's abstract)

BRGM, 1982, Low temperature Pb, Zn, F, Ba vein type deposits from the European and North African Variscan provinces: Actes du symposium tenu à Orléans, 21-23 April 1982, en hommage a Jules Agard: Bull. BRGM, sec.

II, no. 2-3-4, 479 pp. (in French; English abstracts).

BRIL, H., 1982a Fluid inclusion study of Sn-W-Au, Sb- and Pb-Zn mineralizations from the Brioude-Massiac district (French Massif Central): TMPM Tschermaks Min. Petr. Mitt, v. 30, p. 1-16.

A fluid inclusion study in the polymetallic Brioude-Massiac district (French Massif Central) shows two main types of mineralizing fluids corresponding to two principal metallogenic cycles. The first cycle includes Sn-W-Au mineralizations as well as stibnite mineralization. These two types of parageneses originate from complex low saline and CO_2-rich fluids and were deposited at rather high temperatures: about 350°C for Sn-W-Au deposits, above 260°C for stibnite occurrences. The second cycle includes colder vein mineralizations with abundant Pb-Zn minerals, deposited between 150-100°C from highly saline fluids, quite different from the former ones. These caused the remobilization of antimony, which was redeposited with Pb in the form of sulphosalts during the second metallogenic cycle. (Author's abstract)

BRIL, H., 1982b, New thermometric data on fluid inclusions in fluorspar from the Langeac district (Haute-Loire), and place of these mineralizations within the regional metallogeny: Comp. Ren. des Seances de L'Acad. Sci., Ser. 2: Mecanique, Physique, Chimie, Sci. de la Terre, Sci. de L'Univers, France, v. 294, no. 2, p. 107-110 (in French).

See previous item. (E.R.)

BRIL, H., 1982c, Late lead-zinc mineralizations (2nd deposit cycle) in the Brioude-Massiac district (French Massif Central): geochemical and isotopic data: Bull. BRGM, Sec. II, v. 2, no. 3, p. 225-235 (in French; English abstract). Author at Groupement d'intérêt sci. BRGM-CNRS, 1 A rue de la Férollerie, 45045 Orléans Cedex, France.

The study of fluid inclusions in the mineralizations of the Brioude-Massiac district has made it possible to distinguish two metallogenic cycles:

- first cycle: vein type mineralizations of W-Sn-(Au)(type A) and of stibnite (type B);
- second cycle: quartz veins with sphalerite and Pb-Sb sulfosalts (type C), galena-sphalerite (type D), barite veins with or without sulfides (type E).

Types C and D are characterized by fluids, present in bi-phased inclusions, moving from solutions with very high salinity to fluids with 18-19% NaCl equivalent, whereas homogenization temperatures of inclusions decrease from about 150 to 100°C.

D and E sphalerite analysis determine, at 150°C, a fS_2 between 10^{-15} and 10^{-18} atm. Their iron content does not vary much. Inversely, C sphalerites, with very high variations in their iron content, are interpreted as partial inheritance from the first cycle.

The isotopic sulfur ratios are quite different between the first and the second cycle: the first cycle shows clear enrichment in ^{34}S, whereas D and E sulfides have low ratios ($\delta^{34}S$ from -3.5 to +4.5‰), and C sulfides, intermediate ratios. In barite, ratios are scattered and very high (from +16.8 to + 27‰).

Alteration parageneses give evidence of temperatures from 200 to 100°C and neutral to slightly acidic pH.

These data show up the originality of the depositional conditions of the second cycle in comparison with the first (fluids, geochemistry, temperatures, alterations) and its clearly hydrothermal character (s.l.).

They reveal the singularity of the sulfosalts-bearing paragenesis, suggesting an origin due to a partial inheritance from the mineralizations of the first cycle. (Author's abstract)

BRIL, Hubert and RAMBOZ, Claire, 1982, Tin-tungsten mineralization of the Brioude-Massiac (Cantal) and the southern Massif Central; analytical comparison of the mineralogy and the associated fluid phases: C.R. Acad. Sci. Paris, Ser. II, v. 294, p. 387-390 (in French; English abstract).

Vein type tin and wolfram deposits are studied on both sides of the Haut-Allier thrust. In both areas, tin and wolfram are found to be transported by a CO_2, CH_4 and N_2-rich low-salinity aqueous fluid, starting to circulate above 400°C. Most metals are precipitated because of the dilution of the CO_2-rich fluid by an aqueous one, less frequently due to the boiling of the CO_2-rich fluid. Because wolframite is commonly associated with phosphorus-bearing minerals in both districts, it is suggestd that wolfram was transported in the CO_2-rich fluid as a phosphorus-bearing complex. (Authors abstract)

BROWN, G.E., Jr., ed., 1982, The mineralogy of pegmatites: Am. Mineral., v. 67, p. 180-189.

A series of abstracts of papers presented at a 1981 symposium. The most pertinent ones are given in this volume. (E.R.)

BROWNE, P.R.L. and GARDNER, M.W., 1982, Subsurface alteration at the Ngawha geothermal field: a progress report: Proc. Pacific Geothermal Conf. 1982 Part 1, Univ. Auckland Geothermal Inst., Auckland, NZ, p. 49-54.

BROWNE, P.R.L. and WODZICKI Antoni, 1977, The aluminium-in-quartz geothermometer: a field test in Geochemistry 1977, A collection of papers by New Zealand geochemists in honor of S.H. Wilson. New Zealand Dept. Sci. & Industrial Research, DSIR Bull. 218, p. 35-36. Author at N.Z. Geol. Survey, Lower Hutt.

The aluminium-in-quartz geothermometer has been tested on samples of optically clear hydrothermal quartz from the Broadlands geothermal field, by comparing drill-hole and fluid inclusion temperatures with those determined from the aluminium concentration vs temperature curve of Dennen et al. (1970). Drillhole and fluid inclusion temperatures are both in the range 262-279°C, whereas aluminium-in-quartz temperatures are 177, 195, 213, 375, 501 and 645°C, showing that the geothermometer is unreliable in this situation. (Authors' abstract)

BRUHA, D.J., McKEE, E.H. and NOBLE, D.C., 1982, Paragenetic, fluid-inclusion and geochronological study of the Teresita vein system, Huachocolpa district, central Peru (abst.): Geol. Soc. Am. Program with Abstracts, v. 14, p. 152-153. First author at Dept. Geol. Sci., Mackay Sch. Mines, Univ. Nevada-Reno, Reno, NV 89557.

Teresita is one of many Pb-Zn-Ag vein systems hosted by propylitically altered volcanic rocks in the Huachocolpa district, Peru. Vein paragenesis can be divided into 4 stages: I qtz+py±gn±sl; II ore-stage sl+gn+py+minor cp+td; III coarse qtz+py+muscovite; IV hydrothermal leaching with replacement of sulfides by ankerite+qtz±barite. Stage-II sphalerite commonly contains abundant trapped solid inclusions, suggesting rapid growth from rapidly ascending hydrothermal fluids. Propylitized wall rock was overprinted with qtz+ser±kaol, with the introduction of some K_2O. Addition of CO_2 then formed carbonate minerals.

Primary fluid inclusions in stage-II sphalerite yield filling temperatures of 225-250°C, increasing to 240-270°C for latest, Fe-poor stage-II sphalerite. Primary inclusions in main stage-III quartz yield temperatures of 260-370°C, largely in the range 290-325°C, whereas late stage-III inclusions homogenize at 160-180°C.

Late Neogene igneous activity began about 10.5 Ma at Huachocolpa. Dacite lavas in the vicinity of Teresita have yielded ages of 9.3 and 8.4 Ma and a porphyry body 6 km north of Teresita has been dated at 7.9 ± 0.2 Ma. Coarse stage-III hydrothermal muscovite from Teresita has been dated at 6.4 ± 0.3 Ma. A system of unaltered rhyodacite dikes, dated at 4 Ma, cuts veins and altered rocks.

The highest temperatures of latest stage II and stage III suggest renewed igneous activity at depth beneath the Teresita system after main stage-II mineralization. The replacement of sulfides by stage-IV ankerite and the carbonatization of wall rock may reflect the breakdown of carbonates undergoing contact metamorphism at depth. (Authors' abstract)

BUI, H.D. and PARNES, R., 1982, A reexamination of the pressure at the tip of a fluid-filled crack: Int'l. J. Engrg. Sci., v. 20, no. 11, p. 1215-1220.

BUKHALOVA, G.A., MIRSOYANOVA, N.N. and YAGUB'YAN, Ye.S., 1982, Quinary system Li, Na, Sr, Ba||F, Cl: Zhurn. Neorg. Khimii, v. 27, no. 9, p. 2410-2414 (in Russian). Authors address not given.

The data from the paper may be used for studies of salt melts immiscible with silicate melts in T range 300-900°C. (A.K.)

BUKHAREV, V.P., GOSTYAEVA, N.M., NAUMENKO, V.V. and SHEMYAKINA, T.I., 1981, Temperature conditions of formation of ore and metasomatite minerals of the skarn-magnetite deposit Blagodat' Mt. (Middle Urals): Geochimiya i rudoobrazovaniye, v. 9, p. 29-36 (in Russian). Authors at Inst. Geochem. and Physics of Minerals, Kiev, Ukraine.

In the Ural and other magnetite deposits (Kacharskoe, Davydovskoe, Anzas, Tayat-Tabrat etc.) scapolite skarn metasomatites are very common. The metasomatites bear also pyroxene, sphene, apatite, magnetite, garnet, albite, chlorite, epidote, analcite and calcite. Inclusions in pyroxenes homogenize in L at 750-780, 560-350°C (P) and at 250-150°C (S); in scapolite at 700-550 and 540-400°C (P), in isotropic garnets 670°C (P), and in zoned garnet 500-420°C (P), other varieties of garnet bear S inclusions with Th 220-130°C. Inclusions in epidote yielded Th 580°C (in G) and 420°C (in L), both types of inclusions were P; S inclusions in epidote gave Th 180-170°C. Apatite bears P inclusions with Th 315-220°C (some inclusions yielded Td 420°C) and S ones - with Th 130-120°C. Th for albite were 220-180°C, for analcite 260-180°C, for calcite 320-160°C (in skarns) and 350-250°C (in marbles). The paper gives also Td of magnetites: 450-620°C. (Abstract by A.K.)

BULAU, J.R., 1982, Intergranular fluid distribution in olivine-liquid basalt systems: Ph.D. dissertation, Dept. Geol. & Geophy., Yale Univ., May 1982, 116 pp.

The distribution of intergranular fluid in olivine-liquid basalt systems has been investigated at high pressures. Experiments were run from 2 days to 32 days in a piston-cylinder apparatus of temperatures to 1360°C and pressures to 20 kb. Observations of quenched run products using reflected visible light and scanning electron microscopy indicate that surface tension was a dominant force in controlling phase distribution in long-term experiments. The fluid wetting angle, which is determined by the ratio of crystal-liquid surface tension to crystal-crystal surface tension, was already between 20 degrees and 35 degrees.

Observations of run products also show that glass, which represents quenched melt, is located on olivine grain corners and edges, indicating that the melt forms an interconnected network in three dimensions. Grain faces appear to be fluid-free. Both of these observations are consistent with theoretical predictions that at equilibrium fluid must occur only along grain edges and corners when the wetting angle is greater than 0 degrees and less than 60 degrees.

A model of surface topology indicates that total system surface tension energy is a function of melt fraction. For all wetting angles greater than 0 degrees and less than 60 degrees a minimum exists in this function when crystal-liquid interfaces take the form of spherical surfaces. In the model system the value of this critical melt fraction is dependent upon the wetting angle, decreasing from near 20 volume percent at 0 degrees to 0.6 volume percent at 60 degrees. Fluid can only be stabilized by surface tension against removal by buoyancy forces and other nonhydrostatic stresses if its fraction within the assemblage is below the critical amount. (Author's abstract)

BULL, B.W., 1982, Mineralization of the area around Gunnislake, E. Cornwall: a fluid inclusion and paragenetic study (abst.): J. Geol. Soc. London, v. 139, part 1, p. 96.

The minor granitic intrusions of Kit Hill, Gunnislake and Hingston Down lie between Dartmoor and Bodmin Moor. A number of E-W striking mineral veins traverse the area, and are in spatial and probable genetic association with the intrusions.

The veins carry cassiterite, wolframite and a number of sulphide minerals. There is little evidence for a spatial zonation of the vein deposits. Examination of polished sections reveals a sequence of mineral deposition which is similar for all the E-W striking veins. Replacement phenomena are common, and it is likely that dissolution of specific minerals has played an important role in vein development.

Heating and freezing studies have been made on the vein minerals. A broad range of homogenization temperatures has been obtained, and are summarized as follows:

(1) Quartz-cassiterite-wolframite veins: Th approximately 200-400°C for quartz and cassiterite;

(2) Sulphide veins with cassiterite and wolframite: (a) Th approximately 200-300°C for quartz, (b) Th approximately 100-200°C for fluorite.

Salinities are variable, and results range from 0 to 42.2 eq. wt % NaCl. The majority lie between 0 and 25 eq. wt % NaCl.

N-S striking veins also traverse the area, and are not restricted to the vicinity of the granite outcrops. In contrast to the E-W veins, they bear only a more limited sulphide assemblage. Homogenization temperatures from fluorite lie between 110 and 140°C. Salinities are between 20 and 25 eq. wt % NaCl. (Author's abstract)

BUNTIN, T.J. and ULMER, G.C., 1982, Merensky Reef potholes: Bushveld plutonic fumaroles? (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 455.

BURCH, C.R., 1982, The use of a stereomicroscope brightfield/darkfield illuminator in conjunction with the Zeiss photomicroscope II for the examination and photography of gemstone inclusions: J. Gemm., v. 18, no. 1, p. 28-36.

BURT, D.M., SHERIDAN, M.F., BIKUN, J.V. and CHRISTIANSEN, E.H., 1982, Topaz rhyolites - distribution, origin, and significance for exploration: Econ. Geol., v. 77, p. 1818-1836. First author at Dept. Geol., Arizona State Univ. Tempe, AZ 85287.

Topaz rhyolites of both the productive and nonproductive type may be valuable indicators of subsurface mineralization. Their distribution coincides very closely with that of (1) fluorite and silver-base metal districts, (2) the central and eastern tungsten belts of Kerr (1946), and (3) topaz-rich porphyry Mo-W deposits of the Climax and Henderson type. Topaz rhyolite volcanic vent areas might then reflect the existence of large F-rich magma chambers below with (1) subvolcanic breccia, porphyry, and greisen vein deposits of Mo, W, Sn, and other elements, (2) base and precious metal veins and fluorite-rich replacements, and (3) more deeply seated rare metal pegmatites. (From the authors' abstract)

BUSHLIAKOV, I.N. and KHOLODNOV, V.V., 1982, Distribution of fluorine and chlorine between the apatite and biotite as an indicator of the fluid conditions and genesis of granitoids: Dokl. Akad. Nauk SSSR, v. 266, no. 5, p. 1260-1263 (in Russian).

BYRNE, P.A. and STOESSELL, R.K., 1982a Methane solubilities in multisalt brines (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p 457.

Solubilities of methane and salting coefficients at 550 psia and 25°C have been determined for 14 multisalt brines consisting of combinations of the following salts: NaCl, KCl, $MgCl_2$, $CaCl_2$, Na_2SO_4, K_2SO_4, $MgSO_4$, Na_2CO_3, K_2CO_3. (From the authors' abstract)

BYRNE, P.A. and STOESSELL, R.K., 1982b Methane solubilities in multisalt solutions: Geochimica Cosmo. Acta, v. 46, p. 2395-2397. First author at Coastal Studies Inst., Louisiana State Univ., Baton Rouge, LA 70803, USA.

Provides an equation that predicts methane solubility in multisalt brines containing Na^+, K^+, Mg^{+2}, Ca^{+2}, Cl^-, SO_4^{2-}, and CO_3^{2-} ions. k_{mi} values reported by Stoessell and Byrne (1982b) can be used in solubility predictions in brines at earth surface conditions. Prediction in reservoir brines would require determination of k_{mi} for the different salts at reservoir temperatures and pressures. (From the authors' abstract)

BYRNE, R.H. and YOUNG, R.W., 1982, Mixed halide complexes of lead. A comparison with theoretical pedictions: J. Solution Chem., v. 11, no. 2, p. 127-136.

CADEK, J., MAJER, V. and MALKOVSKÝ, M., 1982, Transport of fluorine in low temperature hydrothermal brines: Bull. BRGM, Sec. II, v. 2, no. 4, p. 379-382 (in English). Authors at Ústřední ústav geol., Malostranské nam. 19, 118-21 Praha 1, ČSSR.

Fluid inclusion studies of significant fluorite deposits indicate that the most of them were formed from hydrothermal solutions very high in NaCl and at temperatures below 250°C. A few analyses of fluids in inclusions show appreciable amounts of Ca and Mg in these solutions. Using new data on stability constants of chloride and fluoride complexes with calcium and magnesium and solubility measurements, the distribution of individual fluorine species was calculated. The complex MgF^+ and CaF^+ respectively is the most important one in hydrothermal brines, corresponding in composition to analyses of fluids included in fluorite. Complex NaF^0 and free fluoride ions play a significantly smaller role. The solubility of fluorite in these brines reaches high values up to several hundred ppm at temperatures around and above 250°C and decreases with temperature in the whole temperature range as a result of change in stability of MgF^+ and CaF^+. (Authors' abstract)

CAI, Jianming, LIU, Ruolan and ZENG, Guangsheng, 1982, Study of fluid inclusions and their relation to mineralization of Pangushan tungsten deposit, Jiangxi Province, China, in United Nations Econ. and Social Commission for Asia and the Pacific (RMRDC) Symp: Tungsten Geology, Jiangxi, China, held in Bandung, Indonesia, 1982: Geol. Pub. House, Beijing, China, p. 233-243. First author at Zhengdu College of Geol.

Pangushan tungsten deposit is a large Bi-W, quartz vein type deposit, located in southern Jiangxi province. Samples have been collected systematically for fluid inclusion study. Fluid inclusions, mainly gas-fluid inclusions, commonly occur in quartz of ore-bearing quartz veins and granite, and their abundance is directly proportional to the grade of ore (WO_3). CO_2-bearing inclusions increase in ore shoots. Th of the fluid inclusions ranges from 187° to 325°C, and there is a slight declining trend from the top downward in the vein. Freezing points of the liquid phase in fluid inclusions have been measured and the salinity and density of the ore-forming fluid and the formation pressure of the quartz veins have been estimated.

The salinity of the ore-forming solution is relatively homogeneous and stable from top to bottom of the veins, averaging 6.4-7.5 wt.% NaCl, except in granite, where it is higher, averaging 11%. The estimated density is 0.8-0.9 g/cm^3, and the formation pressure of the veins is above 360 bars.

Fluid inclusion study indicates that the ore forming fluid originated mainly from hidden biotite granite at depth, and the highly CO_2-charged ore fluid played an important role in the transportation and accumulation of tungsten. The source of ore fluid is considered to be large and the ore-forming environment relatively stable during mineralization, consequently a large Bi-W deposit formed. The vein systems are supposed to be cognate and formed simultaneously as products of the same process, and exhibit a reverse depositional zoning pattern. (Authors' abstract)

CAMPBELL, A.R. and RYE, D.M., 1982, Fluid inclusion and stable isotope study of the San Cristobal mine, Peru (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 458. First author at Dept. Geol., Harvard Univ., 24 Oxford St., Cambridge, MA 02138.

The San Cristobal mine is located in the Andean Cordillera of central Peru. The ore mineralization occurs principally in one main vein with wall rocks of phyllites and volcanic rocks. There are three stages of mineralization: 1) pyrite, wolframite, and quartz with minor muscovite and augelite ($Al_2PO_4(OH)_3$); 2) pyrite, chalcopyrite, sphalerite, galena and barite; 3) carbonate.

Homogenization temperatures of primary and pseudo-secondary fluid inclusions were measured in augelite (300-400°C), quartz (270-310°C), and sphalerite (160-210°C). The salinity varied between 4-8 eq. wt.% NaCl during the first two stages. The average $\delta^{34}S$ values of the second stage minerals are py=6.2‰, sp=6.3‰, cp=5.8‰, gn=4.2‰, and bar=16.5‰. The sulfur isotope data suggest a non-magmatic source for the sulfur. Evaporitic sulfides are a likely source for the sulfur. Sedimentary anhydrite is known to occur in the San Cristobal region. In contrast with the sulfur isotope data from San Cristobal are the data from three similar quartz-wolframite vein deposits, Pasto Bueno, Panasqueira, and Tungsten Queen. They each have an average $\delta^{34}S$ of about 0‰ suggesting a magmatic source for sulfur. It is interesting to note that not only is San Cristobal the only one of the four deposits with heavy sulfur but also the only one with a major period of base metal sulfide mineralization. (Authors' abstract)

CANDELA, P.A. and HOLLAND. H.D., 1982, The partitioning of copper and molybdenum between magmas and hydrothermal fluids (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 458. Authors at Dept. Geol. Sci., Harvard Univ., Cambridge, MA 02138.

The partitioning of Cu and Mo between silicate melts and aqueous fluids has been determined at 750°C and 1.4 kb. The vapor/melt partition coefficient for Cu, D(Cu), defined as the ratio of the concentrations of Cu in the vapor to Cu in the melt was found to be D(Cu)=9.2(mCl). The partition coefficient for Mo, D(Mo), is equal to 2.5, and is independent of the F and Cl concentration. With these data the efficiency of the removal of the metals from magmas into aqueous fluid can be calculated as a function of 1) the bulk solid/liquid partition coefficient (BPC) of these metals; 2) the initial and saturation water content of the melt (which together determine the amount of melt crystallized before water saturation); and 3) the chlorine content of the melt (in the case of Cu).

Cu is concentrated so efficiently into a moderately to high saline aqueous phase, that liquid-vapor extraction seems to be a reasonable process to account for the concentration of Cu in porphyry Cu deposits. However, geological evidence suggests that Cu behaves as a compatible element during magmatic processes (BPC>1). Therefore efficient extraction of Cu results when aqueous fluids are evolved early in the crystallization of the intrusion. The value of D(Mo) is small relative to D(Cu) at moderate to high chloride concentrations, and the extraction of Mo from melts into aqueous fluids therefore tends to be less efficient. However, vapor-liquid partitioning can extract the requisite quantities of Mo from granitic melts of batholithic size if Mo acts as an incompatible element, and if the water content of the magma at water saturation is on the order of several weight percent. (Authors' abstract)

CAPUANO, R.M. and COLE, D.R., 1982, Fluid-mineral equilibria in a hydrothermal system, Roosevelt Hot Springs, Utah: Geochimica et Cosmo. Acta, v. 46, p. 1353-1364. Authors at Earth Sci. Lab. Div., Univ. Utah Res. Inst., 420 Chipeta Way, Suite 120, Salt Lake City, UT 84108.

The availability of fluids and drill cuttings from the active hydrothermal system at Roosevelt Hot Springs allows a quantitative comparison between the observed and predicted alteration mineralogy, calculated from fluid-mineral equilibria relationships. Comparison of all wells and springs in the thermal area indicates a common reservoir source, and geothermometer calculations predict its temperature to be higher (288°C ± 10°) than the maximum measured temperature of 268°C.

The composition of the deep reservoir fluid was estimated from surface well samples, allowing for steam loss, gas release, mineral precipitation and ground-water mixing in the well bore. The deep fluid is sodium chloride in character, with approximately 9700 ppm dissolved solids, a pH of 6.0, and gas partial pressures of O_2 ranging from 10^{-32} to 10^{-35} atm, CO_2 of 11 atm, H_2S of 0.020 atm and CH_4 of 0.001 atm.

Comparison of the alteration mineralogy from producing and nonproducing wells allowed delineation of an alteration pattern characteristic of the reservoir rock. Theoretical alteration mineral assemblages in equilibrium with the deep reservoir fluid, between 150° and 300°C, in the system $Na_2O-K_2O-CaO-MgO-FeO-Fe_2O_3-Al_2O_3-H_4SiO_4-H_2O-H_2S-CO_2-HCl$, were calculated. Minerals theoretically in equilibrium with the calculated reservoir fluid at >240°C include sericite, K-feldspar, quartz, chalcedony, hematite, magnetite and pyrite. This assemblage corresponds with observed higher-temperature (>210°C) alteration assemblage in the deeper parts of the producing wells. The presence of montmorillonite and mixed-layer clays with the above assemblage observed at temperatures <210°C corresponds with minerals predicted to be in equilibrium with the fluid below 240°C.

Alteration minerals present in the reservoir rock that do not exhibit equilibrium with respect to the reservoir fluid include epidote, anhydrite, calcite and chlorite. These may be products of an earlier hydrothermal event, or processes such as boiling and mixing, or a result of errors in the equilibrium calculations as a result of inadequate thermochemical data. (Authors' abstract)

CARROLL, Michael and RUTHERFORD, M.J., 1982, Experiments on basalt in equilibrium with a H-O-S fluid: amphibole stability (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 461.

CATHELINEAU, M., 1982a, Significance of fluorite in the uranium deposits of the Hercynian chain: Bull. BRGM, sec. II, v. 2, no. 4, p. 407-413 (in French). Author at Centre Rech. sur la Gépl. de l'uranium, BP.23, 54501 Vandoeuvre-lés-Nancy Cedex, France.

The main part of hydrothermal uranium deposits, associated with Hercynian granites of the western part of the Variscan range, are more and more considered to be the result of late hydrothermal circulation, independent of granite cooling and related to geothermal systems. Crystallization of a carbonaceous paragenesis and fluorite marks the end of activity of most geothermal systems during an isobaric decrease of temperature (150-90°C). However, several deposits show close relations between uranium and fluorine deposition which permit definition of a fluorite stage around 260-270 M.Y. (Author's abstract)

CATHELINEAU, M., 1982b, The uranium deposits associated with south-armorican leucogranites and their surrounding rocks: relationships and reactions between mineralization and various structural, and geological settings: Sci. de la Terre Mem. 42, 375 pp. plus 24 p. of plates (in French; English abstract).

The uranium deposits of Vendée and South-Brittany (Compagnie Générale des Matériaux Nucléaires: mines of Chardon, Ecarpière Commanderie, Retail and Pénaran) are spatially associated with syntectonic sudarmorican leucogranites of Guérande and Mortangne, and their surrounding metamorphic rocks. The study of these deposits has been performed from the point of view of comparisons between solid phases, associated fluids, and ore-forming processes as a function of geological and structural environment. The main points, developed here, are as following: (1) Polyphase genesis: the observed features of the mineralization have not been produced by a single phenomenon but have a polyphase genesis which started in Devonian times and continued to the present, involving chemical and mechanical reworking of the primary ore to give new paragenesis. (2) Relationship between tectonics and mineralization: structural studies of the deposits have shown the importance of anisotropies in an homogeneous environment for the opening and location of joints, and therefore, the location of deposits. Jointing is often hydraulic; mineralization occurs in extension joints of a modest size, which are genetically associated with major faults, but never occurs in great mylonitic zones or breccias. (3) Paragenesis zoning is clearly demonstrated as a function of the surrounding lithology; from the granite to metamorphic series, the following sequence is found: clays - silica (granite), fluorite - silica, sulphides - silica (contact occurrences), carbonates-silica in Ca-Ma rich environment, and complex sulphides (Pb-Zn-Cu-As-Fe-Bi-Cd...) in metamorphic series. (4) Alteration: infiltrating fluids induce at each phase of mineralization a specific alteration of the wall-rock. Crystallography and chemistry of the alteration minerals (muscovites, phengites, mixed-layer phases, K-smectites), and the geochemical evolution of the host-rocks show a general feature of alteration of protonic but especially potassic type, produced by fluids in disequilibrium with the granite feldspars. (5) Reactions between fluids and host-rocks: the primary uranium paragenesis is the result of reactions between poorly saline, weakly carbonaceous fluids, (pressure of few hundred bars, temperature range = 150-400°C), and the host-rocks. Two types of reaction occur: (a) Influence of the dynamic opening of joints on the thermodynamic state of fluids, especially gas fugacity (preferential trapping due to chemical factors); and (b) Chemical reactions between fluids and host-rocks by mass transfer, and alteration processes, are factors of equilibrium shifts and uranium deposition.

Results and conclusions presented in this memoir aim at last to show the range of causes and processes (source: granitic or metamorphic, heat flows of various origin, deposition processes, age, ...) which lead to the genesis of the uranium vein type deposits. (Authors' abstract)

CAVARRETTA, Giuseppe, GIANELLI, Giovanni and PUXEDDU, Mariano, 1982, Formation of authigenic minerals and their use as indicators of the physicochemical parameters of the fluid in the Larderello-Travale geothermal field: Econ. Geol., v. 77, no. 5, p. 1071-1084.

CENTER FOR PETROGRAPHIC AND GEOCHEMICAL RESEARCH (CRPG), 1982, Annual Report, Nancy, France, 127 pp. (in French).

Includes a brief discussion of the Center activities on equilibrium between fluids and minerals, and abstracts of recent papers by Center scientists, with citations. (E.R.)

CERCONE, K.R., 1982, Diagenetic and thermal history of Niagaran Pinnacle reefs in northwest Michigan (abst.): Geol. Soc. Am. Program with Abstracts, v. 14, p. 461. Author at Dept. Geol. Sci., The Univ. Michigan, Ann Arbor, MI 48109.

Petrographic characteristics of cores from the middle Silurian reef trend of northwest Michigan record the following sequence of diagenetic events: 1) Marine cementation and transformation of metastable carbonates to low-magnesian calcite; 2) Dolomitization associated with brecciation and solution; 3) Precipitation of equant calcite and then halite in pores; 4) Fracturing and infilling by geopetal sediment; 5) Precipitation of pyrite, dolomite and locally bitumen in fractures and pores; and 6) Precipitation of late-stage calcite in fractures.

The absolute age of this sequence can be determined for the earliest and latest events. Fibrous synsedimentary cements show patchy luminescence, suggesting that they coalesced in a late middle Silurian reducing groundwater system. The close association of late-stage dolomite and pyrite with bitumen argues that these minerals precipitated during the influx of hydrocarbon-related waters and the emplacement of hydrocarbons into the reefs. Assuming that the geothermal gradient has been 30°C/km throughout the Phanerozoic and that 800 meters of post-Mississippian strata have been removed from the section by erosion, a thermal model of Niagaran/Salinan burial history can be constructed which yields calculated values for the maturity of organic matter in the reefs corresponding to the values observed (3.0 to 3.5 on the TAI scale). This mode predicts that the A1/A2 source beds could not have expelled hydrocarbons and associated aqueous fluids until at least the middle Pennsylvanian, thus dating the pyrite and dolomite as late Paleozoic. A late Paleozoic to earliest Mesozoic age is also indicated for late-stage calcite on the basis of fluid inclusion filling temperatures, which range from 83° to 107°C. (Author's abstract)

ČERNÝ, P., ed., 1982, Short course in granitic pegmatites in science and industry: Min. Assoc. Can. Short Course Hanbook, v. 8, 555 pp.

Includes a short discussion of fluid inclusion data (p. 44-45). (E.R.)

CHAKOUMAKOS, B.C., REGISTER, M.E., BROOKINS, D.G., EWING, R.C. and LANDIS, G.P., 1982, The Harding pegmatite: a summary of recent research (abst.): Am. Mineral., v. 67, p. 182-183. First author at Dept. Geol. Sci., Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24061.

The Harding pegmatite, located in the Picuris Range 30 km SW of Taos, New Mexico, has yielded commercial beryl, niobium-tantalum minerals, lepidolite and spodumene over a period of half a century. The pegmatite is being donated by Arthur Montgomery to the University of New Mexico to be preserved for educational purposes.

The Harding pegmatites crop out in a belt 800 m long and 50-150 m wide. The main dike, exposed for a length of 300 m with a maximum thickness of 24 m, displays remarkable internal zonation. Zones of contrasting mineralogy parallel the contacts of the dike. Eight lithologic units are distinguished: (1) border zone of quartz + albite + muscovite ± perthite; (2) massive quartz ± albite ± muscovite; (3) quartz + lath spodumene; (4) quartz + sugary albite ± perthite; (5) blocky perthite ± quartz ± albite; (6) microcline + spodumene + lepidolite + albite + muscovite + quartz ("spotted rock"); (7) cleavelandite + rose muscovite ± quartz; and (8) cleavelandite + quartz ± muscovite. The latter three are partially or wholly due to subsolidus replacement.

Ages for 42 whole rock and mineral separates from the individual zones were determined using Rb/Sr. The linear fit of the Rb/Sr data for cleavelandites from the cleavelandite-quartz zone yields an age of 1,396 ± 172 m.y.b.p.; for whole rocks of the "spotted rock" unit, 1,336 ± 73 m.y.b.p. The average of these two ages, 1,366 m.y.b.p., may be taken as the age of the pegmatite.

Fluid inclusions in 62 beryl and quartz samples from all the lithologic units were examined. Homogenization temperatures (uncorrected for pressure) for primary inclusions from the wall, massive quartz and quartz-lath spodumene zones are in the range of 275°C to 325°C. The estimated fluid inclusion salinity, based on freezing point depression, shows that primary inclusions have a consistent salinity of 14-16 wt.% NaCl. The estimated fluid pressure, based on oxygen isotope data and the NaCl and CO_2 content of the fluids in the inclusions, suggests pressures in the range 2.0-2.5 kbar (6.0-7.5 km). Pressure corrected homogenization temperatures are consistent with the previously determined liquidus and solidus for a composite Harding sample containing 8 wt.% water. (Authors' abstract)

CHAROY, B., 1982, Tourmalinization in Cornwall, England, in Metallization Associated with Acid Magmatism, A.M. Evans, ed.; New York, J. Wiley, p. 63-70. Author at Equipe de Recherches sur les équilibres entre fluids et minéraux C.R.P.G., Vandoeuvre Ecole Nationale Supérieure de Géologie, Nancy, France.

The significance of anomalous boron contents expressed in several generations of tourmaline is discussed with reference to particular occurrences in Cornwall. It is shown that tourmaline can precipitate throughout the magmatic-hydrothermal activity in the province and that boron in complex form plays an important part in the transport of metals such as tin and tungsten. (Author's abstract)

CHAYKIN, V.G., 1982, Fluorite occurrence in areas of activization of the East-European Platform: Sovetskaya Geolgiya, no. 9, p. 60-70 (in Russian). Author at All-Union Sci.-Res. Inst. of Geol. of Non-Ore Raw Materials, Moscow, USSR.

The paper bears fluid inclusion data on fluorite, quoted from various papers. (A.K.)

CHEANG, K.K., 1982, Oxygen isotope, fluid inclusion, microprobe and petrographic studies of the Precambrian granites from the southern Wind River Range and the Granite Mountains, central Wyoming, U.S.A.; constraints on origin, hydrothermal alteration and uranium genesis: PhD dissertation, Univ. Georgia, Athens, Georgia, 154 pp.

Indexed under Fluid Inclusions. (E.R.)

CHEKVAIDZE, V.B., KUDRYAVTSEVA, N.G., ISAKOVICH, I.Z. and PUGACHYOVA, I.P., 1982, Differentiation of the sulfide-polymetal ores in the Eastern part of the Zyryanovskiy ore field: Geol. Rudn. Mest., v. 24, no. 1, p. 42-52 (in Russian). Authors at the Central Sci.-Res. Geol.-Prosp. Inst., Moscow, USSR.

Galena-quartz mineralization near the contact of subvolcanic intrusions formed at 400-490°C (Th in quartz and calcite), sulfide-polymetal ores in metasomatites at 350-190°C (Th in quartz), Cu-Fe sulfide ores of contact-metamorphic origin at 500-400°C (Th). (A.K.)

CHEN, Zunda and HU, Lisui, 1982, The geological characteristics and primary zoning of Huangsha vein-type tungsten deposit: Tungsten Geology Symposium, Jiangxi, China, sponsored by ESCAP/RMRDC and Ministry of Geology, PRC, 12-22 Oct., 1981: Pub. by ESCAP/RMRDC, Bandung, Indonesia, p. 257-268 (in English). Authors at Geol. Res. Dept of the Metallur.-Geol. Prospecting Co., Jiangxi Province.

The large-scale quartz vein type wolframite deposit in Huangsha occurs in the endo- and exo-contact zone above a buried granite body. The distribution and the attitude of these ore bodies bear an intimate relationship to the geometry of the ridge of the granite body, and they display concentric annular zoning. Multiple pulsation in tectonic activity and mineralization is also recognizable. Veins of the same mineralization stage, as a whole, show normal depositional zoning starting from the ore source, with WO_3 content rising to a peak value, then decreasing gradually outwards. High-grade ore occurring at the center of the vein belt generally coincides with the portion where the total thickness of vein is greatest and the ore and gangue constitutents are most complex. Size and CO_2 content of inclusions in quartz vary directly with the intensity of tungsten mineralization. At the top of the deposit, a strong geochemical anomaly has been found showing the following zonation in element assemblage from the vein belt outwards: Cu, Bi, Rb_2O halo about 20 m in width; W, Sn, Be, Li_2O halo 30-50 m in width; and F halo 150-200 m wide. (Authors' abstract)

CHERNOV, R.V., 1982, Studies of reaction of aluminum fluoride with alkaline metals chlorides in melt: Zhurn. Neorg. Khimii, v. 27, no. 5, p. 1162-1165 (in Russian). Author at Inst. of General and Inorg. Chem. of Acad. Sci. Ukr. SSR, Kiev, Ukraine.

The paper presents data on formation of [ions] $KAlF_6$ and $NaAlF_6$ in fluoride and chloride melts, that may be pertinent to silicate-salt immiscible melt systems in inclusions. (A.K.)

CHERSKII, N.V., GROISMAN, A.G., NIKITINA, L.M. and TSAREV, V.P., 1982, Results of the first experimental determinations of natural gas hydrate decomposition heats: Akad. Nauk SSSR, Dokl., v. 265, no. 1, p. 185-189 (in Russian).

CHINKUL, M., 1982, A study of the fluid inclusions and O and H stable isotopes at Jabal Sayid and its bearing on mineralization*: Thesis, M.Sc. in Applied Geol., Univ. King Abdul Aziz, Jeddah, Saudia Arabia, 167 pp. (in French).

Sulfide mineralization of Jabal Sayid occurs in a volcanic-sedimentary sequence of Upper Proterozoic age.

The mineralized host-rock has a calc-alkaline affinity and appears to represent a back-arc environment. The environment of deposition was not very deep. The host-rock was later metamorphosed to greenschist grade. Microthermometric study of fluid inclusions in quartz has shown the presence of a first hydrothermal fluid and a second metamorphic fluid. The first hydrothermal fluid introduced only 10% of the total inclusion fluids, while the second metamorphic fluids are subdivided into two subgroups that represent two episodes of which the first constitutes 20% and the second 70%.

The hydrothermal fluids are aqueous solutions that contain 6.4-7.4 wt. % equiv. NaCl. Metamorphic fluids are aqueous fluids that contain approximately 5.9 wt. % eq. NaCl, 10 mole % CO_2 and 0.5 mole % CH_4 and traces of other volatiles.

Mineralization was probably deposited at temperatures of 300-400°C and at a pressure that varied from 1-1.6 kb. The first episode (hydrothermal), probably related to mineralization, took place at temperatures comparable to mineralization temperatures but at a lower pressure (0.4-0.9 kb). The second metamorphic episode (regional greenschist) probably took place at temperatures comparable to the first but at higher pressures (2-2.8 kb).

Hydrogen and oxygen isotopic compositions of chlorites (non-schistose rocks) of the main mineralization gave δD between -75.3 and -86.3‰ and $\delta^{18}O$ between +5.9 and +8.1‰. Hydrothermal quartz (which precedes the mineralized veins) of the same host rock gives $\delta^{18}O$ between +10.9 and 13.2‰.

These results show that the hydrothermal mineralization was not affected by the regional greenschist metamorphism and also show that the hydrothermal fluids are composed mainly of a mixture of magmatic and sea waters and of a small amount of meteoric water.

Estimated composition of the hydrothermal fluid of the main mineralization is the following:

	200°C	300°C	400°C
magmatic water	35%	60%	75%
sea water	50%	35%	25%
meteoric water	15%	5%	0%

Hydrogen and oxygen isotopic composition of chlorites (schistose

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*Fluid inclusions and stable isotopes were done at CRPG.

rocks) are δD of -73.5 to -74.3‰ and $\delta^{18}O$ of +1.4 to 1.5‰, which shows that a mixture of meteoric and marine waters comprised the circulating fluid that accompanied regional metamorphism.

The water/rock ratio (calculated) of the metamorphic rocks was 1.07 for marine water and 0.47 for meteoric water which shows that sea water is more abundant than meteoric water in the circulating fluids during regional metamorphism. (Abstract translated courtesy R. Bodnar)

CHKHARTISHVILI, T.A. and NAUMOV, V.B., 1982, Thermometric investigation of granitoid rocks of the Kelasursky intrusive (Abkhazia): Bull. Acad. Sci. Georgian SSR, v. 107, no. 3, p. 549-552 (in Russian with Georgian and English abstracts). (See Translations)

CHOU, I.-Ming, 1982a, Differential thermal analysis of the sylvite liquidus in the $KCl-H_2O$ binary above 440°C at elevated pressures (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 463. Author at U.S. Geol. Survey, 959 National Center, Reston, VA 22092.

As a part of the phase-relation studies in the system $NaCl-KCl-H_2O$ at elevated pressures and temperatures, the sylvite liquidus in the binary system $KCl-H_2O$ was determined by differential thermal analysis at pressures as great as 2 Kb. The experimental technique used in this study was described in detail by Chou and Eugster (1981, EOS, 62, p. 410) and Chou (1982, Geochim. Cosmochim. Acta, in press).

The melting temperatures (in °C) of sylvite in the $KCl-H_2O$ binary, measured at pressures above 0.5 Kb, are given in the following table, in which X_{KCl} represents the mole fraction of KCl.

X_{KCl} / P(kb)	0.5	1.0	1.5	2.0
1.000	783	795	808	821
0.813	708	718	728	739
0.670	640	650	658	667
0.561	581	588	594	601
0.471	526	532	536	542
0.362	441	443	446	448

The isopleths of these liquidus temperatures above 0.5 Kb have positive slopes, which become steeper as X_{KCl} decreases. At lower pressures, the slopes of these isopleths become negative, and the isopleths intersect the sylvite-liquid-vapor three-phase cure at shallow angles. This is exactly what would be predicted when the present sylvite-saturated liquid-composition data at higher pressures are compared with those reported by Keevil (1942, J. Am. Chem. Soc., 64, p. 841-850) on the three-phase curve.

The causes for the reversal of these isopleth slopes at lower pressures are not known. The nonbinary nature of the system due to hydrolysis of KCl might be responsible, but more studies are required to resolve the problem. Using the same experimental approach, Gunter et al. (unpublished data) observed a similar phenomenon in the $NaCl-H_2O$ binary system. (Author's abstract)

CHOU, I.-M., 1982b, Phase relations in the system $NaCl-KCl-H_2O$. Part I: Differential thermal analysis of the NaCl-KCl liquidus at 1 atmosphere and 500, 1000, 1500, and 2000 bars: Geochimica Cosmo. Acta, v. 46, p. 1957-1962. Author at U.S. Geol. Survey, 959 National Center, Reston, VA 22092, USA.

A simple differential thermal analysis (DTA) technique has been developed to study phase relations of various chemical systems at elevated pressures and temperatures. The DTA system has been calibrated against known melting temperatures in the system NaCl-KCl. Isobaric sections of the liquidus in the system NaCl-KCl have been determined at pressures of 1 atmosphere and 500, 1000, 1500, and 2000 bars. The measured liquidus temperatures at 1 atmosphere agree with the best available data to within 5°C. The melting temperatures for pure end members at higher pressures agree with the values calculated from the Simon equation (Clark, 1959) to within 3°C. No previous melting data are available for the intermediate compositions at elevated pressures. Using the data in both heating and cooling scans, the minimum melting temperature at 1 atmosphere in the system was located at 658° ± 3°C where the sample has an equimolar composition. (From the author's abstract)

CHOU, I.-M., 1982c, Migration rates of brine inclusions in single crystals of NaCl, in The Scientific Basis for Nuclear Waste Management, S.V. Topp, ed.; New York, Elsevier Sci. Pub. Co., Inc., p. 303-310. Author at U.S. Geol. Survey, 959 National Center, Reston, VA 22092.

The paper estimates migration rates for all-liquid brine inclusions in single crystals of NaCl by utilizing recent data for brines and the model of Anthony and Cline. The predictions are compared with experimentally measured migration rates. (From the author's text)

CHRISTIE, A.B., 1982, Fluid inclusions, stable isotopes and geochemistry of porphyry copper and epithermal vein deposits of the Hauraki gold-silver province, New Zealand: Ph.D. dissertation, Victoria Univ. of Wellington, New Zealand, 796 pp.

Tertiary epithermal Au-Ag-Pb-Zn-Cu vein, and porphyry copper deposits occur in the Hauraki Province, Coromandel Peninsula, New Zealand.

The epithermal deposits were extensively mined for gold and silver in the late 1800's, and early 1900's and produced approximately 300 million grams (30 million ounces of silver). They occur in Jurassic greywacke suite rocks, lower Miocene-Pliocene andesites and dacites, and upper Miocene-Pleistocene rhyolites although the deposits in the andesites and dacites produced most of the gold and silver mined.

Base metal assemblages of the epithermal deposits are dominated by pyrite, sphalerite, galena and chalcopyrite, whereas acanthite and native gold (electrum) are the most common precious metal minerals. Tellurides (e.g. hessite) and seleniferous - selenide minerals are locally important. Gangue minerals are mainly quartz and calcite.

Near neutral or slightly alkaline fluid pH is indicated for the epithermal fluids by the occurrence of sericite and/or adularia in wall rock alteration mineral assemblages. Acidic fluids, forming kaolinite, are characteristic of late stages or near surface environments.

Fluid inclusion filling temperatures, and sulphur isotope temperatures from sphalerite-galena pairs, indicate that base metal deposition occurred mainly between 320 and 290°C, precious metal assemblages predominantly in the range of 280 - 200°C and late stage barite, in some deposits, generally below 200°C. There is fluid inclusion evidence for boiling during mineralization in some deposits.

Apparent salinities of the epithermal fluids, determined from fluid inclusion freezing temperatures, range from 0 - 6.1 eq. wt. % NaCl. No consistent difference in average apparent salinity was recognized between the different types of epithermal deposits, although the highest recorded values were from the base metal deposits.

The absence of liquid CO_2 in fluid inclusions limits the maximum possible concentration of CO_2 to approximately 3 mole %. Extraction and measurement of CO_2 from some samples indicates an average concentration of approximately 1 mole %. Corrections for dissolved CO_2 required to transform apparent salinities to true salinities indicate that CO_2 is the major solute in low salinity inclusions and that its concentration varied widely during mineral deposition in most deposits.

Thermodynamic models of the geochemical environments of mineral deposition indicate that the large gold-silver deposits were formed by solutions in which sulphur occurred predominantly in reduced form, whereas many other deposits formed from solutions with approximately equal concentrations of oxidized and reduced aqueous sulphur species.

Mineral deposition resulted from several different processes including: changes in fluid pH accompanying reactions with the wall rocks, mixing with other types of fluids, boiling, and variations in the concentration of CO_2 in solution. These various processes acted separately in different parts of the hydrothermal system and general deposited characteristic mineral assemblages.

Deuterium/hydrogen ratios of water extracted from fluid inclusions indicate that most hydrothermal fluids were originally meteoric water.

Sulphur isotope ratios of sulphide and sulphate minerals, in association with the thermodynamic relations of the mineral assemblages, indicate that the sulphur was derived from at least two different sources; sedimentary sulphate and magmatic SO_2, the relative importance of each varying from one deposit to another.

Two types of hydrothermal systems are postulated for the formation of the epithermal deposits. During andesitic volcanism in the Miocene-early Pliocene, hydrothermal fluid convective cells were generated by heat from near surface small intrusive bodies of magma, whereas during rhyolitic volcanism in the late Miocene-Pleistocene the heat sources were larger plutons at greater depth.

Porphyry copper deposits are associated with quartz diorite stocks intruded into Jurassic greywacke suite rocks and Miocene andesites. They are "diorite" model hypabyssal and volcanic types. The major minerals are quartz, pyrite, chalcopyrite and sphalerite. Additional minerals differ between the different deposits and define two contrasting geochemical environments of deposition, one characterized by low fS_2, fO_2, and S, indicated by the presence of pyrrhotite, and the other of moderate to high fS_2, fO_2, and S, indicated by the occurrence of bornite, magnetite or hematite. Associated hydrothermal alteration is generally propylitic although limited phyllic and "potassic" (defined by secondary biotite) types also occur in some deposits.

Fluid inclusion and sulphur isotope studies of the Miners Head porphyry copper deposit suggest that copper mineralization occurred at a temperature of approximately 425°C from fluids with apparent salinities up to 15.5 eq. wt. % NaCl and containing sulphur of magmatic origin, predominantly as H_2S. (Author's abstract)

CHUPIN, V.P. and KOSUKHIN, O.N., 1982a Diagnostics and methods of study of melt inclusions in minerals of granitoids and pegmatites: Geologiya i Geofizika, no. 10, p. 66-73 (in Russian; English abstract). Authors at Inst. Geol. Geophys. of Siberian Branch of Acad. Sci. USSR, Novosibirsk.

Melt inclusions in granitoids of moderate and great depths are very small (few micrometers) and they are filled by a completely crystallized aggregate of quartz, feldspars ± micas and volatiles (H_2O, CO_2). P melt inclusions in feldspars are frequently altered or have leaked; they may be studied if feldspar is fresh. The essential problem is the determination of whether the inclusions are "normal" or "anomalous" or altered (e.g. refilled). "Normal" inclusions usually have euhedral habit after homogenization. Probably so called "gas-solidified" inclusions described by Zakharchenko (1971, 1976) are not "normal," but trapped minerals with sticking G bubble and have partly or completely leaked. The authors discuss also grouping of melt inclusions in mineral grains and distribution of Th in inclusion groups and in a given grain, and indicate that rapid heating and use of large inclusions may lead to too high Th values. Quartz inversion may cause a change of inclusion volume. Minerals crystallizing under high P may need even significant P correction to Th (for 5-7 kbar ΔT is -30 to -50°C). The authors describe the possibility of evaluation of volatile content of melt inclusions. (Abstract by A.K.)

CHUPIN, V.P. and KOSUKHIN, O.N., 1982b, Studies of melt inclusions in minerals of rocks of acid composition, in Use of methods of thermobarogeochemistry during prospecting and studies of ore deposits, N.P. Laverov, ed.: Moscow, "Nedra" Publ. House, p. 154-161 (in Russian).

The paper presents the methodological problems of studies of melt inclusions in minerals of granites and pegmatites: correct diagnostics of crystallized inclusions, recognition of their P nature, peculiarities of thermometric studies, relation between Th and T of crystallization, possibilities of evaluation of volatile content, dissolved in melt. (Authors' abstract translated by A.K.)

CLAYTON, C.J., 1982, Growth history and microstructure of flint (abst.): Int'l. Assoc. of Sedimentologist, Abstracts, 3rd European Regional Mtg., Copenhagen, Denmark, p. 105-107. Author at Dept. Geol., Univ. London King's College, Strand, London WC2R 2LS.

Proposes that structural and surface bound water is locally redistributed to form microscopic fluid inclusions during recrystallization. (E.R.)

CLEMENT, C.R. and SKINNER E.M.W., 1982, Kimberlite textures I (abst.): Terra Cognita, v. 2, p. 209. Authors at Geol. Dept., De Beers Cons. Mines Ltd., P.O. Box 47, Kimberley, 8300, South Africa.

The occurrence of hypabyssal- and diatreme-facies kimberlites in kimberlite pipes has long been recognized. In this contribution, the first of two companion papers, the range of textures exhibited by hypabyssal-facies kimberlites is described and the origins of the different textures are evaluated.

Particular attention is paid to the genesis of a variety of segregationary textures. The irregular to globular segregations in these rocks are commonly composed of the volatile-rich, late-crystallizing components of the kimberlites but relatively high temperature anhydrous minerals also occasionally occur in segregations. Volatile-rich segregations are ascribed to a variety of causes; some are interpreted as segregation vesicles (gas cavities filled by residual liquids) and others are regarded as direct segregations of melt. Most are, however, ascribed to condensation of gas-rich exsolved volatiles following varying degrees of vesiculation under conditions where the escape of the exsolved fractions was inhibited. The possibility that some segregations may relate to carbonate-silicate or silicate liquid immiscibility is examined.

The textures of rocks which are intermediate in character between hypabyssal- and diatreme-facies kimberlites are also described and their modes of origin assessed. (Authors' abstract)

CLEMENTE, R.R. and SUNAGAWA, I., eds., 1982, Crystal growth processes in sedimentary environments: Estudios Geologicos, v. 38, no. 3-4, p. 125-377 (in English with Spanish and English abstract).

Twenty-four papers on the subject, including some with implications to the understanding of inclusions in diagenetic minerals. (E.R.)

CLEMENTE, V.C., 1982, Geochemistry and related geology of the southern Negros geothermal field, Philippines (abst.): Proc. Pacific Geothermal Conf. 1982 Part 1, Univ. Auckland Geothermal Inst., Auckland, NZ, p. 411.

CLOCCHIATTI, Robert, JORON, J.-L., KERINEC, Francoise and TREUIL, Michel, 1982, Some preliminary data about the Merapi Volcano (Java, Indonesia) lavas and their agglomerates: C.R. Acad. Sci. Paris, Ser. II, v. 295, p. 817-822 (in French; English abstract).

The Merapi lava is a low-Si high-K andesite. This lava exhibits fragments of thermally metamorphosed calcareous rocks that occur at shallow depth (3 to 4 km) beneath the volcano. The most common assemblage that crystallized after solution of calcareous rocks both in melt and vapor phase is calcic clinopyroxene, wollastonite and plagioclase; sphene, meionite, bustamite, uvarovite, chromite and apatite are accessory minerals. Most agglomerates carry interstitial siliceous high-K glass. CO_2 produced by thermal decomposition of calcareous rocks is present in the joints between crystals and in mineral fluid inclusions. CO_2 release induced the R.E.E. enrichment of agglomerates and the contamination of fluid phase. (Authors' abstract)

COCHRAN, Ann, 1982, Fluid inclusion populations in quartz-rich gold ores from the Barberton greenstone belt, eastern Transvaal, South Africa: Master's thesis, Univ. of Arizona.

Fluid inclusions in gold-bearing quartz-rich ores from five mines in the Barberton Greenstone Belt were studied to detect differences and similarities in inclusion character according to sample locality and sulfide mineralogy. Through freezing-heating studies, many of the Barberton inclusions encountered were found to have formed at restricted amphibolite-grade conditions of 4.5 kilobars pressure and 610°-655°C temperature regardless of the locality or the sulfide mineralogy. Inclusion population counts and bulk fluid analyses reveal differences in fluid content, chemistry, and inclusion type according to the major sulfide phase present in the sample.

Fluid inclusion populations in Witwatersrand Basin quartz-vein pebbles may provide useful provenance indicators for the Witwatersrand sediments. Inclusions from the Barberton quartz vein samples were compared with those reported from the Witwatersrand quartz-vein pebble. The comparison provided no correlation between the Barberton and Witwatersrand quartz based on fluid inclusion populations. (Author's abstract)

COLE, D.R. and OHMOTO, H., 1982, Time estimates for oxygen isotopic exchange during mineral-fluid interaction in hydrothermal systems (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 466.

COLLIER, James, 1982, The geology and uranium mineralization of the Florida Mountain area, Needle Mountains, southwestern Colorado: Ph.D. dissertation, Colorado School of Mines.

The Florida Mountain area in the Needle Mountains mining district of southwestern Colorado is cut by numerous veins bearing uranium and base and precious metals. In addition to uranium, the area has anomalously high concentrations of a variety of metals, including gold, silver, and molybdenum. Uranium presents the greatest economic potential and was the major focus of this research.

The veins are hosted by two Precambrian granitic map units, the Eolus and Trimble granites. Trace-element interpretations suggest that there were at least three intrusive phases, and part of what has been mapped as Eolus Granite is actually a comagmatic and more primitive phase of the Trimble Granite. The Trimble Granite was the final stage of extensive fractionation of mafic igneous sources. The observed variation in plutonic rock types was the product of both melting and fractionation processes. More highly differentiated fractionation series were probably the result of remelting of products of earlier partial melting. Uranium and other incompatible elements were strongly enriched during both melting and differentiation.

Uranium in early intrusive rocks is present only in common accessory minerals such as zircon and allanite, but disseminated, uranium-rich minerals such as uraninite formed in the more felsic, highly differentiated units. These were later destroyed by hydrothermal alteration to liberate uranium for concentration in the vein systems.

The Chicago Basin stock, a composite hypabyssal body of granite and rhyolite porphyries, was emplaced during the late Tertiary. Geochemical evidence indicates that the stock is a cupola of a larger intrusion, another apophysis of which is inferred to occur nearby. Although these intrusions were sources of metals such as molybdenum, they are not likely to have been the sources of uranium. Instead, they established the convective circulation system by which uranium was leached from the Precambrian granite country rocks. They also helped open pre-existing fractures during intrusion. Leaching of uranium occurred principally along two large breccia zones, the Bullion and Trimble faults.

Pitchblende was deposited from oxidizing, paragenetically early fluids at approximately 300°C. Later fluids were more reducing; a sulfide-dominant stage precipitated at about 250°C. Pitchblende-depositing fluids were rich in CO_2 and either boiled or effervesced CO_2. Uranium was precipitated as a result of increase in pH and/or reduction produced by boiling or effervescence. Uranium is believed to have been transported as the complex $UO_2F_3^-$.

The vein systems of the Florida Mountain area and its immediate surroundings possibly contain a resource of uranium that, although small by some world standards, is comparable in size to several hard rock uranium mines of the United States and larger than other known intragranitic deposits. Economic, political, and environmental factors seriously constrain the viability of the deposits. (Author's abstract)

COLOMER, G., DÉCHAMPS, M., DHALENNE, G. and REVCOLEVSCHI, A., 1982, Study of the origin of polyhedral cavities in crystals of nickel oxide and their morphological evolution during heat treatment: J. Crys. Growth, v. 56 (1981), p. 93-100. Authors at Lab. de Chimie Appliquée, Univ. Paris-Sud, Bâtiment 414, F-91405 Orsay Cédex, France.

The content of microscopic polyhedral cavities observed in NiO crystals grown by both the flame fusion and floating zone techniques was analyzed, and their geometrical evolution upon high temperature thermal treatment studied in order to determine their origin and characteristics. The gas content of these defects (both oxygen and nitrogen) indicates that they originate from shrinkage cavities. The morphological evolution of the cavities towards tetrakaidecahedra, the surface of which is essentially made of {111} planes, indicates a high stability of these faces due to a strong adsorption of N_2 (and/or O_2). (Authors' abstract)

COOK, S.J., 1982, The physical-chemical conditions of contact skarn formation at Alta, Utah: MS thesis, Univ. Utah, Salt Lake City, Utah, 169 pp.

Indexed under Fluid Inclusions. (E.R.)

COOLEN, J.J.M.M.M., 1982, Carbonic fluid inclusions in granulites from Tanzania - a comparison of geobarometric methods based on fluid density and mineral chemistry: Chem. Geol., v. 37, p. 59-77. Author at Inst. voor Aardwetenschappen, Vrije Univ., 1081 HV Amsterdam, The Netherlands.

This is a shorter version of 1980 thesis (Fluid Inclusion Research--Proc. of COFFI, v. 13, p. 46-47). (E.R.)

COSENS, B., 1982, Initiation and collapse of hydrothermal circulation at the Mid-Atlantic Ridge, 23°N (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 467. Author at Dept. Geol., Univ. Washington, Seattle, WA 98195.

Gabbro and basalt, collected from an area south of the Kane Fracture Zone along the Mid-Atlantic Ridge, have three stages of alteration which record the cooling of a hydrothermal system: 1) Stage 1. Penetration of seawater began between 400 and 550°C, altering pyroxene to fibrous green amphibole. 2) Stage 2. Propylitic alteration formed along connected fractures at 250 to 300°C. As fracture density increased, the Fe/Mg ratio of chlorite increased, the final result being an Fe-chlorite - quartz - sulfide breccia. 3) Stage 3. Late smectite veinlets formed at low temperatures (<200°C) after active circulation ceased.

By assuming local equilibrium between alteration minerals and the hydrothermal fluid, constraints can be placed on the fluid composition responsible for Stage 2 alteration, the stage associated with deposition of sulfides. The following activities of species in solution were determined for the system $FeO-Na_2O-CaO-MgO-Al_2O_3-SiO_2-H_2O$ at 350 bars and 250°C: Log $a(Ca^{++})/a^2(H^+)=8.0$, Log $a(Na^+)/a(H^+)=5.0$, Log $a(Fe^{++})a/^2(H^+)=-7.5$, Log $a(Mg^{++})/a^2(H^+)=6.0$. Log $a(SiO_2)$ was set at quartz saturation (-2.3 at 350 bars and 250°C).

Fluid inclusions record the introduction of a low temperature, seawater-salinity fluid during formation of the latest quartz veins associated with Stage 2 alteration. Mixing of this and the hydrothermal fluid caused a drop in temperature and increase in oxidation state, resulting in increased precipitation of quartz, pyrite and chalcopyrite. The salinities of fluid inclusions trapped in quartz during Stage 2 alteration are as much as 3 times that of seawater. Concentration of a fluid initially of seawater salinity may be the result of boiling at ≥350°C and ≤3000m depth. Recognition of boiling in seafloor hydrothermal systems may have important implications for studies of heat transport and deposition of metals. (Author's abstract)

COX, G.F.N. and WEEKS, W.F., 1982, Equations for determining the gas and brine volumes in sea ice samples: Cold Regions Res. and Engrg. Lab. Rept. 82-30, 13 pp.

Equations are developed that can be used to determine the amount of gas present in sea ice from measurements of the bulk ice density, salinity and temperature in the temperature range of -2 to -30°C. Conversely these relationships can be used to give the density of sea ice as a function of its temperature and salinity, considering both the presence of gas and of solid salts in the ice. Equations are also given that allow the calculation of the gas and brine volumes in the ice at temperatures other than that at which the bulk density was determined. (Authors' abstract)

CRAIG, H. and CHOU, C.C., 1982, Methane: the record in polar ice cores: Geophy. Res. Letters, v. 9, no. 11, p. 1221-1224. Authors at Isotope Lab., Scripps Inst. Oceanography, Univ. California at San Diego, La Jolla, CA 92093.

Methane mixing ratios in trapped air in the Dye 3 Greenland ice core decrease from 1.25 ppmv below the firn-ice transition (~90 years B.P.) to a baseline value of 0.70 ppmv at a depth of ~250 m (~500 years B.P.). Below this level to a depth of 1950 m (~27,000 years B.P.) the mixing ratio appears to be constant at the baseline level, and in agreement with data of Robbins et al. (1973) on 700-2470 year-old Antarctic ice. The uniformity of these CH_4 mixing ratios in both hemispheric ice caps and over some 26 millennia indicates that, whether or not the absolute values correctly reflect the true atmospheric mixing ratios vs. time, the atmospheric CH_4 mixing ratios were nevertheless essentially constant over this range of time. Above 250 m depth the trapped-air CH_4 mixing ratios increase linearly up to ~100 m depth, and then increase sharply just below the firn-ice transition. The mixing ratio vs. age trajectory is strongly offset from the estimated atmospheric record of the past 15 years, but when corrected for the ~90 year difference in age of air and ice at firn closure, the ice-core data track quite precisely into the recent atmospheric record. Thus we believe that these data correctly reflect past CH_4 atmospheric mixing ratios. The increase in atmospheric methane concentration begins at ~1580 A.D. and amounts to ~0.40 ppmv by 1918, and ~0.90 ppmv by 1980; the equilibrium greenhouse warming associated with this increased CH_4 concentration is about 0.23°C over the past 400 years, and at the current rate of increase the warming due to CH_4 is about 38% of the CO_2 warming effect. (Authors' abstract)

CRAWFORD, M.L. and MARK, L.E., 1982, Evidence from metamorphic rocks for overthrusting; Pennsylania Piedmont, USA: Can. Mineral., v. 20, p. 333-347.

CRERAR, D.A., NAMSON, Jay, CHYI, M.S., WILLIAMS, Loretta and FEIGENSON, M.D., 1982, Manganiferous cherts of the Franciscan assemblage: I. General geology, ancient and modern analogues, and implications for hydrothermal convection at oceanic spreading centers: Econ. Geol., v. 77, no. 3, p. 519-540. Authors at Dept. Geol. & Geoph. Sci., Princeton Univ., Princeton, NJ 08544.

Fluid inclusion analyses on veins of undetermined age show seawater salinity, temperatures of roughly 200°C, and tentative entrapment pressures corresponding to 1,700-m water depth. Early and intermediate veins were injected into unconsolidated siliceous sediment producing a characteristic bleached and pseudobrecciated texture. An analogy is drawn with the present-day field of hydrothermal mounds near the Galapagos rift and with ophiolitic complexes of the northern Apennines and other localities. (From the authors' abstract)

CRONN, D.R. and NUTMAGUL, Winai, 1982, Volcanic gases in the April 1979 Soufriere eruption: Sci., v. 216, p. 1121-1123.

Six gas samples from the 17 April 1979 Soufriere eruption plume were analyzed for carbonyl sulfide, carbon disulfide, carbon monoxide, carbon dioxide, methane, nitrous oxide, fluorocarbon-11, fluorocarbon-12, methyl chloroform, and carbon tetrachloride. Only carbon monoxide, carbon dioxide, carbonyl sulfide, and carbon disulfide were found to have increased mixing ratios as compared with those in clean tropospheric air, but the increases were not sufficient to contribute greatly to the global budgets of these four components. (Authors' abstract)

CUNNINGHAM, C.G., RYE, R.O., STEVEN T.A. and MEHNERT, H.H., 1982, The origins of replacement and vein-type epithermal alunite deposits and their implications for exploration (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 470. Authors at U.S. Geol. Survey, Denver Fed. Center, Denver, CO 80225.

Replacement and vein-type alunite deposits formed in highly contrasting epithermal environments in the Marysvale volcanic field of Utah. Alunite deposits replacing intermediate-composition lava flows formed in near-surface highly oxidizing conditions at the tops of hydrothermal plumes that were spaced irregularly around a 23-m.y.-old monzonite stock. They are horizontally zoned outward from alunitic cores to kaolinitic and propylitic envelopes. Characteristic alteration minerals change vertically from a pyrite-pyropylite assemblage upward through alunite, jarosite, hematite to a flooded silica cap. $\delta^{34}S_{SO_4}$ values of +11.5 to +15.4 per mil indicate that sulfur was derived from underlying Mesozoic evaporites. The pyrite-propylite-alunite transition probably marks the paleowater table and the top of the flooded silica cap the paleoground surface.

Vein alunite deposits formed 14 m.y. ago as open-space fillings in extension fractures above a concealed stock. Large crystals of nearly pure alunite grew inward from the walls. Fluid inclusions containing low-density vapor indicate that the alunite crystallized in a wet-steam geothermal system. $\delta^{34}S_{SO_4}$ values near zero per mil indicate that the vein alunite sulfur had a magmatic source and it appears to have been oxidized in a high-temperature environment above the pluton. Similar $\delta^{34}S$ values characterize sulfide minerals in base and precious metal deposits surrounding the alunitic core of the hydrothermal system.

Sedimentary sulfur in the replacement alunite deposits indicates that the hydrothermal systems interacted with the sedimentary rocks beneath the volcanic field where they may have formed skarn and replacement deposits. The magmatic sulfur and vapor-rich fluid inclusions in the vein alunite deposits suggest minimal wall rock interaction, and the underlying stock may host porphyry-type deposits. (Authors' abstract)

DADZE, T.P., SOROKHIN, V.I. and NEKRASOV, I.Ya., 1981, Solubility of SnO_2 in water and in aqueous solutions of HCl, HCl+KCl, and HNO_3 at 200-400°C and 101.3 MPa: Geokhimiya, no. 10, p. 1482-1492 (in Russian; translated in Geochem. Int'l., v. 18, no. 5, p. 142-152, 1982).

DANGIĆ, Adam, 1982, Determination of temperature and composition of hydrothermal fluids based on the fluid inclusion study: Zapisnici SRSKO Geolosko Drustvo, Serbian Geolog. Soc., Comptes Rendus for 1981, published 1982, Beograd, Jugoslavia (in Serbian; English abstract). Author at Faculty of Mining & Geol., Univ. Belgrade, Dusina 7, 11000 Belgrade, Yugoslavia.

This paper presents determination of temperature and main composition of hydrothermal fluids based on the study of fluid inclusions for a pneumatolytic-hydrothermal paragenesis in the Srebrenica Zn-Pb ore area in Yugoslavia.

Tertiary hydrothermal activity in the Srebrenica area was started with a pneumatolytic-hydrothermal stage, represented by quartz-tourmaline-sulfide veins (Dangić, 1978, 1979-80). Fluid inclusions in quartz have been studied in ore vein No. 45, composed by: quartz, tourmaline, pyrite, and sporadically sphalerite, galena and traces of cassiterite.

Both temperature and composition of fluids were studied by nondestructive techniques. Phase changes in fluid inclusions during heating and freezing tests were measured on dual-purpose laboratory heating/freezing stages at the University of Göttingen, W. Germany.

Fluid inclusions in quartz vary in size from about 20 to below 1 μm, and have negative crystal shape, or partly irregular or irregular forms (Figs. 1,-4). Most of them are two-phase liquid-vapor inclusions (Figs. 1, 2, 4), but polyphase vapor-liquid-solid inclusions, with a daughter mineral (salt crystal) are present, too.

Th varies from 220 to 421°C, and their distribution is characterized by three peaks (Fig. 5). The "filling temperatures,"* calculated from Th and pressure and salinity corrections, indicate that the hydrothermal fluids reached 487°C.

The freezing temperatures vary in a wide range, from -0.8°C to -43.6°C, but the temperatures of about -20°C and lower are dominant - they represent primary inclusions. The freezng temperatures indicate that density and salinity of fluids varied significantly. Many inclusions are characterized by NaCl equiv. % higher than for saturated NaCl-solution. This indicates that hydrothermal fluids have, as base cations, not only Na but potassium and magnesium likely were present too. (Author's abstract)

*Presumably formation or trapping temperature is actually meant.(E.R.)

DARIMONT, A. and COIPEL, J., 1982, Dispersion of homogenization temperatures in aqueous inclusions - boiling or necking-down phenomena, in R. Kreulen and J. Touret, guest eds., Current Research on Fluid Inclusions: Chem. Geol., v. 37, p. 151-163. Authors at Inst. de Géologie Appliquée, 4000 Liège, Belgium.

Microthermometric fluid inclusion studies lead to the interpretation of sometimes very complex homogenization temperature histograms. This paper presents a simulation of boiling and necking-down phenomena and their theoretical homogenization temperature (Th) distributions.

For pure water, the maximum temperature observed during the homogenization in liquid or gaseous phase is the critical temperature of water.

The models have been extended to NaCl-H_2O systems, but they remain incomplete due to the lack of published data for densities of the gaseous phase (for higher temperatures than 325°C) and densities of the liquid phase (for higher temperatures than 500°C). They reveal similar curves but it appears that the maximum observable temperature may be higher than the critical temperature of the solution considered.

This simulation should help pointing out these processes in observed distributions. (Authors' abstract)

DAWSON, J.B., 1982, Contrasting types of mantle metasomatism (abst.): Terra Cognita, v. 2, p. 232-233.

DAY, H.W. and FENN, P.M., 1982, Estimating the P-T-XH_2O conditions during crystallization of low calcium granites: J. Geol., v. 90, p. 485-507.

DEINES, P., 1982, The relationship between inclusion composition and carbon isotopic composition of host diamond (abst.): Terra Cognita, v. 2, p. 202. Author at Dept. Geosci., The Pennsylvania State Univ., University Park, PA, USA.

The ^{13}C content of the diamonds from the Premier and Finsch kimberlite is not related to diamond shape, color, state of deformation, type of mineral or the type of mineral paragenesis included. For the Premier mine it could be demonstrated that inclusion-containing and inclusion-free diamonds have the same mean $\delta^{13}C$ value. However, an isotopic composition difference between diamonds from Premier and Finsch kimberlites is observed, and in both occurrences there is a distinct association of diamonds of higher ^{13}C contents with inclusions low in SiO_2 (olivine, eclogite suite garnets and clinopyroxenes), Al_2O_3 (orthopyroxenes, peridotite suite garnets, eclogite suite garnets and clinopyroxenes), Cr_2O_3 (olivine, orthopyroxene, peridotite suite garnets, eclogite suite clinopyroxenes), MgO and Mg/(Mg+Fe), (olivines, orthopyroxenes, peridotite suite garnets, eclogite suite garnets), Na_2O, K_2O,TiO_2 (eclogite suite clinopyroxenes) and high in FeO (olivines, orthopyroxenes, and peridotite suite garnets), CaO (periodotite suite garnets, eclogite suite garnets and clinopyroxenes) and Ca/(Ca+Mg) (eclogite suite garnets and clinopyroxenes). Mg-Fe partitioning between ultramafic suite minerals occluded by the same diamond indicates higher pressure and temperature conditions of equilibration for diamonds with $\delta^{13}C$ larger than -4‰ and essentially peridotite subsolidus conditions for those with lower $\delta^{13}C$ values. For eclogite type inclusions, equilibration conditions in excess of 1100°C and 140 km depth are deduced and no further separation of carbon isotopic composition according to equilibration conditions was observed. The data are interpreted to indicate that in the mantle zones exist in which the average $\delta^{13}C$ value of carbon is above -4‰ and that these zones lie below about 140 km depth. (Author's abstract)

DELANEY, J.R., 1982, Generation of high salinity fluids from seawater by two-phase separation (abst.): EOS, Trans. Am. Geophys. Union, v. 63, p. 1135-1136. Author at Sch. Oceanography WB-10, Univ. Washington, Seattle, WA 98195.

High salinity aqueous fluids (2 to 5 times seawater) in fluid inclusions within secondary mineral assemblages from submarine ridges and seamounts (Jehl, 1977; Delaney et al., 1980; Vanko and Batiza, 1982) may be formed in several ways. One mechanism involves formation of two fluid phases from a previously homogeneous phase. In a rising, high temperature fluid of seawater salinity, two-phase separation may produce very different results depending upon whether the fluid is a T-P conditions (A) less extreme or (B) more extreme than the so-called 'critical point' ('cp') [defined for the NaCl-H_2O system as the intersection between the critical curve (Sourirajan and Kennedy, 1962) and the compositional plane for a seawater analogue (in this case, 3.5 wt.% NaCl)].

(A) If the maximum temperature of the rising fluid is less than the critical temperature, then intersection of the fluid T-P path with the liquid-vapor curve will result in: 1) an expansion of the unit volume of the bulk fluid, 2) partitioning of NaCl into the dominant liquid phase, and 3) partitioning of volatiles into the separating vapor phase. (B) If T_{max} of the rising fluid is sufficiently high, it may encounter the V-L curve at T and P greater than 'cp' and a dense brine will separate, causing: 1) a possible decrease in unit volume of the bulk fluid, and 2) a reduction in salinity, but retention of volatile components in the dominant vapor-like fluid.

In Case A, high salinities would develop only after extensive boiling and some type of physical separation of phases. Fluid inclusions formed in Case B could have very high salinities if crystal growth incorporates dense brine plus some vapor-like fluid. Both cases require temperatures in the vicinity of 400 degrees. (Author's abstract)

DELANEY, J.R. and COSEN, B.A., 1982, Boiling and metal deposition in submarine hydrothermal systems: Marine Tech. Soc. J., v. 16, no. 3, p. 62-65. First author at Sch. Oceanography, Univ. Washington, Seattle, WA.

The probability that boiling will occur in an active submarine hydrothermal system is inversely related to the pressure on the system. The onset of boiling will tend to cool the two-phase solution, enrich the liquid in dissolved salts and increase its pH, while generating a salt-poor, acidic vapor phase enriched in volatile components. Precipitation of base and precious metals may be triggered by the changes in the fluid which attend boiling. If so, the process should be most effective in hydrothermal systems in shallow ridges and seamounts. (Authors' abstract)

DELOULE, E., 1982, The genesis of fluorspar hydrothermal deposits at Montroc and Le Burc, The Tarn, as deduced from fluid inclusion analysis: Econ. Geol., v. 77, p. 1867-1874. Author at Lab. de Géochimie-Cosmo. (LA 196), Inst. de Phys. du Globe et Dept. des Sci. de la Terre, Univ. Paris VI et VII, 4 Place Jussieu, 75230 Paris Cedex 05, France.

The genetic conditions of two fluorspar hydrothermal deposits are determined by the study of fluid inclusions. Observations through a cooling- and heating-stage microscope yield information on the salinity and deposition temperature. Chemical analysis by crushing and leaching allows determination, using chemical geothermometers, of the fluid's chemical composition and initial temperature. Using thermodynamic modeling, we describe the evolution of the solution and the process of fluorite deposition from a rock source in a hot reservoir at a temperature close to 300°C to deposition ending close to 180°C. (Author's abstract)

DELOULE, E. and BOURRAT, X., 1982, Historical tracing of fluids from a study of the inclusions in the fluorite veins of the Tarn region (France): Bull. BRGM, sec. II, v. 2, no. 4, p. 347-352 (in French; English abstract). First author at Lab. Géochimie et Cosmo., Inst. Physique du Globe, 75230 Paris Cedex 05, France.

The conditions of genesis of two fluorspar hydrothermal deposits are determined by fluid inclusions studies. Observations on a cooling and heating stage microscope give us information on deposition temperatures. Chemical analysis by crushing and leaching allows us to determine the chemical composition of the fluid, and its initial temperature with chemical geothermometers. With help of thermo-dynamical modeling, we can describe the solution evolution and the process of fluorite deposition, from the rock source in a hot reservoir close to 300°C until the deposit close to 180°C. (Authors' abstract)

DELOULE, E. and ÉLOY, J.F., 1982, Improvements of laser probe mass spectrometry for the chemical analysis of fluid inclusions in ores, in R. Kreulen and J. Touret, guest eds., Current Research on Fluid Inclusions: Chem. Geol., v. 37, p. 191-202. First author at Bureau de Recherches Géol. et Minières, 45018 Orléans la Source, France.

To obtain chemical information on geologic fluids, we have performed laser probe mass spectrometry on fluid inclusions. This process permits us to directly analyze individual micro fluid inclusions inside the crystals. The microprobe employed uses laser-beam interaction to erode the material thickness over the inclusion site as far as the cavity. As the fluid is released, the components of fluid inclusion are partly ionized by laser interaction. The ions are then accelerated in an ion source, separated by an applied magnetic field and detected by a photographic plate detector.

By means of the Saha equation applied to the plasma obtained by laser interaction we studied a theoretical model of fluid ionization. We calculated the ionization yields of different chemical species. With this method, we obtained semi-quantitative results for the determination of the atomic ratios (Na + K)/Cl in the case of fluid components in quartz, fluorite and dolomite samples. (Authors' abstract)

DEMIKHOV, Yu.N., KOROSTYSHEVSKII, I.Z. and BEREZOVSKII F.I., 1982, Reliability of the determination of the isotopic composition of hydrogen, carbon, and oxygen in water and carbon dioxide from gas-liquid inclusions in minerals of metamorphogenic formations: 9 Vses. Simpoz. po Stabil. Izotopam V. Geokhimii, Moskva, 16-19 Noyab, 1982, M. 1982, (2), p. 492-494 (in Russian).

DEMIN, Y.I., 1982, Thermal behavior of granitoids and their associated mineralization (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 65-66. Author at Moscow State Univ., Moscow, USSR.

A thermodynamic analysis of granite parageneses, a study of melt inclusions in quartz and feldspar,* an investigation of the composition of coexisting minerals have provided data evidencing a narrow temperature range of crystallization (850-950°C), similar acidity-alkalinity conditions and the same water content (2% usually) of the melt in most of the various types of geosynclinal granites. (From the author's abstract)

DEMIN, Yu.I. and SERGEEVA, Nat.Ye., 1982, Rare-earth mineralization in the sulfide-polymetal deposit Novoberezovskoe (Rudnyi Altai): Geol. Rudn. Mest., v. 24, no. 4, p. 95-100 (in Russian). Authors at Moscow State Univ., Moscow, USSR.

Sphalerite-chalcopyrite-pyrrhotite ores yielded Th 160-435°C (14 measurements). (A.K.)

DEVINA, O.A., YEFIMOV, M.Ye., MEDVEDEV, V.A. and KHODAKOVSKIY, I.L., 1982a Thermodynamic parameters of $B(OH)_3^0$ and $B(OH)_4^-$ in aqueous solution at 298-573 K: Geokhimiya, no. 4, p. 550-564 (in Russian).

DEVINA, O.A., YEFIMOV, M.Ye., MEDVEDEV, V.A. and KHODAKOVSKIY, I.L., 1982b Thermodynamic properties of the uranyl ion in aqueous solution at elevated temperatures: Geokhimiya, no. 10, p. 1454-1463 (in Russian).

DE VIVO, B., CORTINI, M., BELKIN, H.E. and ROEDDER, E., 1982, Inclusion geobarometry from ejected mafic Vesuvian xenoliths: Geol. Soc. Am. Abstracts with Programs., v. 14, p. 474. First author at C. Studio Geocr. e Geoch. Form. Recenti, CNR, Roma, Italy.

The Somma-Vesuvius volcano is situated at the southernmost part of the Italian-Thyrrhenian volcanic province. Lavas and tephra range in composition from trachytes to phonolites and leucitites. Mafic xenolithic nodule (*N*) ejecta related to Vesuvian explosive activity have been classified into 4 varieties: cumulate, "skarn," hornfels, and hypabyssal lava equivalents. We have investigated the fluid and silicate melt inclusions (*I*) of the cumulate and "skarn" types. *N* from 3 separate eruptive episodes were studied in order to better understand their depth and temperature (*T*) of formation and petrogenetic history. Two primary *I* types, formed by trapping of immiscible fluids, are present: silicate melt (now glass in part crystallized to various daughter minerals, plus a small shrinkage bubble) and seemingly pure CO_2 (now liquid and vapor plus a small amount of glass). Both types occur in the pyroxene, olivine, spinel, apatite, and biotite of all investigated *N*. All CO_2 *I* in biotite and rare larger CO_2 *I* in other minerals appear to have decrepitated during eruptive decompression. If we assume that the *T* of eruption (and mineral growth) was ≈ 1200°C, the density of the CO_2, determined optically or from the *T* of homogenization, provides the pressure of *I* trapping, hence the depth of crystal growth. Microthermometry of the CO_2 *I* was difficult; most are less than ≈ 30 μm and are optically poor. Geobarometry of primary CO_2 I in apatite, olivine, and pyroxene from all the "skarn" and cumulate N gives a crystallization depth of 5 ± 2 km, whereas primary CO_2 I in spinel from one "skarn" N indicate a crystallization depth of 15 ± 2 km. This discrepancy could result from a real difference in the petrogenesis of the spinel or possibly subsequent I leakage in other phases. These preliminary geobarometric studies reveal a different picture for the origin of the cumulate and "skarn" N than has been suggested. (Authors' abstract)

DEVYATYKH, G.G., SNOPATIN, G.Ye. and CHURBANOV, M.F., 1981, Solubility of water in liquid hydrogen sulfide: Zhurn. Neorg. Khimii, v. 26, no. 6, p. 1707-1709 (in Russian).

DICKSON, F.W., 1982, Kinetics of quartz reaction with H_2O at 200°C and 170 bars (abst.): EOS, Trans. Am. Geophys. Union, v. 63, p. 1128.

DILLES, J.H., 1982, Lateral and vertical alteration and mineralization patterns around the Ann-Mason porphyry copper deposit, Yerington, Nevada (abst.): Geol. Soc. Am. Program with Abstracts, v. 14, p. 160. Author at Dept. Geol., Stanford Univ., Stanford, CA 94305.

The early Jurassic Ann-Mason porphyry copper deposit has been tilted ~90° W so that present exposures represent a 4.5 km cross-section. Detailed mapping, petrography, X-ray and fluid inclusion studies indicate that central potassic (K) alteration and ore formation were caused by high T, saline fluids of probable magmatic origin. K alteration was associated with outward and more extensive deep Na-Ca and high level Na alteration that define a large convective hydrothermal system of possible seawater origin. The deposit is hosted in quartz monzodiorite where cut by a quartz monzonite porphyry dike swarm that emanates from a quartz monzonite cupola. Mapping at 1" = 400' of 12 km^2 of exposure defined alteration patterns indicating that >18 km^3 of rock were hydrothermally altered. Central K alteration contains the highest grades (+0.4% Cu) and is characterized by 2° biotite, chalcopyrite, and quartz veining. Fluid inclusion studies indicate it was formed by fluids at T>500°C and >23 wt% equiv. NaCl. K alteration extends along the porphyry dike swarm to the uppermost exposures and is weakly developed within the quartz monzonite cupola. Na-Ca alteration is developed extensively at and below the ore zone and is characterized by Olig-Amph-Qtz-Sph assemblages. It is both pre-ore deep along the cupola contact and syn-ore laterally along porphyry dikes. Above the ore zone, K alteration is flanked by propylitic alteration characterized by chloritized mafic minerals and is overprinted by Na assemblages comprised of Alb-Qtz-Chl-Py-Rut. Minor structurally controlled Qtz-Ser-Py zones and related tourmaline breccias cut all other alteration types and form a funnel-shaped, upwardly expanding zone above ore. In conclusion, the Ann-Mason deposit, characterized by vertically and laterally extensive Na-Ca and Na alteration, contrasts with classic cratonic U.S. deposits, characterized by sericitic alteration, possibly due to its early Jurassic island arc setting and the involvement of hydrothermally convecting seawater. (Author's abstract)

DIX, O.R. and JACKSON, M.P.A., 1982, Lithology, microstructures, fluid inclusions, and geochemistry of rock salt and of the cap-rock contact in Oakwood Dome, east Texas: significance for nuclear waste storage: Report of Investigations No. 120, 59 pp., U.S. Dept. Energy, Contract NO. DE-AC97-80ET-46617. Authors at Bureau of Econ. Geol., The Univ. Texas at Austin, Austin, TX 78712.

Abundant fluid inclusions were found in halite, many with (or between) many solid inclusions of anhydrite. Some opaque (organic?) material is present in some. The bubbles expanded 8x to 10x on breaching to atmospheric pressure. The amount of H_2O as inclusions ranged from 0.05 to 0.0005%, from the upper and lower intervals in the sample. Compressed gas inclusions occur as films on grain boundaries and between solid inclusions of anhydrite and the host salt.

Speculations are presented on the origin of the water and the pressure of trapping. (E.R.)

DOBRETSOV, N.L., ANDREEV, G.V., GORDIYENKO, I.V., KONNIKOV, E.G., LITVINOVSKIY, B.A. and REYF, F.G., 1982, Model correlation of endogene processes (on the example of Transbaikalia): Geologiya i Geofizika, no. 12, p. 22-32 (in Russian; English abstract). Authors at Geol. Inst. of Buryatian Div. of Siberian Branch of Acad. Sci. USSR, Ulan-Ude, USSR.

The paper bears some reference data on Th of melt inclusions in granites. (A.K.)

DOLGOV, Yu.A., 1982a Migration and location of ores in ore lodes and pegmatites (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 196-197.

DOLGOV, Yu.A., 1982b The problem of hermeticity of inclusions in crystals, in Use of methods of thermobarogeochemistry during prospecting and studies of ore deposits, N.P. Laverov, ed.: Moscow, "Nedra" Publ. House, p. 119-126 (in Russian).

Diffusion through crystals may occur due to four mechanisms: vacancy exchange, movements through interaction (-ion) space, exchange of atoms and cyclic movement of atoms. Diffusion in whole crystal is characterized by surface of section of all possible paths of migration related to crystal volume or section; this [yields a] very small value for the effective coefficient of diffusion through solid substance. In some cases diffusion velocity in solids may be very significant, e.g. at 300°C velocity of gold diffusion in lead is higher than NaCl diffusion in water solution at room temperature. But in general, diffusion coefficients in gases under normal P are in ranges 10^{-1} cm^2/sec., in liquids -10^{-5} cm/sec., in solids -10^{-10} cm^2/sec. In case of post-magmatic fluids their migration through structural channels is of low probability for most components, except for elements of small atomic size or crystals with large interatom distances. One may suppose that the role of transcrystalline diffusion increases in the neighborhood of melting T and P causing plastic deformation. Three problems should be recognized: 1) possibility and ranges of volatile transport through crystal, 2) possibility of location of volatiles as inclusions due to transcrystalline diffusion, 3) if such inclusions form, their use for thermobarogeochemistry should be elucidated. Following studies were performed for recognition of hydrogen diffusion through crystals: low-density inclusions in quartz were homogenized and then significantly overheated, up to 1300°C, cooled and homogenized again. Such runs were repeated several times and Th did not change in the limits of heating stage accuracy so H_2 diffusion through quartz was not detectable. Tektites bear G inclusions with H_2 up to 40% that was preserved for 15 million years. Even zeolites formed on the ocean floor bear inclusions with vacuoles lined by non-permeable crystal layer so the inclusions frequently do not leak. The conclusions are as follows:

1. Detectable diffusion velocities were not recognized for post-magmatic minerals, although minerals with perfect cleavage, zeolites etc.

may have relatively large diffusion coefficients.

2. Diffusion is possible for magmatic minerals in individual cases that should be investigated.

3. Individual high diffusion velocities may be expected under deep metamorphic, anatectic and upper mantle conditions.

4. In all physical changes under the effects of P and T the significance of inclusions as geothermometers and geobarometers remains. (Abstract by A.K.)

DOLOMANOVA, E.I., NOSIK, L.P. and ROZHLESTVENSKAYA, I.V., 1982, Geochemical features of the formation of tin ore deposits according to isotopic composition data for chemical elements in gas-liquid mineral inclusions: Nov. Dannye Miner., v. 30, p. 70-91 (in Russian).

CO_2 and SO_2 are present in the gas-liquid inclusions of cassiterite specimens from Sn ore deposits. H_2O is present in cassiterite from deposits of cassiterite-sulfide-quartz and cassiterite-sulfide formations. In vein-quartz inclusions, CO_2 and H_2O are always present. The $\delta^{13}C$ and $\delta^{18}O$ values of CO_2 and the $\delta^{34}S$ values of SO_2 show that the ore deposits were localized in diverse oxidizing-reducing conditions. (C.A. 98: 219065g)

DOROGOVIN, B.A., BYDTAEVA, N.G. and SHATAGIN, N.N., 1982, Thermobarogeochemical methods of mapping of quartz-bearing Archean rocks and prospecting for quartz vein mineralization in the Aldan Shield, in N.P. Ermakov, ed., Thermobarogeochemistry in Geology - Materials of the Sixth All-Union Symposium on Thermobarogeochemistry: Vladivostok, Far East Sci. Center, Acad. Sci. USSR Pub. House, p. 135-140 (in Russian).

For abstract, see entries: Dorogovin and Bydtaeva, and Dorogovin, Bydtaeva and Shatagin (first entry) in Fluid Inclusion Research--Proceedings of COFFI, vol. 11, 1978, p. 51. (A.K.)

DOROSHENKO, Yu.P and PAVLUN, N.N., 1982, Physicochemical conditions of Akchatau ore deposit genesis (based on inclusions in minerals): Mineral. Sb. (Lvov), v. 35, no. 2, p. 44-51 (in Russian). Authors at L'vov Gos. Univ., Lvov, USSR.

This is the full paper corresponding to Doroshenko and Pavlun, 1978, Fluid Inclusion Research--Proc. of COFFI, v. 12, p. 45, 1979. (E.R.)

DRUITT, T.H., ANDERSON, A.T., Jr. and NAGLE, F., 1982, Water in rhyolitic magma, Bishop, California (abst.): EOS, Trans. Am. Geophys. Union, v. 63, p. 451. First author at Dept. Earth Sci., Univ. Cambridge, Cambridge, England.

The concentration of H_2O in an inclusion of glass in a phenocryst of quartz from the basal Plinian air fall unit of the Bishop Tuff was found to be 4.9±0.5 weight percent by a vacuum gas analyzer method. This value is consistent with extrapolation of Hildreth's work on the overlying Bishop ash flows and with the first extruded part of the magma body being saturated with a gas rich in H_2O before eruption. Probably the top of the Bishop magma body was at least 4±1 km below the surface before the eruption of 0.7 myr ago, as suggested by others. Analyses of two inclusions in quartz phenocrysts from the last erupted Mono lobe reveal a minimum of about 2 weight percent of H_2O, consistent with Hildreth's estimate of around 3 percent. Inclusions of rhyolitic glass in quartz appear to preserve the concentrations of H_2O present in the ambient environment of crystallization. (Authors' abstract)

DUBA, A.G. and SHANKLAND, T.J., 1982, Free carbon and electrical conductivity in the Earth's mantle: Geophy. Res. Letters, v. 9, no. 11, p. 1271-1274. First author at Earth Sci. Div., Lawrence Livermore Nat'l. Lab., Livermore, CA 94550.

Laboratory measurements indicate that solid carbon, either amorphous or as graphite, enhances the electrical conductivity of rocks. Carbon in quantities of only a few ppm, providing it forms an interconnected phase, could give rise to electrical conductivities of the order seen in the high conductivity layers in the earth's mantle. This possibility is consistent with carbon petrology in mantle rocks and puts the formation and migration of abiogenic carbon compounds into a broader context. (Authors' abstract)

DUBESSY, J., AUDEOUD, D., WILKINS, R. and KOSZTOLANYI C., 1982 The use of the Raman microprobe MOLE in the determination of the electrolytes dissolved in the aqueous phase of fluid inclusions, in R. Kreulen and J. Touret, guest eds., Current Research on Fluid Inclusions: Chem. Geol., v. 37, p. 137-150. First author at C.R.E.G.U., 54501 Vandoeuvre-les-Nancy, France.

The SO_4^{2-} concentration of aqueous solutions in fluid inclusions is easily measured down to $2 \cdot 10^{-3}$ mol/kg H_2O, using the Raman microprobe MOLE. HCO_3^- and CO_3^{2-} have not yet been detected in inclusions studied by the Raman microprobe. For the cation-chloride systems, the Raman microprobe MOLE is a powerful tool for determining the stoichiometric hydrates that form under cooling. Raman spectra are given for the stoichiometric hydrates of most geological interests: $NaCl \cdot 2H_2O$, $CaCl_2 \cdot 6H_2O$, $MgCl_2 \cdot 6H_2O$, $MgCl_2 \cdot 12H_2O$, $FeCl_3 \cdot 6H_2O$ and $KCl \cdot MgCl_2 \cdot 6H_2O$. With these reference spectra it is shown that it is possible to identify hydrates formed in natural fluid inclusions. (Authors' abstract)

DUDÁS, F.O., 1982, Volatile content as a control on the vesiculation of subaqueously erupted basalts (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 478. Author at Dept. Geosci., The Pennsylvania State Univ., University Park, PA 16802.

The volume of vesicles in subaqueously erupted basaltic lavas has been used as an indicator of water depth at the time of eruption. Though the relationship between depth and vesicle volume has been convincingly demonstrated for volatile-poor tholeiites, the occurrence of highly vesicular lavas in the deep basins usually associated with island arcs suggests that volatile content is a significant control on the extent and depth of vesiculation.

Simple calculations employing an empirical H_2O solubility model have been used to relate vesicle volume, H_2O content and vesiculation depth. These calculations, for a CO_2-free, basalt-H_2O system, assume that H_2O exsolution is an equilibrium process, and that the vesicles represent the total volume of H_2O exsolved. The P-T-solubility relations of H_2O in tholeiitic melts can lead to large vesicle volumes even at great water depths, and can explain the vesiculation observed in deep water basalts. Furthermore, H_2O contents within the range required to produce vesicles in abyssal basalt lavas have been measured in some basalt glasses.

Exsolution of mixed CO_2-H_2O fluids is not sufficiently constrained by experimental data to allow development of a quantitative model, but the addition of CO_2 leads to vesicle formation at greater depth, and at lower total volatile content. Crystallization of anhydrous phenocrysts also lowers the total volatile content required for vesicle formation. Thus, vesicle volume, without critical data on the amount and proportions of volatile species present, cannot be used to infer ocean depth at the time of eruption. (Author's abstract)

DUNN, P.G. and FOWLER, L.L., 1982, Origin of the Cretaceous Copper Flat porphyry copper deposit, southwestern New Mexico (abst.): Geol. Soc. Am. Program with Abstracts, v. 14, p. 161. First author at Chevron Resources, P.O. Box 36674, Tucson, AZ 85740.

The Copper Flat deposit occurs in a quartz monzonite stock within andesitic rocks at the eastern edge of the Black Range about 56 kilometers east of the Santa Rita deposit. The andesite forms a circular outcrop approximately 6 kilometers in diameter and is at least 1 kilometer thick. It is in vertical fault contact with surrounding Paleozoic sedimentary rocks. The emplacement of the stock and related dikes, which cut both the stock and the andesite, was controlled by a well-developed fault pattern. Biotite in the quartz monzonite has been dated at 73.4 million years.

The porphyry copper deposit is restricted to the quartz monzonite and is centered around a large breccia pipe which is about 450 meters long and 200 meters wide. Fragments in the pipe consist almost entirely of quartz monzonite and are in a matrix composed primarily of hydrothermal pyrite, chalcopyrite, biotite, quartz, and potash feldspar. Fluid inclusion data suggest that the matrix formed at a temperature of 350°C and at a depth of between 1 and 2 kilometers. The pipe appears not to have vented, and the fragments have not been appreciably displaced. The pipe formed as a result of expansion due to boiling of the hydrothermal fluid.

Whole rock chemical analyses indicate that the igneous rocks represent an alkalic-calcic comagmatic series. Mineralization and the formation of the breccia pipe were the culmination of the magmatic event. (Authors' abstract)

DUNNING, J.D. and PETROVSKY, D.M., 1982, Effects of surface active aqueous environments on the morphology of cracks in natural and synthetic quartz (abst.): EOS, Trans. Am. Geophys. Union, v. 63, p. 441. Authors at Dept. Geol., Indiana Univ., Bloomington, IN 47405.

Cracks propagated in the presence of six surface active aqueous environments in sixty-two identically oriented parallelepipeds of natural and synthetic quartz were examined and mapped with an optical microscope. The degree of branching was determined by measuring the bifurcation index (total crack length/main path length) of each crack. Cracks propagated in the ambient atmosphere displayed little or no branching, with an average bifurcation index close to 1.0. Cracks propagated in distilled water, nonionic fluorocarbon, and anionic sodium dodecyl sulfate displayed moderate degrees of branching and bifurcation indicies between about 1.1 and 1.25. Cracks propagated in cationic dodecyl trimethyl ammonium bromide and catonic fluorocarbon displayed extensive branching and bifurcation indices between 1.5 and 3.0. Crack propagation in the ambient atmosphere, distilled water, and aqueous solutions of the nonionic and anionic surfactants was far more stable and controllable than crack propagation in the cationic surfactants. The variation in crack morphology as a function of chemical environment is delineated in a model, presented here, which relates branching and velocity increases to the dynamic surface energy reduction occurring in each environment at the instant of crack initiation. The magnitude of surface energy reduction is related to the affinity of the adsorbate for the surface and the heat of adsorption of the adsorbate. In cationic surfactant environments, higher heats of adsorption and affinity result in higher surface energy reductions and high initial propagation velocities which result in increased bifurcation of cracks. Surface energy reduction and coverage values generated in calorimetric and Augier spectroscopy studies are consistent with this model. (Authors' abstract)

DZYUBA, A.S., 1982, Formation of gas inclusions during growth of a crystal from a melt: Kristallografiya, v. 27, p. 551-555 (in Russian; translated in Sov. Phys. Crystallogr., v. 27, no. 3, p. 333-335). Author at Khar'kov State Univ.

The author investigates the kinetics of capture of gas bubbles by crystals of salol growing from a melt. The formation of gas inclusions is discussed for various relations between the velocity of the front and the rate of growth and dimensions of the gas bubble. (Author's abstract)

EADINGTON, P.J., 1982a Calculated solubilities of cassiterite in high temperatue hydrothermal brines, and some applications to mineralization in granitic rocks and skarns, in S. Somiya, ed., Proceedings of the First International Symp. on Hydrothermal Reactions, March 22-26, 1982, Japan, p. 335-345.

EADINGTON, P.J., 1982b A brief survey of fluid inclusions and their significance in the base metal ores at the Conrad Lodes and Webb's Consols deposit, in New England Geology, Proc. of a Symp. on the Geol. of the New England Region, Armidale, Australia, July 1982 in honor of Univ. New England Emeritus Professor A.H. Voisey, P.G. Flood and Bruce Runnegar, eds., pub. by Dept. Geol., Univ. New England, and AHV Club, Armidale, N.S.W., p. 321-326. Author at CSIRO Div. Mineral., North Ryde, New South Wales.

The Conrad Lodes (Pb, Ag, Cu, Sn) and Webb's Consols Deposit (Pb, Zn, Ag) are two small epigenetic base metal deposits occurring in leucogranite host rock in the Tingha-Emmaville region of the New England Fold Belt.

Fluid inclusion measurements and invarient equilibria for sulphide minerals in the ores fix the formation temperature for the Conrad Lodes between about 330°C and 400 ± 50°C and for the Webb's Consols Deposit between 250°C and 400 ± 50°C. Stable isotope and composition data from the hydrothermal solutions are best accounted for by mixing of meteoric water with a small component of magmatic water. (From the author's conclusions)

EADINGTON, P.J. and SUN, S.S., 1982, Variations in temperature, chemical composition, and oxygen isotope ratios of hydrothermal solutions in the Mole granite, in New England Geology, Proc. of a Symp. on the Geol. of the New England Region, Armidale, Australia, July 1982 in honor of Univ. New England Emeritus Professor A.H. Voisey, P.G. Flood and Bruce Runnegar, eds., pub. by Dept. Geol., Univ. New England, and AHV Club, Armidale, N.S.W., p. 321-326. Authors at CSIRO Div. Mineral., North Ryde, New South Wales.

Fluid inclusion and oxygen isotope measurements show that hydrothermal solutions in the Mole Granite were initially enriched in ^{18}O and dissolved salts (550°C and 60 wt.%) with a high Fe/Na ratio and probably were of direct magmatic origin. These solutions were progressively depleted in ^{18}O and salts by dilution resultng from an influx of surface-derived water of meteoric origin (to 250°C and 2.5 wt.%). The cassiterite ores were deposited during initial dilution of the magmatic solutions and the base-metal ores were deposited from hydrothermal solutions that were dominantly of meteoric origin.

The degree of dilution of the magmatic solutions suggests an upper limit for the meteoric water/rock ratio of 1.0 (mole oxygen basis) under the defined conditions. This could be sufficient to deplete the granite in ^{18}O by 4 to 5‰. However, as most of the interaction took place at relatively low temperatures, oxygen exchange was probably confined to major fractures. (From the authors' conclusions)

EASTOE, C.J., 1982, Physics and chemistry of the hydrothermal system at the Panguna porphyry copper deposit, Bougainville, Papua New Guinea: Econ. Geol., v. 77, p. 127-153. Author at Geol. Dept., Univ. Tasmania, Box 252C, G.P.O. Hobart, Tasmania 7001, Australia.

Various hydrothermal processes have been suggested as important in the formation of porphyry coppers, e.g., orthomagmatic evolution of salt-rich liquid, condensation of salt-rich liquid from magmatic vapor, convection of ground water driven by magmatic heat, and boiling of ground water. A fluid inclusion study based on detailed two-dimensional sampling indicates that all of these processes may have contributed to the evolution of the Panguna deposit, but that the copper was deposited mainly by salt-rich liquid expelled directly from the magma. Significant salt-rich liquid may also have condensed from a vapor plume.

A scheme for cooling the boiling liquids (initially unsaturated in NaCl at magmatic conditions) through supersaturation to unsaturation near 400°C (by mixing with an externally derived liquid) is suggested to explain the systematic variation in homogenization properties of the salt-rich liquids. For a pressure near 300 bars determined at the outer boundary of the ore zone, the sequence of predicted phase changes based on the $NaCl-H_2O$ system corresponds with observed changes. Variations in the KCl and NaCl content of salt-rich liquid could be explained by the precipitation of halite, but that is incompatible with boiling. Salt-rich liquid was pumped into the ore zone by the hydrostatic-lithostatic pressure difference, then descended through the ore zone because of its density relative to ground water. Phenomena in the top of the system were dominated by the interaction of vapor and ground water.

An oxygen fugacity near that of the hematite-magnetite buffer, and the predominance of SO_2 among vapor sulfur species, have been deduced from mineralogy and limits on partial pressures. The formation of mixed metal halides enhances the volatility of Fe, but vapor transport of Fe is insignificant. Zn and Mo undergo significant vapor transport. Cu may be transported in liquid in some cases and vapor in others. The alteration of wall rock to biotite generates HCl, which is probably removed by boiling. The sulfate in anhydrite may be a decomposition produced of SO_2, but a second mechanism is implied below 500°C, where sulfide deposition becomes greater relative to sulfate. The high oxidation state of magmatic fluids during copper mineralization was due to the loss of H_2 from the magma in those early evolved volatiles that formed an amphibole-bearing assemblage. (Author's abstract)

EASTOE, C.J. and EADINGTON, P.J., 1982, Problematic fluid inclusions from the Panguna porphyry copper deposit, Bougainville (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 480. First author at Dept. Geosci., Univ. Arizona, Tucson, AZ 85721.

The relatively barren Biotite Granodiorite stock was emplaced between major episodes of copper mineralization at Panguna. Most of the stock is altered to sericite-chlorite and sericite-clay assemblages, and associated copper mineralization is limited mainly to vuggy, marginal intrusive breccias. Later, sparse quartz-chalcopyrite veins cut the stock. Quartz phenocrysts within the stock contain a distinctive suite of gas-rich and salt-rich fluid inclusions, some apparently primary, and solid inclusions of copper-iron sulfide and aklali silicate. The salt-rich inclusions contain halite, sylvite, birefringent salt, hematite, opaques, liquid and vapor, and in certain phenocrysts homogenize by vapor disappearance near 1000°C. Such inclusions have salt contents of about 65 wt % (in terms of NaCl + KCl), and TmNaCl (near 530°C) and TmKCl (near 150°C) measurements conform to the curve established for salt-rich liquids from elsewhere in the deposit. They are distinct from inclusions in a neighboring vein (TmKCl near 180°C, TmNaCl near 570°C and bubble disappearance at lower temperatures). The silicate inclusions approach alkali feldspar in composition and begin to melt by 950°C in the presence of quartz and water. The temperatures are unrealistic for a magma precipitating quartz near 1 kb, and a problem in the interpretation of very high temperatures from salt-rich fluid inclusions is indicated. The inclusions demonstrate the co-existence of salt-rich liquid, vapor and silicate liquid, and indicate a magmatic source for the copper. (Authors' abstract)

ECKSTEIN, Yoram and LOPEZ, C.V., 1982, Temporal changes in physico-chemical parameters of fluids during a production test at Momotombo, Nicaragua: Geothermal Resources Council, Transactions, v. 6, p. 253-256. Authors at Dept. Geol., Kent State Univ., Kent, OH 44242.

Evolution of physico-chemical characteristics of the fluids discharged during a monitored six-month production test at Momotombo points to rapid transformation of the reservoir from water-, to steam-dominated. The transformation followed an invasion of the peripheries of the hot reservoir by cold ground water from the pyroclastic and lacustrine formations underneath Lake Managua. Rapid cooling of the periphery of the geothermal reservoir led to intraformational precipitation of silica sealing off the reservoir to any fresh recharge. The process was reflected in radical changes in pressure, temperature and production rates, accompanied by significant evolution of chemical parameters of the discharged fluids, such as B/Cl, Na/K and Na/Cl ratios, and concentrations of silica, chloride, sulfate and boron. (Authors' abstract)

EDMOND, J.M., 1982, The chemistry of ridge crest hot springs: Marine Tech. Soc. J., v. 16, no. 3, p. 23-25. Author at Massachusetts Inst. Tech., Cambridge, MA.

Submarine hot springs have been sampled at three locations on the open ridge axes of the eastern Pacific - 21°N and 12°N on the East Pacific Rise and at 86°W on the Galapagos Spreading Center. In addition water has recently been collected from springs that issue from sediments over the buried axis in the Guymas Basin in the central Gulf of California. The general chemistry of these systems will be discussed here. (Author's abstract)

EFIMOVA, M.I., BLAGODAREVA, N.S., VASILENKO, G.P., STEPANOV, G.N. and NOSENKO, N.A., 1982, Skarn ore deposits of Primorjie and their formation temperatures (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 241-242. Authors at Far-East Geol. Inst., Valdivostok, USSR.

The skarn deposits of Primorjie are presented by various ore formations (Table) and are distributed within the Sikhote Alin folded belt and the activization zones of the Khankai crystalline massif. The ore specializations of the skarn are regularly alternating in various structural-facial zones of Primorjie and the skarn mineralization is genetically related to definite magmatic complexes: the tungsten-bearing skarns of the Main synclinorium and the Alchan zone are related to the mafic granites; the Zn-Pb and boron-silicate ore formation of the Coastal anticlinorium - to granites of the andesite formation; the Sn-bearing skarns of the Coastal anticlinorium - to the biotite-hornblende granites; the skarn mineralization of the Khankai massif - to the monzonite granite complex. The deposit formation proceeded through a range of stages; the origin of mineral associations of different ages was determined by the composition of the primary ore-forming solutions and by evolutional trend of main parameters of the ore genesis (temperature and pressure). The most high temperature conditions are characteristic of the hedenbergite-wollastonite skarns of the scheelite-gold-pyrite formation, while the skarn-magnetite formation (of Sn-bearing skarns) is the last member in descending temperature range. (Authors' abstract)

Table

Skarn formations	Main stages of mineralization	Basic mineral associations	Temperatures, °C
Skarn-scheelite-gold-pyrite	Skarn	Hedenbergite (Hd) - wollastonite (Wol), grossular (Grs) + vesuvianite (Ves);	780-600
		cummingtonite + epidote (Ep)	450-37
	Greisen	Quartz (Q) + albite + muscovite (Mc) + apatite + scheelite (Sche) + chlorite (Clr)	340-270
	Sulphide	Arsenopyrite + G + Clr + Mc + pyrrhotite (Po) + Ep + tourmaline (Tour) + stilpnomelane (St)	300-240
	Calcite	Calcite (Ca) + Clr + Mc + pyrite (Py) + St	240-120
Skarn-scheelite-cassiterite-polymetallic	Skarn	Hd + andalusite + Ves + ilvaite (Il)	770-450
	Magnetite	Hd + Magnetite (Mt) + andradite	420-360
	Magnetite-fluorite	Mt + Sche. + fluorite (Fl) + cassiterite (Css) + Ves + phlogopite	360-350
	Sulphide	Sphalerite (sph) + galenite (Gl) + chalcopyrite (Cp) + Clr + Ep + St + Ca	180-120
Skarn-borosilicate	Skarn	Wol + Hd	600-410
	Datolite	Datolite (Dt) + Grs + danburite + Q	395-420
	Sulphide	Sph + Gl + Po + Q	360-320
	Calcite	Ca + Clr + Mc + Fl	180-120
Skarn-polymetallic	Skarn	Hd + Wol + Grs	590-360
	Sulphide	Sph + Gl + Po + Cp + Q + Dt	360-220
	Calcite	Ca + Q + apophyllite + Fl + Py + ilvaite	210-80
Skarn-magnetite	Skarn	Pyroxene + Grs + Mt + hornblende	420-320
	Sulphide	Sph + Po + Gl + Css	360-320
	Calcite	Ca + Clr + Fl + Py + zeolite	150-90

EGGLER, D.H. and BAKER, D.R., 1982, Reduced volatiles in the system C-O-H: implications to mantle melting, fluid formation, and diamond genesis, in S. Akimoto and M.H. Manghnani, eds., High-Pressure Research in Geophysics: Advances in Earth and Planet. Sci., v. 12, p. 237-250. Authors at Dept. Geosci., The Pennsylvania State Univ., University Park, PA 16802, USA.

Kimberlite, melilitite, carbonatite, and some nephelinitic magmas are believed to be produced by melting of carbonated peridotite. The lowest possible fO_2 at which carbonates in peridotite are stable is at saturation with graphite or diamond. Those conditions are proposed as probable fO_2-buffering conditions for generation of the magmas, conditions that are between the quartz-fayalite-magnetite and magnetite-wüstite buffers over a large pressure-temperature range. By contrast, at much more reduced conditions, CH_4-H_2O-H_2, rather than CO_2-H_2O, are the volatile species, and carbonates are unstable. Trapped volatiles in some diamonds seem to have contained CH_4, indicating that those diamonds could not have been in equilibrium with kimberlite magmas or the source region of kimberlites. CH_4, the chief volatile at very reduced conditions (near the iron-wüstite buffer), has a depolymerizing effect on silicate magmas. This effect could lead to the production of cumulate eclogites from peridotite-derived melts at pressures as high as 5 GPa. (Authors' abstract)

EICHELBERGER, J.C. and WESTRICH, H.R., 1982, Water in obsidian and in magmas (abst.): EOS, Trans. Am. Geophys. Union, v. 63, p. 1121. Authors at Sandia Nat'l. Lab., Albuquerque, NM 87185.

Water contents have been directly determined for a large number of obsidian samples from both explosively and effusively erupted young ($\leq 10^3$y) volcanic units at Mono Craters/Inyo Domes, Katmai, and the Cascade Range. Because the samples are unaltered, bubble-free, crystal-poor or free, and release water at high temperatures, the measured water contents are believed to represent magmatic water dissolved in melt at the time of cooling. Water contents range from 0.1 to 3 wt.%, or up to an order of magnitude greater than previously reported for fresh, subaerially erupted volcanic glass. Mean water contents of 0.1 to 0.4 wt.% are associated with flows and domes, and 0.4 to 2.0 wt.% with Plinian air fall and pyroclastic flow eruptions. Water contents decline with time and with declining explosiveness of eruption within sequences.

Absence of bubbles implies that magma represented by these samples was either under sufficient load to be vapor undersaturated at the time of cooling or was quenched following decompression sufficiently quickly to prevent vesiculation. Evidence for simultaneous brecciation and quenching of magma prior to eruption, together with rapid rates of vesiculation observed experimentally, suggest that some of the obsidian in tephra represents magma cooled at depth, probably by groundwater. In contrast, obsidian in flows cools after eruption, but still under load from the pumiceous carapace.

Magma which was bubble free at the time of cooling could have previously vesiculated and degassed, provided that confining pressure increased following degassing. Such cycles of unloading and loading clearly occur in the case of obsidian fiamme in welded tuffs (0.2 wt.% H_2O) and may occur under other circumstances as well.(Authors' abstract)

EINAUDI, M.T., 1982a, Description of skarns associated with porphyry copper plutons: southwestern North America, in S.R. Titley, ed., Advances in Geology of the Porphyry Copper Deposits, Southeastern North America, p. 139-184.

Includes reference to pertinent fluid inclusion studies from the literature. (E.R.)

EINAUDI, M.T., 1982b, General features and origin of skarns associated with porphyry copper plutons: southwestern North America, in S.R. Titley, ed., Advances in Geology of the Porphyry Copper Deposits, Southeastern North America, p. 185-210.
See previous item. (E.R.)

ELDERS, W.A., HOAGLAND, J.R., McDOWELL, S.D. and COMBO R., J.M., 1979, Hydrothermal mineral zones in the geothermal reservoir of Cerro Prieto, in W.A. Elders, ed., Guidebook: Geology and Geothermics of the Salton Trough, Field Trip No. 7, Geol. Soc. Am. 92nd Annual Meeting, San Diego, Nov. 1979, p. 36-43. First author at Inst. Geophy. & Planet. Phys., Univ. California, Riverside, CA, USA.
Includes some temperature data on fluid inclusions. (E.R.)

ELLIOTT, W.C., GRANDSTAFF, D.E., ULMER, G.C., BUNTIN, T., and GOLD, D.P., 1982, An intrinsic oxygen fugacity study of platinum-carbon associations in layered intrusions: Econ. Geol., v. 77, p. 1493-1510.

EMANUEL, K.M., 1982, A geochemical, petrographic and fluid inclusion investigation of the Zuni Mountains fluorspar district, Cibola County, New Mexico: MS thesis, Univ. New Mexico, Albuquerque, New Mexico.
Indexed under Fluid Inclusions. (E.R.)

EMONS, H.-H., KEUNE, H. and SEYFARTH, H.-H., 1982, Chemical microscopy, in Comprehensive Analytical Chemistry, v. 16, G. Svehla, ed.,: Elsevier Sci. Pub. Co., Amsterdam, p. 1-328.
Includes a section on design and calibration of cold and hot stages, sample preparation, etc. (E.R.)

ERMAKOV, N.P., 1982a Main results of scientific and applied utilization of inclusions of mineral-forming media in the U.S.S.R. (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 197-199. Author at Moscow State Univ., Moscow, USSR.
A review. (E.R.)

ERMAKOV, N.P., ed., 1982b Thermobarogeochemistry in geology - Materials of the Sixth All-Union Symposium on Thermobarogeochemistry: Vladivostok, Far-East Sci. Center, Acad. Sci. USSR Pub. House, 188 pp. (in Russian), 600 copies printed; price 2 rbls 35 kopecks.
The book is the second volume containing the full text of thirty-two selected lectures that were delivered during the symposium in Vladivostok, USSR, in 1978 (for papers of the first volume "Thermobarogeochemistry and Ore Genesis" see Fluid Inclusion Research--Proceedings of COFFI, vol. 13, 1980). The issue consists of the four parts: I. Thermobarogeochemistry of metamorphic, metasomatic and hydrothermal processes (5 papers); II. Temperature conditions of formation of magmatic intrusive and effusive rocks (9 papers); III. Conditions of formation of nonmetallic mineral raw material deposits in the light of thermobarogeochemical data (8 papers); IV. Methods and technique of field and laboratory studies (10 papers). The contents of these papers are essentially satisfactorily covered by the abstracts that were published in the two abstract volumes published in 1978 before the symposium and translated in Fluid Inclusion Research--Proceedings of COFFI, vols. 11-13 (1978-1980). Citations only of the individual papers will be found in this volume. (A.K.)

ERMAKOV, N.P. and KHITAROV, D.N., 1982, All-Union Seminar "Use of methods of thermobarogeochemistry for prospecting and studies of deposits of raw material:" Sovetskaya Geologiya, no. 7, p. 119-122 (in Russian). First author at Moscow State Univ., USSR.

A review. (A.K.)

ERMAKOV, N.P. and PIZNYUR, A.V., 1982, Thermobarogeochemical principles of local evaluation and prognosis of endogeneous ore mineralization, in Use of methods of thermobarogeochemistry during prospecting and studies of ore deposits, N.P. Laverov, ed.: Moscow, "Nedra" Publ. House, p. 209-213 (in Russian).

Practical use of thermobarogeochemical methods helps to establish the following features of ore depostis: 1. stages of endogeneous processes; 2. changes of ore mineral composition in stages; 3. changes of T, P, phase state, composition and concentration of each flow of mineral-forming fluids in horizontal and vertical sections; 4. pulsation phenomena; 5. ways of migration and width of each flow of ore-forming fluids; 6. boiling of solutions; 7. distinguishing of commerical ore stages; 8. T, P and chemical gradients; 9. depth of ore formation, vertical extent of ores, level of erosion denudation, suspected lower ore body boundary, etc. The above listed methods are used especially for exploration: decrepitophonic method of prospecting, decrepitation studies of light fraction of alluvium and other detrital rocks, method of diagnostics of commerical ore stages for local evalution of ores; the latter includes the recognition of specific features and Th of inclusions in commercial ore stages. The above methods was verified in Mo ore deposits, where characteristic features are as follows: presence of quartz with inclusions bearing halite dm, presence of boiling solutions, Th 450-350°C and lower, P changes (decreases) over an interval to 10^8 Pa, $Cl-Na-CO_2-H_2O$ filling of inclusions, total salt concentration over 30 wt. %, high decrepitation activity of metasomatites. (Abstract by A.K.)

ETHERIDGE, M.A. and WALL, V.J., 1982, High fluid pressures during regional metamorphism and deformation - implications for mass transport, deformation mechanisms and thermal evolution (abst.): Geol. Soc. Newsletter (London), v. 11, no. 4, p. 16. Authors at Monash Univ.

Evidence is presented to support the conclusion that pore fluid pressures (P_f) during regional metamorphism are generally greater than or equal to the minimum principal compressive stress (S_3). The resultant very low effective stresses (σ) lead to significantly enhanced porosity and permeability, even at metamorphic temperatures. Permeabilities between 10^{-18} and 10^{-15} m^2 are considered to be common, resulting in rapid fluid migration on all scales and the dominance of advective (infiltrative) over diffusive mass transport even on the relatively small scale. In view of the importance of intergranular mass transport to rock deformation during metamorphism, the rheological implications of a mobile, high pressure fluid are considered, especially with respect to polyphase mineral assemblages. The fluid is shown to be capable of influencing the rate of dislocation creep in a number of ways. More importantly, advective mass transport along fluid pressure gradients can give rise to a solution-transfer deformation mechanism that competes with conventional pressure solution. A deformation model based upon mass transport between sources in cleavage zones and sinks in tensile fracture sites is developed, and shown to be able to produce strain at competitve rates. The presence of syndeformational tensile veins in a wide range of metamorphic rocks places an upper limit of 20 to 40 MPa on differential stress magnitudes during regional metamorphsm. Finally, the demonstrated extensive fluid flow through low- and medium-grade metamorphic terrains has important consequences for the thermal evolution of regional metamorphic belts. (Authors' abstract)

EUGSTER, H.P., 1982, Rock-fluid equilibrium systems, in High-Pressure Researches in Geoscience, W. Schreyer, ed.: E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart, p. 501-518. Author at Dept. Earth and Planet. Sci., Johns Hopkins Univ., Baltimore, MD 21218, USA.

Equilibrium considerations are based on experiments and thermodynamic calculations and are an essential ingredient to our understanding of rock-fluid interactions. Two examples are used here to illustrate this point, the first concerned with evaporite systems, and the other with the composition of metamorphic fluids.

The thermodynamic treatment of electrolyte solutions recently developed by Pitzer (1973) and extended to high ionic strengths by Harvie & Wear (1980) has made it possible to calculate solubility diagrams at 25°C for the system Na-K-Mg-Ca-SO_4-Cl-H_2O and to predict saturation levels for natural brines, as well as the effects of evaporation, mineral precipitation, brine mixing and solution metamorphism regardless of the ionic strength of the solution. We present here solubility diagrams for all fourteen quaternary subsystems, many of which have not been available before.

By combining solubility determinations on silicates and carbonates in supercritical chloride solutions with published dissociation constants, we have estimated speciation and bulk compositions of metamorphic fluids. Solute concentrations depend strongly on total chloride and hence pH. For silicates, cation abundance sequences normally are Na>K>Ca>Fe>Mg, and K and Ca reversed at high chlorinities. Silica is dominant only at low chlorinities. Fractionation effects between solid solutions and fluid, evaluated for feldspars and micas, indicate further separation between Na, K and Ca and between Fe and Mg. For lack of data, temperature effects cannot be estimated.

Solubility determinations on carbonate minerals in supercritical fluids are largely lacking, but it seems unlikely that the retrograde solubility behavior of calcite persists much above 300°C. At high temperatures, fractionation effects between carbonates and fluids are similar to those between silicates and fluids, with Na and Fe enriched in the fluids, while K, Ca and Mg prefer the solids. At lower temperatures, a significant reversal has been noticed, with Fe preferentially entering carbonate minerals, while Mg is enriched in the fluid. Equivalent data on silicate-fluid interactions are lacking. (Author's abstract)

EVANS, A.M., ed., 1982, Metallization associated with acid magmatism: New York, J. Wiley, 385 pp. Author at Dept. Geol., Univ. Leicester.

A series of papers, mainly on Sn deposits, stemming from a MAWAM conference. Pertinent papers are abstracted in this volume of COFFI. (E.R.)

FAHLEY, M.P. and LEANDERSON, P.J., 1982, Genesis of silver mineralization at Tonopah, Nevada (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 486. Authors at Dept. Geol., Colorado Sch. Mines, Golden, CO 80401.

Fluid inclusions, wall rock alteration, and geochemical studies at Tonopah suggest silver mineralization formed at deep levels within a geothermal system.

Vein filling consists of four stages; early barren stage, base metal stage, silver stage, and late barren stage. Fluid inclusions filling temperatures range from 300°C for the early barren stage to less than 200°C for the late barren stage. Silver mineralization occurs at intermediate temperatures between 270°C and 230°C. Variable liquid to vapor ratios in primary fluid inclusions suggest boiling occurred throughout the geothermal system. Freezing temperature determinations indicate salinities of 1 to 3 wt. % NaCl, suggesting a predominantly meteoric origin for the fluids.

Wall rock alteration zones consist of an inner potassic (adularia-sericite) zone which grades laterally into argillic and propylitic alteration. Phyllic alteration becomes dominant with increasing depth.

Semi-quantitative X-ray fluorescence analyses of select samples indicate anomalous concentrations of Ag, Sb, As, Pb, Zn, Cu, Te, Tl, Se, W, and Sn. Molybdenum increases with depth.

A close relationship between hydrothermal alteration-mineralization and felsic intrusive breccias, and an association of Sn-W-Mo geochemical anomalies may indicate the potential for porphyry-type Mo mineralization at depth. (Authors' abstract)

FALZON, H., DIÉTRICH, J.E. and TURCO, G.H., 1982, The Porres baritic vein (Maures, Var-France): Bull. BRGM, Sec. II, v. 2, no. 3, p. 271-275 (in French; English abstract). First author at Ecole nationale supérieure du Souissi, BP 773, Rabat-Agdal, Royaume du Maroc.

The Porres barite lode, one of the largest in France, is located in an E-W fault cutting a sloping syncline of amphibolites and leptynites. The host amphibolites do not show any sign of hydrothermal alteration. The lode is known, up to now, down to a depth of 280 m and along 600 m of extension; its maximum thickness is in its mean part and mineralization becomes thinner as workings go down. Along its length, four lenses whose formation can be connected with tectonics. Barite is the main mineral, associated with some fluorite; among a few carbonates, calcite is the prevaling one; sulphides are rare and sparse. The barite strontium content is fairly distributed throughout the mine. Barite primary liquid inclusions and decrepitation data give a formation temperature between 50° and 70°C. ^{34}S and ^{18}O isotopic analysis show that the Porres barite sulfate can arise from a preconcentrated Triassic stock. All the data collected up to now seem to be in accordance with a "per descensum" exogenous formation process. (Authors' abstract)

FARFEL', L.S., 1982, Activity of chloride underground waters in hydrothermal ore formation: Izvestiya Vyssh. Uchebn. Zaved.-Geologiya i Razvedka, no. 2, p. 164-167 (in Russian). Author at Central Complex Geol. Expedition of Ministry of Color Metallurgy.

The author gives several examples (from literature) of the present thermal waters found in boreholes, metal content in natural and synthetic thermal solutions and general characteristics of fluid inclusion solutions. For determination of the role of underground waters in formation of an ore deposit in Northern Kazakhstan, the author made a reconstruction of paleohydrogeological conditions of the deposit region. Studies of G/L inclusions in vein quartz and calcite from the ore deposit confirms the essentially chloride composition of ore-forming solutions, similar to underground waters; Th of inclusions 300-350°C. (Abstract by A.K.)

FAYZIYEV, A.R., 1982, Conditions of formation of fluorite deposits of the Central Tadzhikistan, from the data of studies of inclusions of mineral-forming solutions, in N.P. Ermakov, ed., Thermobarogeochemistry in Geology - Materials of the Sixth All-Union Symposium on Thermobarogeochemistry: Vladivostok, Far East Sci. Center, Acad. Sci. USSR Pub. House, p. 87-100 (in Russian).

For abstract, see Fluid Inclusion Research--Proceedings of COFFI, vol. 13, 1980, p. 69. (A.K.)

FEDOROV, P.P. and OL'KHOVAYA, L.A., 1981, Formation of compounds in binary fluoride systems bearing MgF_2: Zhurn. Neorg. Khimii, v. 26, no. 1, p. 218-221 (in Russian). First author at Inst. Crystallogr. of Acad. Sci. USSR, Moscow.

The paper briefly characterizes many compounds and gives a T-composition diagram for CaF_2-MgF_2 between 900 and 1450°C, what may help in interpretation of inclusions in minerals of alkaline (carbonatite) rocks.(A.K.)

FEL'DMAN, V.I., KAPUSTINA, I.G., SAZONOVA, L.V. and GRANOVSKIY, L.B., 1981, General peculiarities of geochemistry of impactites: Vestnik Moskovsk. Univ., Geology, no. 6, p. 48-57 (in Russian).

The paper bears data on gas composition in inclusions in impact glasses, quoted from the works of Dolgov. (A.K.)

FENN, P.M., 1982, Recent progress in experimental studies of pegmatite genesis (abst.): Am. Mineral., v. 67, p. 184. Author at Dept. Geol., Univ. California, Davis, CA 95616.

The experimental studies on the genesis of granitic pegmatites pioneered by R.H. Jahns and C.W. Burnham in the late 1950's have been continued and extended. Using the same composite samples of the Spruce Pine, North Carolina and Harding, New Mexico pegmatites, the detailed phase equilibria as functions of temperature and water content have been determined at confining pressures of 2, 5, and 8 kilobars. The nucleation densities and crystal growth rates of the feldspars and quartz have been measured at several isotherms at 5 kilobars as functions of the water content of the initial melt. The growth morphologies and spatial distribution of the various crystalline phases, both as isolated crystals and in interaction with other phases, have also been tabulated. These parameters are useful in developing models to explain many of the textural features which are distinctive of pegmatites.

One of the most exciting results of the present research has been the direct synthesis of graphic intergrowths of quartz in albite or oligoclase. A model has been developed to explain the origin of this texture based on the simultaneous crystallization of quartz and feldspar from the melt under conditions of local supersaturation. The presence of this texture tends to indicate certain relationships between various kinetic factors such as the nucleation and growth rate of feldspar and the diffusive redistribution of components at the melt-crystal interface rather than any state of bulk chemical equilibrium.

It is hoped that in studying these pegmatites, an extreme case in the development of granitic textures, insights into the more normal paths of crystallization will be gained. (Author's abstract)

FENOGENOV, A.N., 1982, Mechanism of formation of second-order rhythmic layering in trap intrusives (Noril'sk-1): Izvestiya Vyssh. Uchebn. Zaved.-Geologiya i Razvedka, no. 4, p. 156-159 (in Russian). Author at Moscow State Univ., USSR.

The paper describes immiscibility of ultrabasic melt (plagioclase wehrlite) and basic one (gabbro and gabbro-dolerite). (A.K.)

FERRONSKY, V.I. and POLYAKOV, V.A., eds, 1982, Environmental isotopes in the hydrosphere: New York, J. Wiley and Sons, 466 pp.

Includes chapters covering H and O, cosmogenic radioactive isotopes, and radioactive isotopes of heavy elements in natural water, and the origin of the hydrosphere. (E.R.)

FERRY, J.M., ed., 1982a Characterization of metamorphism through mineral equilibria: Washington, D.C., Mineral. Soc. Am. Reviews in Mineralogy, v. 10, 397 pp.

Includes a very brief discussion of fluid inclusion data on metamorphic conditions (Chapter 5), metamorphic fluid compositions (Chapter 6), and stable isotope fractionation during devolatilization (Chapter 8).(E.R.)

FERRY, J.M., 1982b Regional metamorphism of the Vassalboro Formation, south-central Maine, U.S.A.: a case study of the role of fluid in metamorphic petrogenesis (abst.): Geol. Soc. Newsletter (London), v. 11, no. 4, p. 14-15. Author at Arizona State Univ.

A chemical and mineralogical study of regionally metamorphosed impure carbonate rocks from the Vassalboro Formation, south-central Maine, U.S.A., reveals novel insights into the role of fluid in petrogenesis during metamorphism. (a) Although mineral reactions buffered the composition of metamorphic fluid coexisting with the carbonates, the rocks were simultaneously infiltrated by up to 3 rock volumes aqueous fluid during the metamorphic event. The infiltration helped to drive all to the prograde decarbonation reactions. (b) Prograde mineral reactions involved hydrolysis as well as dehydration and decarbonation. The hydrolysis reactions and infiltration caused an almost quantitative extraction of K and Na from high-grade metacarbonates. (c) A positive correlation between the calculated metamorphic heat budget of rock samples and calculated fluid-rock ratios associated with the infiltration suggests that metamorphic fluids played a key role in heat transfer during metamorphism. By controlling the metamorphic heat budget, fluids further influenced which metamorphic reactions occurred in the carbonates and hence the rocks' mineralogical evolution. (Author's abstract)

FLETCHER, D.I., 1982, Geologic setting, geology, and genesis of the Waterloo silver-barite deposit, Calico district, southeastern California (abst.): Geol. Soc. Am. Program with Abstracts, v. 14, p. 163. Author at ASARCO, Inc., Rocky Mountain Exploration Div., 9305 W. Alameda Pkwy., Suite 202, Lakewood, CO 80226.

The Calico silver district occurs near the middle of a northwest-trending belt of precious-metal occurrences associated with Tertiary volcanic centers in the Mojave region of southern California. Disseminated silver-barite mineralization exists in Miocene Barstow Formation lacustrian siltstones and sandstones along the western margin of the Calico Range. The two most prominent occurrences of such mineralization are the Waterloo and Langtry deposits.

Alteration within both deposits is of virtually identical character and consists of pervasive silicification and baritization associated with quartz ± calcite veins, barite veins, and late calcite veins. Altered rocks peripheral to the central ore zones exhibit variable bleaching and iron staining. The lack of major chemical alteration of pre-existing wallrock mineralogy suggests that hydrothermal fluids were largely in chemical equilibrium with wallrocks.

Primary silver minerals are native silver and acanthite in veins and disseminated throughout silicified wallrock. Silver tenor is most closely correlated with the quartz ± calcite veins and with pervasively silicified wallrock.

Fluid inclusions from quartz and barite indicate that fluids were relatively cool (175-195°C) and were moderately dilute (1-10% NaCl equivalent). No daughter salts or carbon dioxide were observed. Evidence of boiling in veins is not uncommon.

A syngenetic-syndepositional genetic model is proposed. Evidence is presented to suggest that the Waterloo deposit developed in a subaqueous hot springs environment with broad lateral alteration of the unconsolidated Barstow Formation sediments. (Author's abstract)

FÖLDVÁRI, I., VOSZKA, R. and PÉTER, Á, 1982, Comments on the gas-bubble entrapment in TeO_2 single crystals: J. Crystal Growth, v. 59, p. 651-653. Authors at Res. Lab. for Crystal Physics, Acad. Sci. Hungary, P.O. Box 132, H-1502 Budapest, Hungary.

The Miyazawa hypothesis [J. Crystal Growth 49 (1980) 515] on the gas-bubble entrapment in Czochralski grown paratellurite is criticized and complemented. To avoid gas-bubbles, instead of applying a concave growing surface, the use of extrapure raw material is proposed. (Authors' abstract)

FOLEY, N.K., BETHKE, P.M. and RYE, R.O., 1982, A re-interpretation of δDH_2O values of inclusion fluids in quartz from shallow ore bodies (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 489-490. First author at U.S. Geol. Survey, Reston, VA 22092.

Large differences between δDH_2O values for fluid inclusions in ore minerals and those in gangue minerals are usually attributed to multiple sources of primary fluids. Such differences in isotopic composition may result, instead, from contamination by overlying ground water. Detailed study of fluid inclusions in quartz from open vugs at Creede, Colorado, indicates that large (60 μm to 2 mm) primary inclusions (PI) homogenize at 190°-270°C, have salinities from 4 to 12 wt % NaCl equiv. and $\delta DH_2O \approx -70‰$, values similar to those from co-deposited sulfides. In contrast, small (1 to 10 μm) pseudosecondary inclusions (PSI) homogenize between 200°C and 260°C, but have salinities near 0% and $\delta DH_2O \approx -100‰$. The difference in δDH_2O is probably even larger due to difficulties in sampling only one type of inclusion and because some PI were opened and diluted during PSI formation. PI are filled with deep-circulating fluids that deposited the ores, whereas PSI contain heated shallow ground water which entered the ore zone episodically during ore deposition. PSI occur along curved healed fractures possibly resulting from small thermal shock of the growth-strained quartz crystals upon incursion of somewhat cooler ground water. Previously reported δDH_2O values for Creede quartz fluids (Bethke and Rye, 1979, Econ. Geol., v. 74, p. 1832) do not represent primary fluids of different δDH_2O from those that deposited the ore; rather, they reflect mixtures of PI and PSI which were not separated in the analytical procedure. This study suggests that in epithermal deposits, overlying ground water can be trapped in quartz in large enough amounts to bias stable isotope analyses. Consequently, δDH_2O values from inclusions in coexisting ore minerals are suspect; careful heating/freezing studies of all types of inclusions may be needed to identify contaminated samples. (Authors' abstract)

FORD, M.M. and FEISS, P.G., 1982, Fluid inclusion studies of Au-bearing and barren quartz veins in the Carolina Slate Belt, central and southern North Carolina (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14,

p. 18. First author at Mobil Oil Exploration and Production, SE Poydras Plaza, New Orleans, LA 70130.

The Carolina Slate Belt (CSB) of central and southern NC was an active Au producing region from the early 1800's until about 1910. Au was produced from quartz veins in greenschist facies metavolcanics and metasediments and from placers associated with weathering quartz vein lodes. In addition to the Au-bearing veins, numerous barren quartz-veins (with and without associated sulfide phases) are present in the CSB. There is no association with known intrusives.

Primary fluid inclusions from 18 Au-bearing and 11 barren quartz veins have been studied. In general, the Au-bearing veins show the same salinity range (<5% NaCl equivalent) as the barren veins. Four samples from sulfide-bearing veins yield significantly higher salinities (5.8-11.7% NaCl equiv.). Th values range from ~110°C to ~390°C for primary inclusions. The values of Th increase slightly, but consistently, from east to west across the strike of the CSB. General conclusions are: 1. the range of Th can vary significantly within a local area, 2. only Au-bearing veins give Th>330°C, 3. both Au-bearing and barren veins occur with Th between 135°C and 330°C; however, a very distinct population of Au-bearing veins yields Th = 170°C-210°C and an equally distinct population of barren veins yields Th = <170°C, 4. no Au-bearing veins yield Th <135°C.

Absence of an independent geobarometer makes systematic pressure corrections of Th of doubtful value. The wide-spread nature of the quartz veins, the overall similarity in petrology, occurrence, salinity, and Th of Au-bearing and barren veins, the general east to west increase in Th which parallels an east-west increase in metamorphic grade and the Th values themselves suggest a metamorphic origin for these discordant veins. Using P = 1.5 kb, a general trapping temperature range of 217-546°C is obtained which is reasonable for greenschist facies. (Authors' abstract)

FORTEY, N.J., 1982, Conference report, mineralizing fluids: J. Geol. Soc. London, v. 139, p. 95-99.

A series of 15 papers, mostly involving or at least pertinent to fluid inclusion studies, by various authors (abstracted in this volume). (E.R.)

FOSTER, C.T., Jr., 1982, Textural variation of sillimanite segregations: Can. Min., v. 20, p. 379-392. Author at Dept. Geol., Univ. Iowa, Iowa City, IA 52240, USA.

Constant $\mu(H_2O)$ is proposed. (E.R.)

FOURNIER, R.O., 1982, Geochemistry in geothermal exploration and production: Proc. Pacific Geothermal Conf. 1982 Part 1, Univ. Auckland Geothermal Inst., Auckland, NZ, p. 209-215. Author at U.S. Geol. Survey, Menlo Park, CA 94025.

Geochemistry has many uses in a geothermal resources development program. It can provide information about reservoir conditions before and during production, the source of recharge, and directions of fluid flow. It has important applications in regard to corrosion, scaling, and waste-disposal problems. When properly used, chemical geothermometers and mixing models applied to hot-spring waters can give accurate information about underground reservoir temperatures and salinities. However, when interpreting chemical data, attention should be given to geologic and hydrologic information. Also, chemical models must be consistent with isotopic data; plots of enthalpy versus chloride, δD, and $\delta^{18}O$ are useful for determining that consistency.

Equations expressing the solubility of quartz in water at the vapor pressure of the solution as (1) a function of temperature and (2) a function of enthalpy permit calculation of silica geothermometer temperatures for dilute solutions up to 330°C, with or without steam separation at any temperature. The solubility of quartz in NaCl solutions (expressed in mg/kg) is similar to that in pure water at temperatures below about 260°C. At higher temperatures quartz solubility in salt solution is greatly increased compared to pure water; this has great importance for determining conditions at which silica scaling is likely to occur. (Author's abstract)

FOURNIER, R.O., HANSHAW, B.B. and URRUTIA SOLE, J.F., 1982, Oxygen and hydrogen isotopes in thermal waters at Zunil, Guatemala: Geothermal Resources Council, Transactions, v. 6, p. 89-91.

FOURNIER, R.O. and POTTER, R.W., II, 1982a, An equation correlating the solubility of quartz in water from 25° to 900°C at pressures up to 10,000 bars: Geochimica Cosmo. Acta, v. 46, p. 1969-1973. First author at U.S. Geol. Survey, Menlo Park, CA 94025.

An empirically derived equation has been formulated expressing the solubility of quartz in water from 25° to 900°C at specific volume of the solvent ranging from about 1 to 10 and from 300° to 600°C at specific volume of the solvent ranging from about 10 to 100. The experimental data used in formulating the empirical relation ranged in pressure from 1 bar at 25°C to about 10,000 bars at 900°C, and the lowest pressure in the low-density steam region was about 30 bars. According to the above equation, the average difference in molality between 518 measured and calculated solubilities is -0.016 m with a standard deviation of 0.089. (From the authors' abstract)

FOURNIER, R.O. and POTTER, R.W., 1982b, [Equation describing the solubility of quartz in water] (abst.): Geol. Survey Research 1981, U.S. Geol. Sur. Prof. Paper 1275, p. 146.

See previous item. (E.R.)

FOURNIER, R.O., ROSENBAUER, R.J. and BISCHOFF, J.L., 1982, The solubility of quartz in aqueous sodium chloride solution at 350°C and 180 to 500 bars: Geochimica Cosmo. Acta, v. 46, p. 1975-1978. Authors at U.S. Geol. Survey, Menlo Park, CA 94025.

The solubility of quartz in 2, 3, and 4 molal NaCl was measured at 350°C and pressures ranging from 180 to 500 bars. The molal solubility in each of the salt solutions is greater than that in pure water throughout the measured pressure range, with the ratio of solubility in NaCl solution to solubility in pure water decreasing as pressure is increased. The measured solubilities are significantly higher than solubilities calculated using a simple model in which the water activity in NaCl solutions decreases either in proportion of decreasing vapor pressure of the solution as salinity is increased or in proportion to decreasing mole fraction of water in the solvent. (Authors' abstract)

FOURNIER, R.O. and THOMPSON, J.M., 1982, An isotopic study of the Coso, California, geothermal area: Geothermal Resources Council, Transactions, v. 6, p. 85-87.

FOWLER, L.L., 1982, Brecciation, alteration, and mineralization at the Copper Flat porphyry copper deposit, Hillsboro, New Mexico: MS thesis, Univ. Arizona, Tucson, Arizona, 133 pp. Indexed under Fluid Inclusions.

FRANTZ, J.D. and BOCTOR, N.Z., 1982, Compositions of supercritical chloride-bearing fluids in equilibrium with manganese mineral assemblages: Carnegie Inst. Wash. Year Book 81, p. 374-377.

FRANTZ, J.D., VIRGO, D. and MYSEN, B.O., 1982, Time-lapse [Raman] spectroscopy for fluorescence radiation rejection: Carnegie Inst. Wash. Year Book 81, p. 437-440.

FREUND, Friedemann, 1982, Volume instabilities in the mantle as a possible cause for kimberlite form[ation]: Terra Cognita, v. 2, p. 263-265.

FUZIKAWA, K., 1982, Carbonates from Lagoa Real uranium district, Bahia State: fluid inclusion and stable isotope studies: Anais do XXXII Congresso Brasileiro de Geologia (Proc. of XXXII Brazilian Geol. Congress), v. 5, p. 2072-2085 (in Portuguese; English abstract).

A limited amount of carbonates is present in uraniferous and barren rocks from the Lagao Real uranium province in central-southern part of the State of Bahia, Brazil.

Fluid inclusion studies of carbonates collected from uraniferous albitites and vein/breccias cutting ore zones indicated CO_2- and CH_4-rich fluids of variable salinities, and Tt of 300-500°C. Away from the mineralized zone the fluids were essentially a brine trapped at less than 100°C. These results are in agreement with previous fluid inclusion studies (Fuzikawa, 1980 and 1981a).

The stable isotope studies indicate a crustal source for carbon and light waters for the δO^{18} values.

These results favor a genetic model where the basement has been thrust over Proterozoic Espinhaco metasediments (Fyfe, 1980). (Author's abstract)

FYON, J.A., SCHWARCZ, H.P., CROCKET, J.H. and KNYF, M., 1982, Grant 49 - gold exploration potential using oxygen, carbon, and hydrogen stable isotope systematics of carbonatized rock and quartz veins, Timmins area, in Geoscience Research Grant Program, Summary of Research 1981-1982, E.G. Pye, ed.: Ontario Geol. Survey Miscellaneous Paper 103, p. 59-64. Authors at Dept. Geol., McMaster Univ.

Oxygen-18 content of vein quartz and vein-hosted and replacement dolomites increases with increasing stratigraphic height in the volcanic pile. The trend possibly reflects buffering of the $\delta^{18}O$ of the metamorphic fluid, from which the vein quartz precipitated, by the host rock. Oxygen-18 exchange took place between the pre-metamorphic replacement dolomite and the metamorphic fluid. No correlation exists with gold tenor. The carbon isotope composition of the dolomites is very uniform in all deposits except those from the Hollinger Mine, which is also the richest gold deposit investigated. Hydrogen isotope variations in water derived from fluid inclusions suggest the presence of H_2 or CH_4.

Hydrogen isotope systematics may closely monitor the oxidation state of the hydrothermal fluid and hence, may be useful in gold exploration. Oxygen and carbon isotope systematics appear less useful in this regard. (Authors' abstract)

GARVIN, J.B., L982, Vesiculation in submarine basalts (abst.): EOS, Trans. Am. Geophys. Union, v. 63, p. 473. Author at Dept. Geol. Sci., Brown Univ., Providence, RI 02912.

Magma vesiculation involves the nucleation and dynamic growth of gas bubbles exsolved from volatile-bearing magmas. If more than 3/4 of the magma volume is made up of bubbles, it will tend to disrupt, producing an explosive eruption. Vesicles (gas bubbles frozen in rapidly cooling magmas) reflect the pre-eruption magma bubble distribution. Computer simulations of the growth and dynamics of gas bubbles in magmas require data on magma volatile content, rise rate, viscosity, face pressure and gravity. Vesicularity, volatile species, and volatile concentration are available for the glassy outer margins of submarine vesicular tholeiites and alkali basalts. In this study, the validity of a computer model of bubble growth and dynamics was tested by varying the volatile species and its concentration in basalt magmas rising from their source regions at physically plausible speeds, until the above data were reproduced. The results show that the simulations were realistic in terms of available data: simulations of basalts erupting at a depth of 700 m in the ocean and containing 0.09 wt.% CO_2 as a dissolved volatile yielded final bubble diameters of ~1 mm and a vesicularity of ~6% (at a rise rate of 0.07 m/s), matching data for Reykjanes Ridge basalts. Smaller volatile concentrations resulted in lower vesicularities. When the simulations were run with H_2O or CO as the magmatic volatile, the agreement with observations was poor, suggesting that CO_2 is the critical magmatic volatile in ocean ridge basalt magmas. The vesicularities of subaerial basalts is currently being studied to investigate the role of CO_2 in their (commonly explosive) eruption. Preliminary simulations using 0.10-0.20 wt.% CO_2 closely matched observed vesicle distributions in Hawaiian tholeiites. Tests using lunar basalt magmas exsolving CO have also duplicated the observed vesicularity of lunar rock. (Author's abstract)

GATTER, I., 1982, Fluid inclusion studies on the polymetallic deposit of Gyöngyösoroszi (N-Hungary) (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 199. Author at Eötvös L. Univ., Budapest, Hungary.

The author has done fluid inclusion studies on minerals from a vein-type polymetallic deposit near Gyöngyösoroszi (N-Hungary, Marta Mts.). The lecture introduces the results of investigations done by homogenization and cryometry on collected surface indications, and the productive zones of the mine. Paleothermic gradient determinations were also performed. (Author's abstract)

GAUNAURD, G.C. and UBERALL, H.M., 1981, Apparatus and process for determining the composition of fluid-filled cavities: U.S. Patent 4,249,422, Feb. 10, 1981.

Of pertinence to the possibility of using acoustic microscopy to locate and characterize fluid inclusions in minerals. (E.R.)

GELETIY, V.F., CHERNYSHEV, L.V. and PASTUSHKOVA, T.M., 1981, Equilibria of solid phases in the PbS-CdS system with water-salt solutions at elevated temperatues and pressures: Geokhimiya, no. 10, p. 1463-1481 (in Russian; translated in Geochem. Int'l., v. 18, no. 4, p. 123-141, 1982).

Abstract in Fluid Inclusion Research--Proceedings of COFFI, v. 14, p. 68. (E.R.)

GERLACH, T.M., 1982, Interpretation of volcanic gas data from tholeiitic and alkaline mafic lavas: Bull. Volcanol., v. 45, no. 3, p. 223-245. Author at Sandia National Lab., Albuquerque, NM 87185, USA.

The analyses of approximately 100 high temperature gas samples from erupting lavas of Surtsey, Erta Ale, Ardoukoba, Kilauea, Mount Etna and Nyiragongo exhibit erratic compositions resulting from analytical errors, condensation effects, reactions with sampling devices, and contamination by atmospheric gases, meteoric water and organic material. Computational techniques have been devised to restore reported analyses to compositions representative of the erupted gases. The restored analyses show little evidence of short-term variations. The principal species are H_2O, CO_2, SO_2, H_2, CO, H_2S, S_2, and HCl. The O_2 fugacities range from nickel-nickel oxide to a half order of magnitude below quartz-magnetite-fayalite. There is no evidence for a unique magmatic gas composition; instead, the erupted gases show regular compositional trends characterized by decreasing CO_2 with progressive outgassing. The gases from more alkaline lavas (Etna, Nyiragongo) are distinctly richer in CO_2, while those from less alkaline (Surtsey) or tholeiitic lavas (Erta Ale, Ardoukoba) tend to be richer in H_2O. Kilauean gases range from CO_2-rich to H_2O-rich. The total sulfur contents of the erupted gases show an excellent positive correlation with lava O_2 fugacity. All restored analyses are significantly lower in H_2O and enriched in sulfur and CO_2 compared to the "excess volatiles." (Author's abstract)

GHENT, E.D., 1982, High-grade metamorphism: preface: Canadian Mineralogist, v. 20, pt. 3, p. 293.

Preface to a whole issue devoted to the subject; some of the papers are abstracted in this volume of Fluid Inclusion Research--Proceedings of COFFI. (E.R.)

GHENT, E.D., KNITTER, C.C., RAESIDE, R.P. and STOUT, M.Z., 1982, Geothermometry and geobarometry of pelitic rocks, upper kyanite and sillimanite zones, Mica Creek area, British Columbia: Can. Mineral., v. 20, p. 295-305. Authors at Dept. Geol. and Geophy., Univ. Calgary, Calgary, Alberta T2N 1N4, Canada.

Temperatures have been estimated using garnet-biotite assemblages for pelitic rocks of the Mica Creek area, British Columbia. These rocks are in the upper-kyanite to K-feldspar-sillimanite zones. The estimates range from 560 to 790°C (Ferry & Spear calibration) and 540 to 700°C (Thompson calibration). Some of the higher-temperature estimates are inconsistent with muscovite-plagioclase-quartz-sillimanite stability limits. Some of these inconsistencies are due to compositional deviations in garnet and biotite from the ideal Fe-Mg binary system. The rims of many garnet grains show evidence of retrograde exchange of Mg and Fe with adjacent biotite. Pressure estimates, based upon garnet-plagioclase-Al_2SiO_5-quartz equilibria, range from 6.1 ± 0.8 kbar (upper kyanite zone) to 7.2 ± 0.8 (K-feldspar-sillimanite zone); since these values are not significantly different, there is no evidence for a change in pressure with metamorphic grade. (Authors' abstract)

GHOSH, D.K. and SAHU, K.C., 1982, Analysis of fluid inclusions in minerals using tunable dye lasers (abst.): [Proceedings & Abstracts], National Workshop on Fluid Inclusion Studies, 22-23 March, 1982, Indian Inst. Tech. Bombay, p. 47-49 (unpaginated). Authors at Indian Inst. Tech., Bombay -76.

It is proposed here that a laser microprobe comprising a tunable dye laser, an optical microscope and a Raman spectrometer, using backscattered radiation, collected by the same microscope objective, can be a powerful method to study inclusions. The tunability of laser will enable use of such wavelength that the absorption within the sample or the inclusions is not high enough to cause damage. This point is particularly important, as the high radiation density provided by the laser, coupled with even moderate absorption offered by the sample or inclusion can result in excessive heating of the sample and subsequently damage. A further prevention of such radiation damage can be brought about by using pulsed dye laser or chopping the output of a continuous wave dye laser and employing grated detection of the scattered radiation. Studies with tunable lasers will also establish the most suitable wavelength for detecting and analyzing specific combinations of inclusion and parent crystals. (From the authors' abstract)

GIARDINI, A.A., MELTON, C.E. and MITCHELL, R.S., 1982, The nature of the upper 400 km of the earth and its potential as the source for nonbiogenic petroleum: J. Petrol. Geol., v. 5, no. 2, p. 173-190.

A review of the earlier data on the gases obtained from "inclusions" and "occlusions" in diamond, mainly by the authors, and some new data on gases evolved on crushing and on solid inclusions in Zaire diamonds, particularly pyrite, quartz, barite, biotite, hematite, goethite, albitic plagioclase, silicate glass and three orange-red, translucent solid hydrocarbons (~100 μm diam.). These data are used to estimate the petroleum potention in the mantle. (E.R.)

GIBSON, E.K., HENRY, D.J., ASHWAL, L.D., WARNER, J.L. and BERGMAN, S.C., 1982, Fluid inclusions in meteorites (abst.): EOS, v. 6, no. 3, p. 364. First author at SN7, NASA/JSC, Houston, TX 77058.

Fluid inclusions have been discovered in achondritic and chondritic meteorites. The morphologic, microthermometric, and Raman spectroscopic characteristics of fluid inclusions in diogenite ALHA 77256 are described.

Two distinct classes of fluid inclusions are in ALHA 77256: (1) Two-Phase. Found in orthopyroxene, these are irregularly shaped (ranging from 1 to 100 μm) and contain widely varying vapor/liquid ratios. Vapor bubble moves slightly at room temperature but more upon heating. Homogenization ranges from 30° to 250°C with no preferred temperature. Critical phenomena have been observed at 160° to 180°C. Upon cooling, the vapor bubble's size increases continuously to -180°C. Freezing has been observed in some inclusions but many do not freeze even at -180°C. Preliminary Raman spectroscopy using the MOLE microprobe has demonstrated that the fluid contains H_2O with little or no CO_2, CH_4, H_2 or other hydorcarbons. The viscous nature of the fluid and peculiar freezing and homogenization characteristics suggest the possibility of high salt concentrations. (2) Three-Phase. These are spherical liquid-vapor droplets encased in an irregular inclusion of a phase that has low relief relative to the orthopyroxene host. Inclusions are up to 40 μm across. Vapor bubble moves spontaneously at room temperature and occupies about 1% of the volume of the droplet. Homogenization temperatures of the liquid-vapor are 80° to 100°C. Freezing has not been observed.

Fluid inclusions have been found in L and H chondrites within olivines (both in and out of chondrules). Morphological and microthermometric characteristics are similar to the diogenites. Clearly, the discovery of fluid inclusions within meteorites places serious constraints on models of meteorite formation and subsequent evolution. (Authors' abstract)

See also Adar et al., 1982, this volume. (E.R.)

GIBSON, E.K., Jr., KOTRA, R.K. and WARNER, J.L., 1982, Direct analysis of trapped vapors and fluids in silicate samples utilizing the laser microprobe-gas chromatographic technique (abst.): Lunar Planet. Sci. XIII, p. 261-262. First author at SN7, NASA/Johnson Space Center, Houston, TX 77058.

Direct chemical analysis of trapped vapors and fluids in terrestrial and extraterrestrial materials is one of the most difficult analytical challenges confronting geoscientists. A newly developed laser microprobe-gas analysis system has the capabilities of direct chemical analysis of gases, volatiles, and fluids in meteorites, lunar samples, terrestrial basalts, and cosmic dust samples. This technique permits the direct chemical analysis of volatiles in either individual inclusions or the complete samples. Samples may be either "thick" thin sections or individual particles. The laser microprobe is used either to "open" the fluid inclusion or "heat" the sample under controlled conditions. Released volatiles are directly analyzed using gas chromatographic techniques employing the ultrasensitive helium ionization detector developed by Andrawes and Gibson. A schematic of the laser and sample holder is shown in Figure 1.

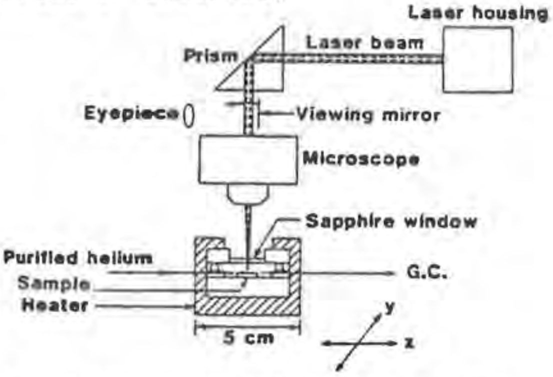
For the direct chemical analysis of fluid inclusions, 60-100 micrometers thick thin sections which have been prepared for thermometric analysis are used. The section is placed in the sealed sample chamber which is attached to the inlet of the gas chromatograph. The chamber for analysis of small particles has an internal volume of 1.54 cm^3, a 1 cm diameter quartz and/or sapphire window while the chamber used for polished circular thin sections has a larger volume. Both chambers have an entry and exit port for ultrapure helium carrier gas. The chamber is mounted on the stage of an optical microscope which permits movement in the x-y-z direction for sample location and focusing. The optical window permits the Nd-glass laser beam to pass. The sample is located and, using a defocused beam, the surface of the sample can be "cleaned." The sample chamber can be heated externally to 150°C to remove absorbed gases. After calibration with the standard gases, the laser is pulsed to drill a 5-10 micrometer diameter pit a few micrometers deep. Gases within the sample chamber are swept into the gas chromatograph for analyses after each pulse. Repeated pulsing will excavate to the depth of the vapor or fluid inclusion. When the inclusion is opened, its contents are released and/or vaporized and swept into the chromatograph column with the carrier gas. Because carrier gas flows at a rate of 10-15 cc/sec., the sample chamber is flushed rapidly and the evolved vapors may be analyzed after each laser pulse. Laser pulses can be spaced 15 seconds apart if rapidity is desired.

The sample serves as its own crucible and the operational blanks are at the nanogram concentration levels as measured by repeated analysis of tektite glass. Laser pulse duration can be as short as 1 microsecond. With the 1 microsecond pulse, propagation of a thermal pulse into the surrounding host material is minimized. The short pulse duration can explosively volatilize a 10-20 micron pit before the thermal pulse propagates into the surrounding host and improves the quantitative recovery of the volatiles.

The gas analysis system has been developed by Andrawes and Gibson (1979). Equipment incorporates an ultrasensitive helium ionization detector equipped gas chromatograph. This analysis method has been demonstrated to be capable of analyzing both inorganic and organic gases at the subnanogram concentration levels. Water can be analyzed both directly and indirectly after reaction of water with calcium carbide to produce acetylene. Determination of acetylene is a routine task whereas water, a polar compound, commonly passes through the chromatograph column too slowly for easy analysis.

In the case of cosmic dust particles, analysis can be accomplished if we assume the dust particle contains the average CI carbon abundance of 4 to 5% C. The carbon "signal" from complete conversion of the particle would be about 20 times our background if we assume everything was converted to either CO or CO_2. In reality, the vapor products produced after laser pyrolysis of the cosmic dust grain would be a mixture of both oxidized and reduced species (e.g., CH_4, CO, CO_2, hydrocarbons, etc.).

With the capability of changing the laser's power output, and selectively filtering the beam, stepwise heating of individual samples can also be accomplished. This feature provides additional flexibility to the laser microprobe capabilities. Experimental results from the analysis of vapors trapped within tektites and terrestrial basalts and meteorites will be discussed to show the application of this new and powerful analytical tool. (Authors' abstract)



GIGGENBACH, W.F., 1982, Carbon-13 exchange between CO_2 and CH_4 under geothermal conditions: Geochimica et Cosmochimica Acta, v. 46, p. 159-165. Author at Isotope Hydrology Sec., Int'l. Atomic Energy Agency, A-1400 Vienna, Austria.

On the basis of recently reported data on the kinetics of carbon-13 exchange between CO_2 and CH_4 at temperatures above 500°C, first order rate constants $\log k = 11.16 - 10{,}190/T$ were derived allowing variations in Δ, the difference in the isotopic composition of coexisting CO_2 and CH_4, to be evaluated as a function of initial composition and cooling rate of the rising geothermal fluid. Observed Δ-values in geothermal discharges are likely to represent frozen in compositions attained after minimum residence times of 20 ka at 400°C or 10 Ma at 300°C. The carbon-13 contents of any biogenic gases are unlikely to have been affected by thermal re-equilibration at temperatures below 200°C. The chemical equilibrium involving CO_2 and CH_4 can be expected to proceed about a hundred times faster than isotopic equilibration. (Author's abstract)

GILETTI, B.J. and YUND, R.A., 1982, Self-diffusion of oxygen in quartz (abst.): EOS, Trans. Am. Geophys. Union, v. 63, p. 466-467.

GING, T.G. and HITE, R.J., 1982, [Water content of rock salt] (abst.): Geol. Survey Research 1981, U.S. Geol. Sur. Prof. Paper 1275, p. 24.

Water content in cored halite samples were determined; the halite is dissolved in methanol, and the extracted water is measured by Karl Fischer titration. This method eliminates problems attempting to determine water content by heating, then measuring weight loss. Water-content information is needed to evaluate salt beds as possible radioactive-waste-disposal sites. Other advantages of the procedure are that (1) halite is separated from silica, clays, and other minerals so that halite and nonhalite weights can be obtained; (2) calcium, magnesium, and potassium contents of halite waters can be determined; (3) bitumen content of the halite sample can be determined - all from the same sample. (Authors' abstract)

GIORDANO, T.H., 1982, Organic ligands and organic metal complexes in ore-forming solutions (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 496.

GIULIANI, G. and WEISBROD, A., 1982, Evolution of the fluid phases in a Sn-W deposit, Zaër granite, Central Morocco: Bull. Minéral., suppl., v. 105, p. 55 (in French).

The mineralized zone of Sokhret Allal is located at the extreme southern end of the Zaër two-mica granite (Central Morocco Massif). It consists of a cluster of subparallel quartz veins (N 100 - 110 E). The veins are often spatially associated with potassium feldspar episyenite dikes that seem to have played the role of mechanical guides for the fracture-related mineralization. Four stages of formation have been identified:

I. Quartz, muscovite, cassiterite I, wolframite, (adularia, apatite)
II. Quartz, muscovite, rutile, cassiterite II, scheelite, (pyrite)
III. Arsenopyrite, pyrite, chalcopyrite
IV. Pyrite, sphalerite, chalcocite, enargite, fluorite.

Stage I is characterized by fluids that varied from "vapors" rich in "volatile" components (24% CO_2, 5% N_2, 1% CH_4) at high temperatures (~500°C) and moderate pressures (500-800 bars?), to low salinity (~5 wt % NaCl) aqueous solutions, not containing more than minor traces of CO_2, N_2, and CH_4, at temperatures on the order of 300°C and very low pressures. The evolution of these fluids, trapped in quartz and cassiterite I, resulted in a mixture of carbonic fluids with dilute aqueous solutions, at slightly supercritical conditions. Deposition occurred at about 400°C.

Stage II fluids were trapped in quartz and cassiterite II. They are aqueous solutions of low to moderate salinity (2-8 wt % NaCl). Temperatures were lower than those at the time of stage I (320-200°C).

The compositions of the stage II aqueous fluids are different than the much more complex carbonic fluids of stage I. The composition is similar to that described for fluids in cassiterite veins of Cornwall, which were trapped at lower temperature (250°-350°C). (Abstract translated courtesy R. Bodnar)

GLASSLEY, William, 1982, Fluid evolution and graphite genesis in the deep continental crust: Nature, v. 295, p. 229-231. Author at Dept. Geol., Middlebury College, Middlebury, VT 05753, USA.

Metamorphism in deep continental crust is often accompanied by carbon-rich, H_2O-poor fluids, and is characterized by the development of granulite facies mineral assemblages. Graphite, a minor phase in many high-grade metamorphic rocks, has also been recognized in recent xenoliths of deep crustal material, demonstrating its presence in modern deep continental crust. Although graphite is most common in biotite schists, it has also been recorded in pyroxene gneisses, two feldspar-quartz pegmatites, marbles and quartzo-feldspathic gneisses. The presence of supracrustal sequences in granulite facies regions suggests that the latter developed through progressive metamorphism and dehydration of shallow level crustal material. Much of this material must have experienced a metamorphic recrystallization in the amphibolite facies, accompanied by the development of hornblende. Although graphite in the high-grade rock may develop from oxidation of organic material, this may not be the most common means for graphite genesis. In much of West Greenland and in southern Norway the low-grade, hornblende-bearing material does not contain significant quantities of organic compounds, although graphite is found in higher-grade metamorphic equivalents. This strongly suggests that introducing CO_2 into deep crustal material leads to fluid evolution and graphite formation. I outline here the evolution of fluid composition in the C-O-H system which is in equilibrium with common crustal mineral assemblages. Thermodynamic data for CO_2-H_2O mixtures and mineral components are used to model the chemical changes in fluid composition which accompany introduction of CO_2 into various types of rock. The results demonstrate that graphite genesis is a direct consequence of deep crustal metamorphism in the presence of a CO_2-rich fluid phase. In addition, the calculations demonstrate that the deep continental crust will not be a reservoir for large volumes of methane-rich gas. (Author's abstract)

GLASSLEY, W.E., 1982, Carbonates as deep crustal CO_2 sources (abst.): EOS, Trans. Am. Geophys. Union, v. 63, p. 450. Author at Dept. Geol., Middlebury College, Middlebury, VT 05753.

Carbonate bodies in a granulite facies terrane in West Greenland are mantled by mineralogically zoned metasomatic rinds which are 10-15 cm wide. The sequence of assemblages in the rinds is: garnet ($Gr_{90}Py_6Al_4$)-scapolite(Me_{86})-cpx($Wo_{50}En_{22}Fs_{28}$)→scapolite(Me_{83})-cpx($Wo_{50}En_{35}Fs_{15}$)-plag(An_{75})→cpx($Wo_{50}En_{38}Fs_{12}$)-plag(An_{81})-anthoph→opx($En_{57}Fs_{43}$)-anthoph-plag(An_{81})→garnet($Gross_{.03}Py_{.34}Alm_{.63}$)-sill-plag($An_{24}$). A variety of geothermometers give temperatures of 750°C(±80); geobarometers give pressures of 7 kb (±2). The metasomatic zones can be theoretically reproduced if μCaO is treated as the only independent compositional parameter. If the CaO is derived through decarbonation reactions involving calcite or dolomite, the number of moles of CO_2 released during reaction can be computed from knowledge of the volume of the metasomatic rinds and of the reactions which relate adjacent assemblages. Such computations give a minimum of 3.1E10 moles of CO_2 released during reaction. Such quantities are sufficient to account for all carbon-bearing phases (scapolite and graphite) in the country rock, with 1.E10 moles of CO_2 remaining as a free fluid phase. The results imply that even in terranes where carbonate accounts for <3% of the terrane volume, sufficient CO_2 may be released to account for the consistent observation that deep crustal metamorphism occurs in the presence of CO_2 rich fluids. (Author's abstract)

GLEBOVITSKIY, V.A., DRUGOVA, G.M. and SEDOVA, I.S., 1982, Conditions of appearance of the oldest metamorphism of the Belomor'ye complex, *in* N.P. Ermakov, ed., Thermobarogeochemistry in Geology - Materials of the Sixth All-Union Symposium on Thermobarogeochemistry: Vladivostok, Far East Sci. Center, Acad. Sci. USSR Pub. House, p. 3-10 (in Russian).

For the abstract, see Fluid Inclusion Research--Proceedings of COFFI, vol. 11, 1978, p. 75. (A.K.)

GOLDSMITH, J.R., 1982, Plagioclase stability at elevated temperatures and water pressures: Am. Mineralogist, v. 67, p. 653-675.

GOLYSHEV, S.I., PADALKO, N.L. and PECHENKIN, 1981, Fractionation of stable oxygen and carbon isotopes in carbonate systems: Geokhimiya, 1981, no. 10, p. 1427-1441 (in Russian; translated in Geochem. Int'l., v. 18, no. 4, p. 85-99, 1982).

GONCHARUK, A.F., 1982, Endogeneous ore mineralization of andesite-basalt formation of Transcarpathia, Kiev: "Naukova Dumka," 166 pp., 350 copies printed, price 1 rbl. 40 kopecks (in Russian). Author at Inst. of Geochem. and Physics of Minerals, Kiev, Ukraine.

The book bears a compilation of Th reference data for the deposits: Baia Mare, Deva (Romania), Dubrinich, Olenevskoe, Vyhorlat-Hutinskaya zone, Grendesh, Rovnoe, Marangosh, Monastyrskoe, Malouglyanskoe, Dragovskoe, Vul'khovich (mostly polymetal-Cu-Au-Ag-Hg mineralization). (A.K.)

GONTAR', K.V., DERKACHEVA, V.N. and ZOLOTAREVA, L.V., 1982, The system

3Li, 3Na||3F, 3Cl, AlF_6: Zhurn. Neorg. Khimii, v. 27, no. 9, p. 2406-2409 (in Russian). Authors at Inst. of Agricultural Machinery, Rostov-on-Don, USSR.

The paper presents three sections of the above system: (I) Li_3F_3 - (10% Li_3AlF_6 + 90% Li_3F_3) - (10% Na_3AlF_6 + 90% Na_3Cl_3) - Na_3F_3; (II) Li_3F_3 - (35% Li_3AlF_6 + 65% li_3Cl_3) - (35% Na_3AlF_6 + 65% Na_3Cl_3) - Na_3F_3; (III) Li_3F_3 - (50% Li_3AlF_6 + 50% Li_3Cl_3) - (50% Na_3AlF_6 + 50% Na_3Cl_3) - Na_3F_3; pertinent to inclusions of ongonite-type melts. (A.K.)

GRAHAM, C.M. and GREIG, K.R., 1982, Generation and mobility of the H_2O-CO_2 fluid phase during regional greenschist and epidote-amphibolite facies metamorphism: a reconnaissance study in the Scottish Dalradian (abst.): Geol. Soc. Newsletter (London), v. 11, no. 4, p. 18. Authors at Univ. Edinburgh, Scotland.

In Dalradian rocks of the SE Scottish Highlands, abundant metabasic sills and volcanics together with calc-mica-schists, phyllites, carbonates and psammites, have been metamorphosed in high-pressure greenschist to epidote-amphibolite facies, ($T \simeq 420-550°C$; $P \approx 8-10$ kbars). In the greenschist facies, CO_2 was generated in country-rock schists to produce a mobile H_2O-CO_2 fluid phase of variable composition ($XCO_2 = 0.02$ to >0.1) which diffused to varying extents into metadolerite sills. Carbon isotope analyses of carbonates in sills and country-rock schists ($\delta^{13}C$ = 14 to -5, P.D.B.) demonstrate that CO_2 was generated by regional oxidation of graphite or other organic carbon. Above the garnet isograd (albite-epidote amphibolite facies) dehydration reactions in metabasic sills involving breakdown of chlorite and formation of garnet and pargasitic hornblende, produced a very H_2O-rich fluid which removed all carbonate and rutile from metabasic assemblages and flushed through adjacent carbonates and calc-mica-schists results in localized development of externally-buffered assemblages containing amphibole, clinozoizite, grossular, K-feldspar, diopside and sphene. (Authors' abstract)

GRANOVSKIY, A.G., L982, Thermobarogeochemical zoning of polymetal deposits of the Northern Caucasus: Geol. Rudn. Mest., v. 24, no. 6, p. 63-73 (in Russian). Author at Rostov State Univ., Rostov, USSR.

The paper bears results obtained during studies of 400 samples collected from the following vein polymetal deposits of the Sadon group: Sadon, Zgid, Arkhon and Kholst. The ores consist of chalcopyrite, arsenopyrite, sphalerite, galena, pyrite, pyrrhotite, native As and Bi, magnetite, hematite, mushketovite plus gangue minerals: quartz, Mn-siderite, calcite, chlorite, barite. General Th range is 360-80°C and P - 74 to 8 MPa. Pre-ore associations formed at 310-360°C, 50-74 MPa, ore associations - 180-320°C, 25-48 MPa and post-ore - 80-160°C, 10-30 MPa. Absolute values of vertical T gradients during formation of ores were 6-24° per 100 m, and they are indices of vertical extent of ore mineralization and may be used for determination of degree of erosion of the deposit. The zones of rapid T and P decrease (20-30°C and 5-12 MPa per 100 m) coincide with areas of most condensed ore mineralization. Concentration, chemical and phase composition of inclusion fluids change with the depth of mineral formation. Gas-liquid, CO_2-H_2O, wealkly alkaline solutions are typical of the studied deposits. Ore-bearing quartz yielded an increase of HCO_3 with decrease of depth (up to 0.14 g-moles per 100 g of sample) and decrease of Cl and SO_4 content (down to 0.01-0.04 g-moles per 100 g) plus increase of total salt content up to 7-8%. Boiling and heterogenization of solutions during ore precipitation were found. (Abstract by A.K.)

GRATIER, J.-P., 1982, Experimental and natural deformation of rock by solution-deposition with mass transfer: Bull. Minéral., v. 105, p. 291-300 (in French; English abstract). Author at I.R.I.G.M., BP 53X, 38041 Grenoble Cedex, France.

Various [procedures] (experimental deformation, chemical analysis on naturally deformed samples) are described which allow model tests of pressure solution-deposition of rocks, with mass transfer either by diffusion through fluid phase, or by infiltration of fluid. The observation of change of shape of fluid inclusions in crystals heated under the microscope, permit establishing relations between the strain-rate (ε) and various parameters: shape of cavities, internal pressure (P). The relation $\varepsilon = f(P)^n$ with values of n near 3-3.5 shows the importance of the curvature of a solid-fluid surface in its "deformation" under pressure by mass transfer. (Author's abstract)

GREEN, H.W., II and VAUGHAN, P.J., 1982, The effect of dissolved CO_2 on olivine plasticity (abst.): EOS, Trans. Am. Geophys. Union, v. 63, p. 1095. Authors at Dept. Geol., Univ. California, Davis, CA 95616.

Microstructural features in peridotite xenoliths from the mantle indicate that a CO_2-rich fluid has exsolved during late stage deformation or during ascent to the surface. To investigate the possible effect of dissolved carbon (in whatever form) on the plasticity of mantle rocks, we are conducting a series of deformation experiments on a synthetic dunite at high temperature and pressure in a modified Griggs apparatus. In half of the experiments, small amounts of AgC_2O_4 are added. Low pressure decomposition of the silver oxalate distributes CO_2 throughout the small porosity of the encapsulated sample and annealing at 3.0 GPa and 1200°C causes the reaction:

$$Fo + CO_2 \rightleftharpoons MgCO_3 + En$$

to run completely to the right, yielding about 5% $MgCO_3$. Preliminary results indicate that the yield stength of carbonated specimens is about 25% less than that of control specimens treated identically. Differences in olivine microstructure in the two classes of experiments suggest that the effect is due to carbon dissolution in the olivine. Various analytical techniques are being used to study this phenomenon. Preliminary data from electron energy loss spectroscopy indicate a carbon peak in the olivine, and annealing of a carbonated specimen in the CO_2 stability field resulted in formation of fluid inclusions within crystals as well as on grain boundaries. (Authors' abstract)

GRELOU-ORSINI, C. and CARRAT, H.G., 1982, Study of intracrystalline inclusions and intercrystalline joints in a uraniferous granite of the Morvan Mountains, France, in R. Kreulen and J. Touret (guest eds.), Current Research on Fluid Inclusions: Chem. Geol., v. 37, p. 103-111 (in French; English abstract). First author at Équipe de Géomorphologie des Socles du L.A. 141, 75005 Paris, France.

The uraniferous monzonitic biotite granite of Dommartin near Chateau-Chinon intruded a volcanic series of Visean age. It lies under a continuous microgranite roof. Two characterisitics are to be distinguished: (1) an important deuteric tardimagmatic alteration with disseminated non-fissural uraninite which may be related to the tightness of the microgranitic roof; and (2) Autunian-Liassic age fracturations with hydrothermal pitchblende vein deposits. The granite is weathered on the surface to a friable sand. It is deeply eroded (down to 200 m), forming a basin in the landscape.

The purpose of this paper is to see if there is any correlation between the uraniferous character of the granite, its macrofissuration and alteration on the one hand, and the inclusion content and microfissuration of the crystals' host-rock on the other.

Fifty quartz, feldspar and polycrystalline aggregate splinters, submitted neither to mechanical processes (sawing, polishing or abrasion) nor chemical processes, have been studied at high magnifications with scanning electronic microscopy.

Quartz splinters have an inclusion content 4 or 5 times higher than in other monzonitic granites. Concentrations of inclusions are found in veils and in the external parts of crystals. The cavities are of average size (1-5 μm) and make up to 0.5-2% of the studied areas. Inclusions in feldspar are more numerous but much smaller and more ramified. Intergranular joints have a smooth topography and are bordered with large pores; their surfaces show a very large number of small inclusions. A great part of the cavities is open and their walls are darkened by deposits.

The abundance of inclusions, their concentration at crystal faces, and their medium size and negative crystal shape point to an important role of fluids at various stages.

Crystals have suffered mechanical stresses due to tectonics and to thermic shocks; the resulting cracks have been healed by the circulation of fluids rich in trace elements. It may be that, during late stages, the continuation of hot fluid circulation led to the burst of a part of the syngenetic and epigenetic inclusions and to the opacification of their walls. (Authors' abstract)

GRIB, Ye.N., 1982, Temperature conditions of crystallization of extrusive lavas in the Uzon-Geyzernaya Depression, in N.P. Ermakov, ed., Thermobarogeochemistry in Geology - Materials of the Sixth All-Union Symposium on Thermobarogeochemistry: Vladivostok, Far East Sci. Center, Acad. Sci. USSR Pub. House, p. 69-73 (in Russian).

For abstract, see Fluid Inclusion Research--Proceedings of COFFI, vol. 11, 1978, p. 79-80. (A.K.)

GRIGORIEV, D.P. and 10 others, 1981, The crystallomorphological evolution of minerals: Preprint series "Scientific Papers," USSR Acad. Sci. Komi Branch, 1981, Issue 76, 28 pp. (in Russian).

GRIGOR'YEV, I.F. and DOLOMANOVA, Y.I., 1981, Thermobarogeochemistry of principal minerals in tin deposits: Geologiya i Razvedka, 1981, no. 8, p. 33-43 (in Russian; translated in Int'l. Geol. Review, v. 24, no. 11, p. 1305-1312). Authors at S. Ordzhonikidze Inst. Geol. Sci., Moscow, USSR.

A review of the results of various methods of study of fluid inclusions in minerals from tin deposits, many of which probably been reported in the literature. The solids left in opened inclusions have been studied by SEM and found to contain Na, K, Ca, Mg, Ba, Cu, Cd, Zn, Fe, Mn, Ag, Pb, As, U, S, Cr, W, and Cl. Microdiffraction (TEM) studies of inclusions in various hosts revealed greenockite, barite, argentite, corundum, ilmenite, sphene, cassiterite, quartz, galena, bismuthite, muscovite, halite, sylvite, sulfohalite ($Na_6(SO_4)_2FCl$), jacobsite ($MnFe_2O_4$), tourmaline, cryolite, clorargyrite [i.e., cerargyrite], scheelite, and hauyne(?).

Emission spectroscopy revealed 15 elements in the liquid phase of inclusions. The gas phase consists of major H_2 and CO_2 and less frequently (N_2+Ar), CH_4, H_2S, SO_2, various hydrocarbons, and H_2O(sic). CH_3x (where x is F or Cl) was found by IR in the channels in quartz. Some quartz had enough Li to decrease the α/β invasion to 535-545°C. Isotopic composition of C, O, and S were determined. Th and Td of inclusions in quartz are close to oxygen isotope temperatures. (E.R.)

GRIGOR'YEVA, T.A. and SUKNEVA, L.S., 1981, Effects of sulfur and of antimony and arsenic sulfides on the solubility of gold: Geokhimiya, 1981, no. 10, p. 1534-1540 (in Russian; translated in Geochem. Int'l., v. 18, no. 4, p. 153-158, 1982).

GRISHINA, S.N., 1982a, Physical aspects of the volumetric method of gas analysis of inclusions in minerals (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 199-200. Author at Inst. Geol. & Geophy., Novosibirsk, USSR.

Despite of the great variety of current precise methods of gas analysis, the analytical results of the true gas compositions of minerals remain inadequate due to the lack of such methods of exposing inclusions that do not distort the original proportions of components. Besides, in finding out the genesis it is more important to know the composition of syngenetic inclusions, even the qualitative one, rather than the quantitive composition of inclusions of many generations. The study of individual inclusions is described using the KP-spectrometer "Mole" providing quantitive data without destroying the sample; however, the use and further improvement of the volumetric method is justified by its incompatible [incomparable?] cheapness and the possibility it gives to study those minerals the fluorescence of which sets serious hardships in the spectrometric analysis.

The volumetric method consists in the exposure of inclusions in a viscous liquid and subsequent absorption of the released gas components after the transfer of bubbles into selective absorber. The chemical aspect of the analysis consists in the use of the classical absorption scheme of gas macroquantities; however, application of this scheme to the analysis of gas microquantities from a bubble calls for the physical interaction of the latter with the liquid medium to be accounted for.

An additional change of the bubble diameter in the absorber may be caused, besides the chemical reaction, by the surface tension effect and by the gas diffusion into the liquid. Our calculations have proved that the effect of the surface tension on the analytical result is small compared with the error of the diameter measurement. With any possible combinations of the initial and finite dimensions of the bubbles, the induced change of the volume didn't exceed 5-10%, and was even less than 1% for bubbles larger than 20[1/] in diameter.

A more significant analytical error is made by the gas dissolution in the liquid medium. Although the kinetics of the mass-exchange between the gas bubble and the liquid has been theoretically studied in every detail, there are some additional peculiarities in these processes arising due to the specific properties of the liquids used. The experiments have confirmed statistically the theoretical relation of the bubble diameter decrease proportional to the time squared. Meanwhile, a wide spreading of the measurements has been revealed, obviously, due to the free convection in the liquid. It has been shown though that the spread of results lessens remarkably under thermostated conditions. But even at a permanent temperature, the irreproducibility of the absorbtion kinetics of bubbles smaller than 20 m[1/] in diameter is so high that any quantitive corrections for the dissolution value become impossible.

The rate of dissolving of acid gases is drastically different from that of the other components in question, the dissolving of which is observable only with time. Therefore the whole amount of the dissolved gas - from the moment of exposure of the inclusions up to the moment of the bubble transfer into the first absorber - is summed up with the amount of the chemically absorbed acid gases. The locking liquids(sic) for dimensional ranges of 20-50 m, 50-100 m, 100-200 m[1/] have been experimentally selected for the further analysis of sparingly soluble components. Considering different size bubble behavior some alterations in the methods have been proposed, which would prevent underabsorption on account of chemosorption rate drop in case of large bubbles. For small bubbles both the time of analysis and the number of the components to be defined are reduced in order to avoid erroneous interpretation of physical absorption as a result of chemical reaction.

The bubble diameter after the exposure of the inclusion and the gas composition limit the use of the method. For bubble diameters less than 20 m[1/] only qualitative analysis is possible. (Author's abstract)

[1/] In all cases presumably μm is intended. (E.R.)

GRISHINA, S.N., 1982b Ranges of use of individual volumetric gas analysis of inclusions, in Use of methods of thermobarogeochemistry during prospecting and studies of ore deposits, N.P. Laverov, ed.: Moscow, "Nedra" Publ. House, p. 108-111 (in Russian). See Translations.

GÜBELIN, E.J., 1982a New synthetic rubies made by Professor P.O. Knischka: Gems & Gemology, Fall 1982, p. 165-168.

A new synthetic ruby, developed by Professor P.O. Knischka using a method of gradient technique (not yet disclosed) through supercooling and saturation, has distinct crystallographic and gemological characteristics. Particularly notable are the great number of faces on the finished crystals and the identifying inclusions. (Author's abstract)

GÜBELIN, E.J., 1982b Gemstones of Pakistan: emerald, ruby, and spinel: Gems & Gemology, Fall 1982 [v. 18], p. 123-139.

Only during the last few years have the gem riches of Pakistan become known to the rest of the world. This article reports on three gem materials currently being mined: emerald, corundum (most importantly, ruby), and spinel. Intensely colored emerald crystals occur in dolomitic talc schists in the Swat Valley. Unusually high optical properties and density serve to distinguish these emeralds from those found elsewhere. Numerous gas-liquid inclusions are also typical. In the Hunza Valley, specimen- and gem-quality crystals of corundum and spinel occur in beds of marble enclosed in gneisses and mica schists. The gemological properties of the Pakistan rubies and sapphires vary only slightly within normal limits. (Author's abstract)

GÜBELIN, E., 1982c Mineral inclusions contribute towards elucidating the genesis of the diamond: J. Gemmology, v. 18, no. 4, p. 297-320.

GUHA, J., GAUTHIER, A., VALLEE, M., DESCARREAUX, J. and LANGE-BRARD, F., 1982, Gold mineralization patterns at the Doyon mine (Silverstack), Bousquet, Quebec: Geology of Canadian Gold Deposits, Proc. CIM Symp. 1980, R.W. Hodder and William Petruk, eds.: Spec. Vol. 24, Can. Inst. Min. and Metal., p. 50-57. First author at Univ. Québec à Chicoutimi.

The volcanic-sedimentary rock assemblage has a widespread chemical alteration pattern characterized by sodium and calcium depletion, potash and sulphur gain, and localized magnesium and alumina gain. This alteration band developed during the evolution of the volcanic pile enclosing the gold-bearing zone. Fluid inclusion studies on quartz from the quartz-carbonate stringers indicate a CO_2-rich fluid with increasing density.

A two-stage evolution of this gold mineralization is envisaged: an initial deposition of gold in volcanogenic sediments followed much later by the evolution of metamorphic fluids. The initial gold concentration was essentially redistributed within the deposit, with probably some local enrichment or reconcentation, but without new addition of gold. (From the authors' abstract)

GUILHAUMOU, Nicole, 1982, Accurate analysis of fluid inclusions by laser molecular microprobe (MOLE) and by microthermometry: Travaux Lab. Geol., Ecole Normale Superieure, no. 14, 68 pp. (in French, English abstract).

Raman microprobe and microthermometry methods are now available to study fluid inclusions. Their combined use permits non-destructive point analysis with great accuracy.

In part I, PVT and PTX diagrams are briefly reviewed for most systems generally used to interpet microcryoscopic data.

Part II shows results in different geological settings: magmatic gaseous inclusions are filled mainly with CO_2 and sometimes a small amount of N_2.

In alpine metamorphism, two points are studied:

Observation of liquid aliphatic hydrocarbon easily destroyed by heating (sometimes under the laser beam) in inclusions of metamorphic quartz from the Brianconnais implies an upper limit of +250°C.

Cracks in the Champsaur sandstones are rich with a $CH_4+C_2H_6$ gaseous phase, which is associated with nearly pure water. This is in opposition with the usual association hydrocarbon-brine we observed well in the deep-seated black shales. Thermobarometric data allow one to differentiate among the cracks.

Inclusions containing H_2O, CO_2, H_2S and native sulfur are studied on a thermochemical background in stratabound fluorite from Sierra de Lujar (Spain).

The H_2S/CO_2 mole ratio shows a correlation with Th of the gaseous phase. Total Th can give us a direct estimation of sulfur paleofugacity for a given temperature.

Part III deals with fluid inclusions in dolomites and quartz, from Triassic outcrops in Northern Tunisia. Different fluids have been determined: liquid aromatic hydrocarbon, pure CO_2, CO_2+N_2 and brines with NaCl and KCl.

The barometric interpretation allows one to distinguish between late quartz which crystallized under hydrostatic conditions in a high geothermal gradient and early quartz and dolomites grown in a lower geothermal gradient (50°C/km). The distribution of sylvite and halite-bearing cavities gives information about Triassic paleogeography. By other methods hydrocarbon liquid inclusions are [found] scattered inside an area already known for petroleum surface occurrences.

The N_2/N_2+CO_2 mole ratio was determined on 400 N_2+CO_2 inclusions, which were free from hydrocarbon, using Raman analysis and optical estimation of the volume ratios of the different phases selected at low temperatures. In the observed range of compositions the two methods agree reasonably well.

The N_2+CO_2 inclusions are divided into three classes of composition:

a) $N_2/(N_2+CO_2)>0.57$. Liquid nitrogen is always visible at very low temperature and Th occurs in the range -151°C to -147°C (nitrogen critical temperature), dry ice (solid CO_2) sublimates between -75°C and -60°C.

b) $0.20<N_2/(N_2+CO_2)\leq 0.57$: liquid nitrogen is visible at very low temperature but dry ice melts on heating; liquid and gas CO_2 homogenize to liquid phase between -51°C to -22°C.

c) $N_2/(N_2+CO_2)\leq 0.20$: liquid nitrogen is not visible even at very low temperature (-195°C) and liquid and gas CO_2 homogenize to liquid phase between -22°C and -15°C. The observed phases changes are used to propose a preliminary phase diagram for the system CO_2-N_2 at low temperatures.

Assuming additivity of partial pressures, isochores for the CO_2-N_2 inclusions have been computed. The intersection of these isochores with those for brine inclusions in the same samples may give the P and T trapping of the fluids. (Author's abstract)

See also Guilhaumou et al., 1981, Fluid Inclusion Research--Proc. of COFFI, v. 14, 1981. (E.R.)

GUTSALO, L.K., 1982, Sources and regularities of distribution of chlorine in thermal waters: Akad. Nauk SSSR Doklady, v. 263, no. 5, p. 1213-1217 (in Russian). Author at Inst. Geol. Geochem. of Mineral Fuels of Acad. Sci. Ukrainian SSR, L'vov, Ukrainian SSR.

HAAPALA, Ilmari and KINNUNEN, Kari, 1982, Fluid inclusion evidence on the genesis of tin deposits, *in* Metallization Associated with Acid Magmatism, A.M. Evans, ed.: New York, J. Wiley, p. 101-109. Authors at Geol. Survey of Finland, Espoo.

Published studies on fluid inclusions in cassiterite are used to evaluate the composition, temperature, and pressure of the ore-forming fluids in different types of tin deposits. (Authors' abstract)

HAGNI, R.D., 1982, Precambrian silver-tungsten-tin mineralization and its relationship to granitic magmatism in southeastern Missouri, USA (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 70-72. Author at Univ. Missouri-Rolla, Rolla, MO, USA.

See Hagni, 1980, Fluid Inclusion Research--Proceedings of COFFI, v. 13, p. 91, 1980. (E.R.)

HALBACH, Heiner and CHATTERJEE, N.D., 1982, An empirical Redlich-Kwong-type equation of state for water to 1,000°C and 200 kbar: Contrib. Mineral. Petrol., v. 79, p. 337-345. First author at SOPTIM Ingenieurbüro GmbH, RoermonderstraBe 139, D-4100 Aachen.

An empirically derived Redlich-Kwong type of equation of state is proposed for H_2O that works very well at upper mantle conditions, at least up to 200 kbar and 1,000°C. At subcritical conditions it predicts the thermodynamic properties of H_2O well enough for the calculation of geologically interesting heterogeneous equilibria. (From the authors' abstract)

HALL, W.E. and BATCHELDER, J.N., 1982, [Stable isotope and fluid inclusion study of Thompson Creek and Little Boulder Creek molybdenum deposits] (abst.): Geol. Survey Research 1981, U.S. Geol. Sur. Prof. Paper 1275, p. 170.

See same authors, 1980, Fluid Inclusion Research--Proceedings of COFFI, v. 13, p. 92 (1980). (E.R.)

HALL, W.E. and SCHMIDT, E.A., 1982, The Thompson Creek, Idaho, porphyry molybdenum deposit--an example of a fluorine-deficient molybdenum-granodiorite system (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 72-73. First author at U.S. Geol. Survey, Menlo Park, CA.

See Hall and Batchelder, 1980, Fluid Inclusion Research--Proceedings of COFFI, v. 13, p. 92, 1980. (E.R.)

HALLBAUER, D.K., 1982a Characterization of pyrite by combined fluid inclusion and trace element studies (abst.): AIME, 111th Ann. Meeting, Dallas, TX, February 1982, Program p. 84. Author at Chamber of Mines of South Africa Res. Org., Mining Tech. Lab., Johannesburg, South Africa.

In many mineral deposits pyrite is present as an abundant component in economically important as well as in barren zones, and knowledge on distinguishing features for different genetic types of this mineral would be of great advantage in mining and exploration. Information of this nature can be obtained by combining fluid inclusion and mineral inclusion studies on fresh fracture surfaces using SEM techniques with single grain trace element analysis. For this purpose between 10 and 30 pyrite grains per localilty and of more than 5 mg in mass were split mechanically. Using electro-thermal AAS one half of each grain was analyzed for about 25 trace elements. The other half was mounted in a SEM to study fluid inclusions, fluid compositions, type of daughter mineral and mineral inclusions. The statistical evaluation of the single grain analyses combined with information on fluid inclusions allowed a characterization of pyrite types. (Author's abstract)

HALLBAUER, D.K., 1982b Composition of fluid inclusions and daughter minerals in pyrite: a guide to the hydrothermal regime (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 200-201. Author at Chamber of Mines of S.A., Johannesburg, SA.

See Hallbauer, 1980, Fluid Inclusion Research--Proceedings of COFFI, v. 13, p. 92-93, 1980. (E.R.)

HALLBAUER, D.K., 1982c A review of some aspects of the geochemistry and mineralogy of the Witwatersrand gold deposits: Proc. 12th CMMI Congress, May 1982, Johannesburg, S.A., 23 pp.

Includes some studies of daughter crystals and solid inclusions (see previous item). (E.R.)

HALLBAUER, D.K. and KABLE, E.J.D., 1982, Fluid inclusions and trace element content of quartz and pyrite pebbles from Witwatersrand conglomerates: their significance with respect to the genesis of primary deposits, in Ore Genesis, The State of the Art, G.C. Amstutz et al. (eds.), Special Vol., p. 742-752.

Geological and mineralogical studies of quartz pebbles and detrital pyrite demonstrate the existence of differences in the provenance areas of the various Witwatersrand goldfields and provide information about the type of primary deposits.

The trace element content determined by INAA and AAS can be used to determine groupings and hence differences in provenance areas while fluid inclusion studies provide information on the type of primary deposits. (Authors' abstract)

SEM studies of solid inclusions and dms in fluid inclusions, and trace element analyses of bulk quartz samples (in part from fluid inclusion contents?) reveal recognizable differences between various sources for quartz (and pyrite). (E.R.)

HANOR, J.S., 1982, The origin of high sodium-bicarbonate waters in the Gulf Coastal Plain: a reassessment of the role of carbonate dissolution and ion-exchange (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 506.

HANSEN, E.C. and BECKETT, J.R., 1982, Modeling of trace element depletion in granulites by a fluid phase (abst.): EOS, Trans. Am. Geophys. Union,

v. 63, p. 448. Authors at Dept. Geophy. Sci., Univ. Chicago, Chicago, IL 60637.

Pronounced depletion in large ion lithophile (LIL) elements is characteristic of some high grade granulite terranes which are bordered by lower grade granulites showing only slight depletion. Depletion may be caused by streaming of CO_2-rich solutions through the rock during metamorphism (K.D. Collerson and B.J. Fryer, Contr. Min. Pet. 67, 151, 1978). This removal process was modeled mathematically by assuming that the ratio of fluid to rock, f, remains constant in a given volume. The one-dimensional equation controlling concentration, c, of an element in the rock as a function of distance x and time t is:

$$-\frac{\partial c}{\partial t} = [Kf/(1+Kf)]V\frac{\partial c}{\partial x} + \left[\frac{D}{1+K}\right]\frac{\partial^2 c}{\partial x^2}$$

where K is the ratio of the concentration of the element in the fluid to that in the rock and D is the diffusion coefficient in the fluid.

For constant fluid flow rate, V, two idealized cases were considered:

1) No diffusion takes place in the fluid (D = 0). The solution yields a moving step function interface between an undepleted zone and a depleted zone.

2) Diffusion in the fluid is finite. A concentration gradient exists between the undepleted and depleted zones.

The feature of steep or nearly discontinuous concentation gradients between incipient granulites and extensively leached granulites is a novel feature of the present results and may account for a sudden onset of pronounced depletion in progressive granulite metamorphism without removal of a partial melt phase, which process is commonly invoked. The position of the depletion front will vary from element to element and this may provide a field test of the vapor leaching hypothesis. (Authors' abstract)

HARMON, R.S., 1982, Stable isotope composition of Dalradian metamorphic fluids (abst.): Geol. Soc. Newsletter (London), v. 11, no. 4, p. 18. Author at Southern Methodist Univ., Texas.

The Dalradian Supergroup is a late Precambrian - early Palaeozoic deformed and metamorphosed complex of continental margin sediments and associated volcanics largely forming the orthotectonic Caledonides of Scotland. The H- and O-isotopic composition of the Highland Border Fracture Zone serpentinites indicate equilibrium fluid compositions in the range $\delta D \approx -50$ to -12‰ and $\delta^{18}O \approx +7$ to 10‰, whereas values for quartz, fluid inclusions, and hydrous minerals from amphibolite facies rocks in the Grampian Highlands give fluid values in the range $\delta D \approx -50$ to -12‰ and $\delta^{18}O \approx +6.5$ to 12.5‰, with fluids in the NE Highlands enriched in both D and ^{18}O relative to those in the Central and SW Highlands. (Author's abstract)

HARPER, G.D., 1982, Inferred high primary volatile contents in lavas erupted in an ancient back-arc basin, California: J. Geol., v. 90, no. 2, p. 187-194.

HARRIS, D.M., 1982, [Microdetermination of H_2O, CO_2, and SO_2 in silicate glass] (abst.): Geol. Survey Research 1981, U.S. Geol. Sur. Prof. Paper 1275, p. 148.

See Fluid Inclusion Research--Proceedings of COFFI, v. 14, 79, 1981

HARRIS, N.B. and EINAUDI, M.T., 1982, Skarn deposits in the Yerington district, Nevada: metasomatic skarn evolution near Ludwig: Econ. Geol., v. 77, p. 877-898. First author at Explor. Res. Div., Conoco Inc., P.O. Box 1267, Ponca City, OK 74603.

In the Yerington district of western Nevada, large bodies of skarn formed in a limestone unit of Triassic age adjacent to a Jurassic granodiorite and quartz monzonite batholith.

Mineral assemblages and fluid inclusion data indicate that both magnesium- and iron-rich skarn formed at low XCO_2, generally less than 0.1. Temperatures of formation of magnesium-rich skarn are inferred to have been in the range 650° to below 400°C. Temperatures of formation of iron-rich skarn are not constrained by observed assemblages. Fluid inclusion data show that late apatite replaced andradite at temperatures between 120° and 200°C, [at 8-10% NaCl equiv.]. (From the authors' abstract)

HARRIS, N.B.W., HOLT, R.W. and DRURY, S.A., 1982, Geobarometry, geothermometry, and late Archean geotherms from the granulite facies terrain of south India: J. Geol., v. 90, p. 509-527. Authors at Dept. Earth Sci., Open Univ., Milton Keynes, England.

Geobarometry and geothermometry of garnet-bearing charnockitic and metapelitic assemblages from the high-grade terrain from South India indicate three fields of equilibration. High pressure granulites ($P = 8.3 \pm 1.0$ kb, $T = 760 \pm 40$°C) are restricted to the charnockites and mafic granulites of the north slopes of the Nilgiris. These place a minimum constraint of ~30 km on the maximum thickness of late Archean crust. Medium pressure granulites ($P = 6.4 \pm 1.0$ kb, $T = 735 \pm 40$°C) characterize the charnockites of the central Nilgiris and the Madras granulites to the east. Low pressure granulites ($P = 5.0 \pm 1.0$ kb, $T = 700 \pm 20$°C) characterize the charnockites and metapelites south of the Bhavani shear zone, although migmatites from the Kodaikanal massif may reflect somewhat higher temperatures. All three granulite fields lie on a metamorphic geotherm (piezothermic array) which is strongly convex to the temperature axis and characteristic of convective heat transfer. The P/T fields encountered in the high grade terrain are therefore consistent with metamorphism induced by a CO_2-rich vapor phase rising from the mantle. (Authors' abstract)

HARVIE, C.E., EUGSTER, H.P. and WEARE, J.H., 1982, Mineral equilibria in the six-component seawater system, $Na\text{-}K\text{-}Mg\text{-}Ca\text{-}SO_4\text{-}Cl\text{-}H_2O$ at 25°C. II: Compositions of the saturated solutions: Geochim. Cosmo. Acta, v. 46, p. 1603-1618. First author at Dept. Chem., Univ. California, San Diego, La Jolla, CA 92093, USA.

Using the solubility model developed by Harvie and Weare (1980), the stable mineral-solution assemblages for the six-component system $Na\text{-}K\text{-}Mg\text{-}Ca\text{-}SO_4\text{-}Cl\text{-}H_2O$ and its constituent 5-, 4- and 3-component systems at 25°C have been defined. Invariant point maps have been constructed showing the connections by univariant lines. The solubility volumes for all 20 minerals considered are also illustrated. Of the 37 invariant points, only 3 have solutions which are Ca-rich; the remaining 34 can be plotted in the reciprocal system $Na\text{-}K\text{-}Mg\text{-}SO_4\text{-}Cl$, which is similar to the seawater system, except that the restriction of halite saturation has been removed. Application of these results and implications for the evolution of major brine types are briefly discussed. (Authors' abstract)

HAYBA, D.O., 1982, A compilation of fluid inclusion and stable isotope data on selected precious- and base-metal epithermal deposits: U.S. Geol. Survey Open-file Report 83-450, 24 pp. Author at U.S. Geol. Survey, Reston, VA 22092.

Compilation includes data on the fluid inclusion temperature, salinity, and chemical analyses, and the oxygen, deuterium and sulfur isotope data from a compilation of the lithotectonic, mineralogical and geochemical traits of 15 epithermal, volcanic-hosted districts (Heald-Wetlaufer et al., 1983). Of the 15 districts, the following 14 have some or all of the above types of geochemical information: Colqui, Peru; Comstock, Nevada; Creede, Colorado; Goldfield, Nevada; Guanajuato, Mexico; Lake City, Colorado; Julcani, Peru; Oatman, Nevada; Pachuca-Real Del Monte, Mexico; Red Mountain, Colorado; Round Mountain, Nevada; Sunnyside mine, Eureka district, Colorado; Summitville, Colorado; and Tonopah, Nevada. No data were found for the Silver City - De Lamar, Idaho district. (From the Introduction)

HAZEN, R.M. and FINGER, L.W., 1982, Comparative crystal chemistry: New York, John Wiley and Sons, 231 pp.

Of pertinence to the problem of the changes in volume of inclusions from external or internal pressure. (E.R.)

HE, Luqing and DIAO, Peiliang, 1982, A study of reliability of gases extracted from inclusion[s] in minerals by heating decrepitation method: J. Central-South Inst. of Mining and Metal., v. 32, no. 2, p. 113 (in Chinese; English abstract).

In order to improve on the reliability [of analyses of] gases in fluid inclusions [that] are extracted by the heating decrepitation method, the specific effects of extraction temperature on dynamic characteristics of water, carbon dioxide, nitrogen, hydrogen and methane evacuated from inclusions in minerals are investigated in this paper. Besides, chemical reactions between gas and gas as well as gas and solid are also studied through the use of gaseous test mixtures.

The investigations of dynamics and thermodynamics show that gas phase of inclusions in examined quartz from gold veins consists mainly of N_2, H_2O and CO_2. However, a considerable part of H_2 and CH_4 found by heating decrepitation method is probably due to chemical reactions and the decomposition of organic matter. In accordance with the calculation of chemical thermodynamics, it is possible that chemical reactions such as $CO + H_2O \rightleftharpoons CO_2 + H_2$, $CH_4 + H_2O \rightleftharpoons CO + 3H_2$ and $2FeO + H_2O \rightleftharpoons Fe_2O_3 + H_2$ can take place under the circumstances of heating decrepitation method. It is demonstrated that the chemical reactions depend on extracting temperature, concentration of gases and presence of water.

The authors have designed a vacuum extraction device for heating decrepitation method. It can avoid chemical reactions. It is possible to extract gases in mineral inclusions reliably. (Authors' abstract)

HE, Zhili, 1982a Inclusion mineralogy: Geological Publication Co., Beijing, PRC, 304 pp. (in Chinese with English Table of Contents).

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(From the author's Contents)

HE, Zhili, 1982b, The classification of mineral inclusions and its significance (a new scheme for the classification of inclusions): Mineral Deposits, v. 1, no. 2, p. 80-90 (in Chinese; English abstract). Author at Beijing Inst. of Iron and Steel Technology.

The author classifies normal inclusions into 8 groups based on phase assemblage or chemical composition, and anomalous inclusions, that cannot be used for understanding the processes involved. Included as anomalous are inclusions formed by "natural" or "artificial" physical processes, and "inclusions formed through chemical reaction: 1) through chemical decomposition, and 2) from heterogeneous mother solution." (E.R.)

HEALD-WETLAUFER, P., FOLEY, N.K. and HAYBA, D.O., 1982, Applications of doubly polished sections to the study of ore deposits, in Process Mineralogy II, R.D. Hagni, ed.: New York , The Metallurgical Soc. of AIME, p. 451-468. Authors at U.S. Geol. Survey, 959 National Center, Reston, VA 22092, USA.

Doubly polished sections (i.e., sections polished on both sides) allow insights into complex paragenetic relationships, the interpretation of which is essential to understanding ore-forming processes. Alternate viewing of these optically superior sections in transmitted and reflected light facilitates the recognition and definition of growth zones in ore and gangue minerals and the interpretation of postdepositional changes, such as hydrothermal leaching and replacement. Many such observations would escape detection by conventional petrographic methods.

Our procedure for preparing doubly polished sections has evolved during the past 20 years and incorporates many standard procedures. Studies from such diverse districts as Creede, Colorado; Hokuroku, Japan; and the Upper Mississippi Valley zinc-lead district, southwestern Wisconsin, demonstrate the value of observations from doubly polished sections in constructing genetic models. The advent of doubly polished sections represents a major advance in the study of ore deposits and they should be a standard tool in every ore petrology laboratory. (Authors' abstract)

HEASLER, H.P., 1982, The Cody hydrothermal system, in S.G. Reid and D.J. Foote, eds., 33rd Annual Field Conf., Wyoming Geol. Assoc. Guidebook 1982, Mammoth Hot Springs, WY, Sept. 15-18, 1982, p. 163-174.

HEDENQUIST, J.W., 1982, Fluid flow in the Waiotapu geothermal system, New Zealand: implications for its potential: Proc. Pacific Geothermal Conf. 1982, Part 1, Univ. Auckland Geothermal Inst., Auckland, NZ, p. 61-67. Author at Geothermal Res. Ctr., DSIR Chem. Div., Wairakei, Private Bag, Taupo, NZ.

The Waiotapu goethermal system lies within the Taupo Volcanic Zone of New Zealand; it has the greatest heat flow and largest area of any system in the country.

The system was explored in the late 1950's; maximum measured temperature was 295°C in the south, with temperature inversions measured in the north.

A mixing model incorporating well and surface spring chemistry indicates that the focus of deep (>1 km) fluid upflow is in the north, below drilled depths. This upflow is deflected southwards by a near surface, laterally flowing fluid. (Author's abstract)

Th of inclusions in calcite and quartz tend to follow the hydrostatic boiling point with depth curve and do not exhibit the present measured inversions providing a measure of bottom hole temperature decline since trapping (20-40°C). Tm ice indicates CO_2 was as much as 10X that in present waters. (E.R.)

HENNEBERGER, R.C., 1982, Evolution of the Ohakuri geothermal system: Proc.

Pacific Geothermal Conf. 1982 Part 1, Univ. Auckland Geothermal Inst., Auckland, NZ, p. 55-60.

HEYEN, Georges, DUBESSY, Jean and RAMBOZ, Claire, 1982, Simulation of phase equilibria in the carbon dioxide-methane-ethane system below 50°C and 100 bar. Application to fluid inclusion study: C.R. Acad. Sci. Paris, v. 294, Ser. 2, p. 261-264 (in French). Authors at Lab. Anal. Synth. Syst. Chim., Liege, Belgium.

An equation of state is proposed for the CO_2-CH_4-C_2H_6 system at <50° and 100 bars. This equation of state can be used for determining the density of C-bearing geol. fluid inclusions provided that their relative molar composition is analyzed by Raman microprobe and that the temps. of CO_2 homogenization and fusion ($ThCO_2$, $TfCO_2$, respectively) are measured for the mixtures. With some limitations, a similar interpretation of $ThCO_2$ and $TfCO_2$ in the nonaqueous part of water-rich carbonaceous mixtures is possible. (Authors' abstract)

HEYEN, Georges, RAMBOZ, Claire and DUBESSY, Jean, 1982, Simulation of phase equilibria in the system CO_2-CH_4 below 50°C and 100 bar: C.R. Acad. Sci. Paris, v. 294, Ser. II, p. 203-206 (in French).

An equation of state is proposed for the CO_2-CH_4 system below 50°C and 100 bar. This equation allows one to predict the P-V-T-X conditions of the phase equilibria in the system. In particular, using the data thus generated, a V-X diagram has been constructed for the intepretation in terms of composition and density of the microthermometric parameters, measured during the study of carbonaceous fluid inclusions. (Authors' abstract)

HIGGINS, N.C. and KERRICH, R., 1982, Progressive ^{18}O depletion during CO_2 separation from a carbon dioxide-rich hydrothermal fluid: evidence from the Grey River tungsten deposit, Newfoundland: Can. J. Earth Sci., v. 19, p. 2247-2257.

Oxygen isotope data for the Grey River tungsten prospect, Newfoundland, Canada, indicate a progressive depletion in $\delta^{18}O$ fluid during mineralization. Early veins with pegmatitic affinities were deposited at 470°C and pressures greater than 1 kbar (100 MPa), from a fluid with a $\delta^{18}O$ composition of 7.4‰ presumed to be of magmatic origin. Successive vein deposition, at progressively lower temperatures and pressures, culminated in the precipitation of wolframite-bearing veins at a temperature of 300°C and pressures of 150-320 bars (15-32 MPa), from a low salinity fluid with a $\delta^{18}O$ composition in the range 3.2-1.6‰.

Low values of $\delta^{18}O$ (and δD fluid) are recorded in many vein tungsten deposits and are normally interpreted as reflecting mixing of isotopically light meteoric fluids or formation brines with magmatic fluids. However, fluid inclusion evidence for the Grey River mineralization indicates that a 40 mol% CO_2 loss occurred by immiscibility and retrograde boiling of the hydrothermal fluid between 420 and 300°C. Such a chemical change would have significantly altered the oxygen isotopic character of the hydrothermal fluid since CO_2 fractionates ^{18}O relative to coexisting water by ~10‰ at 400°C and ~14‰ at 300°C. Calculations using available CO_2-H_2O fractionation factors reveal that up to a 7‰ depletion in $\delta^{18}O$ of the residual aqueous fluid may occur as a result of the 40 mol% CO_2 loss from the hydrothermal fluid. (Authors' abstract)

HOHLFELDER, J.J., BEATTIE, A.G. and SHEFELBINE, H.C., 1982, Water release and mechanical failure in heated geologic salt: SAND--81-1488 Contract AC04-76DP00789, 23 p., NTIS, PC A02/MF A01. Authors at Sandia Nat'l.

Labs., Albuquerque, NM.

The rate of water release and the acoustic emission rate were measured in heated specimens of geologic salt. These measurements show that changes in thermal power applied to the salt cause increased acoustic emission from the salt. The acoustic emission is caused by the salt's cracking. The salt's cracking enhances its prompt release of water. (Authors' abstract)

HOLLISTER, L.S., 1982, Metamorphic evidence for rapid (2 mm/yr) uplift of a portion of the Central Gneiss Complex, Coast Mountains, B.C.: Can. Mineral., v. 20, p. 319-332. Author at Dept. Geol. & Geophy. Sci., Princeton Univ., Princeton, NJ 08544.

The Eocene granulite-facies metamorphic terrane in the Coast Mountains east of Prince Rupert, B.C., was apparently uplifted and eroded at the unusually fast rate of 2 mm/yr. Reactions showing the transition from high-pressure to low-pressure assemblages are the best evidence for this interpretation. These include garnet → hypersthene + anorthite, almandine/pyrope + sillimanite → cordierite, sillimanite + grossular → anorthite, garnet + biotite + sillimanite → cordierite + hercynite + orthoclase, and kyanite → sillimanite. The occurrences of low-density $CO_2 + H_2O$ fluid inclusions, of naturally decrepitated fluid inclusions, and of andalusite in late discordant veins imply that the rocks were still at moderate (>400°C) temperature when relatively near the surface, which is consistent with a model of rapid uplift. Assuming no additional heat input during uplift, petrological, fluid inclusion, geological and available age data from the Central Gneiss Complex can be fit by a model uplift curve published by Albarède (1976). In the model, the uplift of rocks exposed at present occurred between 62 and 48 Ma, beginning at 25 km and terminating at 5 km. (Author's abstract)

HOLLISTER, L.S. and CRAWFORD, M.L., 1982, Metamorphic fluids: evidence from fluid inclusions (abst.): EOS, Trans. Am. Geophys. Union, v. 63, p. 448. First author at Dept. Geophy. Sci., Princeton Univ., Princeton, NJ 08544.

In many metamorphic rocks fluid inclusions occur which contain fluid with a density appropriate for the inferred pressure and temperature of metamorphism and with a composition appropriate for the mineral assemblage. It is therefore reasonable to conclude that fluid inclusions can contain samples of the metamorphic fluid.

Most metamorphic rocks contain both carbonic and aqueous fluid inclusions. The carbonic fluids are dominantly methane in the anchizone and lowermost greenschist facies and carbon dioxide at higher grade. The ratio of these two species also depends on the fO_2 of the rock. The metamorphic aqueous fluid is chloride brine; calcareous rocks typically contain brines with the highest concentrations of dissolved salts. The ubiquitous association of aqueous and carbonic fluids demonstrates that the assumption $P(H_2O)=P(Total)$ is rarely valid. CO_2 and H_2O are immiscible fluids at conditions of the greenschist facies and below. Salts dissolved in the aqueous phase and CH_4 in CO_2 expand the solvus to cover most of the range of CO_2-H_2O mixtures and raise the solvus crest to temperatures of the mid-amphibolite facies. The likelihood of immiscible aqueous and carbonic fluids, particularly in calcsilicates, at low and moderate metamorphic grade suggests a re-evaluation of assumptions concerning mineral equilibria in these environments. (Authors' abstract)

HOLLOWAY, J.R., 1982, Low temperature equilibria in the C-O-H system: invariant graphite-two fluid regions (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 517. Author at Chem. and Geol. Depts., Arizona State Univ., Tempe, AZ 85287.

Published results of the joins H_2O-CO_2, H_2O-H_2 and H_2O-CH_4 show in each case that the fluid phase unmixes to a more dense H_2O-rich aqueous phase and a less dense non-aqueous phase at temperatures below about 400°C. Modified Redlich-Kwong calculations (which predict the observed unmixing with relative accuracies of 2-5%) indicate similar unmixing in ternary $CO_2-CH_4-H_2-H_2O$ fluids. Also at these low temperatures the graphite phase field expands towards the CO_2-H_2O and H_2O-CH_4 joins at all crustal pressures above 300-500 bars. So between 300°-400°C the graphite field intersects the two fluid field, creating two 3-phase fields (CO_2-rich fluid + aqueous fluid + graphite, fl 3 + fl 1 + G, and CH_4-rich-fluid + aqueous fluid + graphite, fl 2 + fl 1 + G), separated by a narrow 2 phase field of graphite + aqueous fluid. At fixed P and T the 3 phase fields are invariant, so fluid compositions and oxygen fugacity are fixed. For example at 200°C and 500 bars f2 + fl + G define an fO_2 about equal to the quartz-fayalite-magnetite (QFM) buffer while f3 + fl + G fixes fO_2 at about 4 orders of magnitude greater than QFM. Increasing pressure maintains the relative differences in fO_2 between the 2 fields, but results in shift to lower values relative to QFM, such that fl + f2 + G is 4 orders of magnitude lower than QFM at 10000 bars.

Many sediments will plot in the fl + f2 + G field at low temperatures where CO_2 is bound in carbonate minerals. In this case the non-aqueous fluid will nearly pure methane. As T increases and decarbonation reactions add CO_2, the fluid system will shift to fl + f3 + G resulting in a major increase in fO_2 over a narrow T interval. These observations have important implications for low T metamorphism, and predict the occurrence of natural gas in many low T metasedimentary rocks. (Author's abstract)

HORNYTZKYJ, S., 1982, Fluorite inclusions in topaz from Nigeria: J. Gemm., v. 18, no. 2, p. 131-137.

HORRALL, K.B., 1982, Mineralogical, textural, and paragenetic studies of selected ore deposits of the southeast Missouri lead-zinc-copper district and their genetic implications: Ph.D. dissertation, Univ. of Missouri-Rolla, 679 pp.

Literature data on fluid inclusions are discussed but apparently no new inclusion studies were made. (E.R.)

HOUK, R.S. and THOMPSON, J.J., 1982, Elemental and isotopic analysis of solutions by mass spectrometry using a plasma ion source: Am. Mineralogist, v. 67, p. 238-243. Authors at Ames Lab.-USDOE and Dept. Chem., Iowa State Univ., Ames, IA 50011.

Solution aerosols are introduced into an atmospheric pressure inert gas plasma where elemental constituents are ionized. An ion sampling interface extracts gas from the plasma into a vacuum system where the ions are mass analyzed and detected. The feasibility of this analytical concept for trace elemental and isotopic analysis was first demonstrated using a capillary arc plasma. Recent work is described which was performed with an inductively coupled plasma. The relative standard deviations obtained for determination of relative abundances of Cu and Rb isotopes are approximately ±1 percent. Samples are directly introduced into the plasma ionization source and can be changed in approximately two minutes by simple procedures performed completely outside the vacuum system. Dissolution and nebulization are the only sample preparation procedures required. Ions from most of the elements studied are obtained under the same operating parameters. Continued improvements in ion extraction techniques are expected to make plasma ion sources valuable for rapid mass spectometric analysis of solutions. (Authors' abstract)

HUANG, Hanlieh, WANG, Weiyu and FENG, Haiqing, 1982, Genesis of wolframite in the vein-type tungsten deposit within limestone: Tungsten Geology Symposium Jiangxi, China, sponsored by ESCAP/RMRDC and Ministry of Geology, PRC, 12-22 Oct., 1981: Pub. by ESCAP/RMRDC, Bandung, Indonesia, p. 279-286 (in English). Authors at Guangxi Inst. Metal. & Geol., Ministry of Metallur. Industry.

The factors controlling the generation of wolframite rather than scheelite in three vein type tungsten deposits occurring within limestone are described [based in part on fluid inclusion studies]. Investigation of metallogenic characteristics at different ore-forming stages shows that wolframite formation depends on the following factors: first (and most important) that large amounts of iron and manganese in the ore solution were available to combine with tungsten, while abundant fluorine in the ore solution could combine with calcium to form fluorite: and that the fluorite and previously formed minerals could adhere to the sides of a fissure and prevent the ore solution from reacting with the country rocks thus lowering the concentration of calcium. Second, that the ore solution evolved from an acidic state to alkaline state with the former lasting longer than the latter. Third, that mineralization lasted for a long time in the "high temperature" range during the gradual decrease of the temperature of the ore solution. Fourth, that other factors including fissures and pressures of the ore solution, also favored the formation of wolframite while hindering the growth of scheelite. (Authors' abstract)

HULBERT, L.J. and von GRUENEWALDT, Gerhard, 1982, Nickel, copper, and platinum mineralization in the lower zone of the Bushveld Complex, south of Potgietersrus: Econ. Geol., v. 77, p. 1296-1306. Authors at Inst. Geol. Res. on the Bushveld Complex, Univ. Pretoria, Pretoria 0002, Rep. South Africa.

The composition of the coexisting silicates suggests that separation of an immiscible sulfide liquid was brought about by a drop in temperature of the magma, possibly caused by the emplacement of less primitive, cooler magma that mixed with the residual, crystallizing, lower zone magma. (From the authors' abstract)

HULSTON, J.R., STEWART, M.K., GLOVER, R.B., CAMALES, R.A., BOGIE, I.M. and BARNETT, P.R., 1982, Stable isotope geochemistry of the Tongonan geothermal system Leyte, Philippines: Proc. Pacific Geothermal Conf. 1982 Part 1, Univ. Auckland Geothermal Inst., Auckland, NZ, p. 265-270. First author at Inst. Nuclear Sci., Lower Hutt.

Stable isotope and geochemical data on samples from natural features, shallow wells and deep wells collected over a number of years from the Tongonan area of Leyte have been evaluated. The variations in the isotopic compositions of the thermal waters are used to describe natural processes occurring within the system. The effect of the "excess enthalpy" of the deep wells on the isotope data is formulated. Water from the deep Tongonan wells shows an oxygen-18 shift of 5% , which is larger than at Wairakei and Broadlands, probably in part because of the high temperatures at Tongonan. Recent measurements indicate that the deuterium shift is very much smaller than previously thought. Isotopic measurements of methane in the gases suggests differing flows from the Eastern and Central Philippine faults. (Authors' abstract)

HUNTER, R.H. and TAYLOR, L.A., 1982, Instability of garnet from the mantle: Glass as evidence of metasomatic melting: Geology, v. 10, no. 12, p. 617-621.

IGLESIAS, J.G., and PÉREZ, J.L., 1982, Physico-chemical formation conditions of the fluorite mineralizations of the Asturian region of Spain: correlations and synthesis: Bull. RGM, Sec. II, v. 2, no. 4, p. 353-357 (in French; English abstract). Authors at Dépt. métal., Ecole des Mines, Oviedo, Espagne.

The following paper presents a study of the main fluorite deposits of the Asturian region. The main geological and mineralogical characteristics are reviewed and correlations based on physico-chemical data obtained by fluid inclusions study are proposed. The deposits can thus be grouped into four districts in which the mixing of waters of different origins has played an important role. (Authors' abstract)

IHLEN, P.M., TRØNNES, R. and VOKES, F.M., 1982, Mineralization, wall rock alteration and zonation of ore deposits associated with the Drammen granite in the Oslo region, Norway, in Metallization Associated with Acid Magmatism, A.M. Evans, ed.: New York, J. Wiley, p. 111-136. Authors at Geologisk Inst., NTH, Trondheim.

A few preliminary observations on inclusions have been made (p. 133). T of mineralization and alteration ~450°C except at Røsåsen mine (>450°C). No boiling seen in central granite, but was seen along margins. Salinities 1-14 wt.% NaCl with ≤5 wt.% CO_2, except Røsåsen (30-40%, with no CO_2). CO_2 was not present in original magmatic fluids; CO_2 was "introduced with meteoritic fluids." Main cations are K and Na, ± Ca; K/Na = ~0.1-0.2, appropriate for a liquid in equilibrium with two feldspars. (E.R.)

IKORSKIY, S.V., 1982, Studies of organic substances in minerals, in Use of methods of thermobarogeochemistry during prospecting and studies of ore deposits, N.P. Laverov, ed.: Moscow, "Nedra" Publ. House, p. 190-198 (in Russian).

The review of literature data concerning the existing methods of studies of carbon-bearing substance in the various forms in which it occurs is presented. The generally accepted schemes of analysis, devices used, methods of preparation and diagnostics of organic substance in minerals are discussed. It is shown that errors may occur during extraction and analysis of carbon-bearing substance and these substances may influence the results of analysis of gas-liquid inclusions. (Author's abstract translated by A.K.)

IKORSKIY, S.V. and VOLOSHIN, A.V., 1982, Typomorphism of composition of gas phase of inclusions in quartz from granitic pegmatites of the Kola Peninsula: Geokhimiya, no. 10, p. 1464-1471 (in Russian; English abstract). Authors at Geol. Inst. of Kola Div. of Acad. Sci. USSR, Apatity, USSR.

Gases evolved from 37 quartz specimens by grinding in vibration steel ball mill were analyzed by gas chromatography. The method permitted determination of He, H_2, O_2, N_2, CH_4, hydrocarbons C_2-C_5, CO and CO_2. All samples bear N_2 and O_2 in ranges 0.1-4 cm^3/kg of sample, N_2/O_2 in quartz > N_2/O_2 in air. He and CO are present up to 0.0005 and 0.005 cm^3/kg, respectively. CO_2 occurs in ranges 0.02-175 cm^3/kg, C_4 - 0.001-2.950 cm^3/kg, C_2H_6 - 0.0001-0.2760 cm^3/kg, CH_4/C_2H_6 ratio - 3-465. The richest in total gases are rare-metal pegmatites (8.3-174 cm^3/kg vs 0.7-65 cm^3/kg in ceramic pegmatites and 0.02-70 cm^3/kg in mica-bearing pegmatites), probably due to long and complicated history of their formation. (Abstract by A.K.)

ILAVSKÝ, J., 1982, Mineralizations of the lead-zinc (baryte, fluorite) deposits of the Czechoslovakian Carpates: Bull. BRGM, Sec. II, v. 2, no. 2, p. 117-125 (in French; English abstract). Author at Geol. Ústav Dionýza Štúra, 81104, Bratislava,ČSSR.

Lead-zinc mineralizations, with or without barite and fluorite, were deposited in the following metalliferous stages: Cambrian, Ordovician, Silurian, Upper Carboniferous, Middle Triassic, Cretaceous and Miocene. The greatest accumulations of them are known in Lower Miocene. These mineralizations belong to both the stratiform type and the hydrothermal vein type. The lead-zinc mineralization are more extensive in the southern structural zones than in the northern ones. They are especially prevalent in the Neovolcanics zone of Miocene age (i.e., Banská Štiavnica ore deposit). Barite and fluorite are only present in very small quantities here.

Barite is however widespread and exploited in the hydrothermal vein deposits of siderite-barite-Cu-Sb-Hg-sulphides of the Gemericum zone, that of Rudňany being well known. They are of Variscan age. Fluorite is now known in this type of mineralization.

The paleothermometric data [decrepitation; 40-340°C] show that the paleotemperatures of the minerals present here, have not had any influence on the presence or absence of barite and fluorite. (Author's abstract)

ILUPIN, I.P., EFIMOVA, E.S., SOBOLEV, N.V., USOVA, L.V., SAVRAVOV, D.I. and KHARKIV, A.D., 1982, Inclusions in diamond from diamond-bearing dunite: Akad. Nauk SSSR, Dokl., v. 264, no. 2, p. 454-456 (in Russian).

IMMITT, J.P. 1981, Skarn and epithermal vein mineralization in the San Carlos caldera region, northeastern Chihuahua, Mexico: M.A. thesis, The Univ. Texas at Austin, Austin, TX.

The San Carlos Pb-Zn-Ag skarn deposit and several Pb-Zn-Cu-fluorite epithermal vein prospects are located along the boundary of the San Carlos caldera near Manuel Benavides (San Carlos) in northeastern Chihuahua, Mexico. The skarn deposit is at the crest of a Laramide anticlinal fold in the Sierra Azul. The anticline was intruded and uplifted by a granitic pluton related to caldera development at 31 mybp. Detailed mapping and petrography reveal that Lower Cretaceous dolomitic limestone and calcareous siltstone have been metamorphosed and metasomatized to form a well-defined zonal alteration pattern around the intrusive core of the fold. Prograde calc-silicate metamorphism resulted in a sequence, with increasing distance from the heat source, of forsterite or diopside, tremolite, and recrystallized carbonate zones. Within the forsterite zone the premineralization calc-silicate assemblage has been replaced by a metasomatic assemblage consisting mainly of magnetite, calcite, galena, and sphalerite. Precipitation of ore minerals took place when acidic magmatic hydrothermal fluids interacted with the dominantly carbonate country rocks. Retrograde serpentine alteration of forsterite and diopside is the only indication of the premineralization metamorphosed lithologies.

The epithermal vein prospects occur near the northwestern margin of the caldera mainly along normal faults near the apex of the La Consolacion dome. This dome was probably formed during emplacement of another peripheral intrusion believed to be present at depth. Veins occur in marbleized Lower Cretaceous shale and argillaceous limestone and in a hydrothermally altered caldera-related Tertiary rhyodacite flow. Ore deposition resulted from circulation and cooling of metal- and fluorine-bearing hydrothermal fluids. Fluid inclusion data indicate a range in temperature from 317-142°C and in salinity from 5.7-2.8 wt% NaCl equiv., with both generally decreasing in younger minerals.

Mineralization in the San Carlos area is spatially, and may have been temporally associated with development of the San Carlos caldera. It may have been controlled by the availability of heat and hydrothermal fluid from caldera-related igneous activity, ease of fluid movement along caldera-related structures, and the presence of reactive host rocks. (Author's abstract)

IRVING, A.J. and MATHEZ, E.A., 1982, The origin of glass in ultramafic xenoliths (abst.): Terra Cognita, v. 2, p. 243. Authors at Dept. Geol. Sci., Univ. Washington, Seattle, WA 98195.

Glass in five types of xenoliths was analyzed (Table). The sum deficiency is interpreted as H_2O. These glasses are believed to form largely by decompression during ascent. (E.R.)

	SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	SUM
A	53.1	0.96	20.4	2.3	0.0	0.8	4.2	1.3	2.5	0.23	95.79
B	61.4	0.02	18.8	3.3	0.0	2.7	8.0	1.0	0.39	0.0	95.61
C	57.7	0.02	18.2	4.1	0.0	4.1	11.3	2.4	0.45	0.0	98.27
D	51.6	0.16	29.5	1.0	0.0	0.40	13.6	3.7	0.23	0.0	100.19
E	59.1	3.5	18.4	3.0	0.0	2.1	4.3	2.2	5.6	0.45	98.85

IVANOV, I.I., RYABOV, E.N., SANDLER, R.A. and BAZHEEVA, G.V., 1981, Binary system $AlCl_3$-$CaCl_2$: Zhurn. Neorg. Khimii, v. 26, no. 3, p. 825-826 (in Russian). Authors at Leningrad Mining Inst., Leningrad, USSR.

Anhydrous binary system $AlCl_3$-$CaCl_2$, T range 0-800°C, is characterized by DTA, X-ray and optic methods. The system belongs to eutectic-peritectic type. A new coordination phase was found: $CaCl_2 \cdot AlCl_3$, melting incongruently at 288°C, refractive index ~1.550-1.560, isotropic (possibly may be found as dm). (A.K.)

IVANOV, I.P. and POKROVSKIY, V.A., 1982, Redox interactions in water-mineral systems: Dokl. Akad. Nauk SSSR, v. 264, no. 1, p. 212-216 (in Russian).

IVANOV, O.K. and SHTENGEL'MEYER, S.V., 1982, Viscosity and temperature of crystallization of melts of ultramafites: Geokhimiya, no. 3, p. 330-337 (in Russian). First author at the Ural Geol.-Mapping Expedition, Sverdlovsk, USSR.

Viscosity 0.3-9 poise was determined for the rock melts of the dunite-bronzitite series at T 1400-1800°C; pertinent to studies of melt inclusions. (A.K.)

IVANOVSKAYA, I.N., SHTERNBERG, L.Ye., MAKHOV, S.F., MUSINA, A.R. and FILONENKO, V.P., 1981, Carbon isotope fractionation in solid-state diamond synthesis: Geokhimiya, 1981, no. 9, p. 1415-1417 (in Russian; translated in Geochem. Int'l., v. 18, no. 4, p. 82-84, 1982).

JACKSON, Kenneth and HELGESON, H.C., 1982, Chemical and thermodynamic constraints on the hydrothermal transport and deposition of tin (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 521. Authors at Dept. Geol. and Geophysics, Univ. California, Berkeley, CA 94720.

Estimation of equation of state parameters for Sn^{++} and calculation of the thermodynamic properties of other aqueous species and the dissociation constants of stannous complexes as a function of temperature using the approach adopted by Helgeson, Kirkham, and Flowers (1981) and Helgeson

(1967, 1969) permit calculation of phase relations in the system $SnO-K_2O-Al_2O_3-SiO_2-FeO-Fe_2O_3-H_2O-HCl-H_2S$ at high pressures and temperatures. These relations can be correlated on activity and fO_2-pH diagrams with fluid inclusion data and field and laboratory observations of mineral compositions and compatibilities in quartz-cassiterite veins in the Southeast Asian tin belt. Petrographic data indicate that the equilibrium mineral assemblages in these veins include quartz, cassiterite, K-feldspar, muscovite, hematite, magnetite, and topaz. Fluid inclusion homogenization temperatures range from 265° to 290°C and freezing point depressions indicate chloride concentrations of the order of 1 m. Thermodynamic calculations confirm that >99 percent of the tin in solution was in the stannous oxidation state. The oxygen fugacity was $\sim 10^{-28}$ bars and fH_2S $\sim < 10^{-0.6}$ bars during deposition of the veins. (Authors' abstract)

JACKSON, N.J., HALLIDAY, A.N., SHEPPARD, S.M.F. and MITCHELL, J.G., 1982, Hydrothermal activity in the St. Just mining district, Cornwall, England, in Metallization Associated with Acid Magmatism, A.M. Evans, ed.: New York, J. Wiley, p. 137-179. First author at Watts, Griffis and McOvat Ltd., P.O. Box 5219, Jeddah, Saudi Arabia.

Field, petrographic, fluid inclusion, radiogenic (K-Ar, $^{40}Ar-^{39}Ar$, Rb-Sr) and stable isotope (D-H, $^{18}O-^{16}O$) studies were applied to mineralization phenomena in the roof zone and north-west flank of the Land's End granite. The ~290 Ma high-level granites were derived from the anatexis of young pelitic-rich crustal rocks with high B, F, Sn, U, etc. Main Stage mineralization, which was both temporally and spatially related to magmatism, comprised a variety of metasomatic activities, emplacement of barren pegmatites, Sn-Cu mineralized fissure vein systems and irregularly shaped mineralized replacement deposits. Isotopic evidence for magmatic-hydrothermal activity is restricted to the earliest mineralization stages. The principal ore-bearing Main Stage fluids were overwhelmingly of meteoric origin and dominantly of low to moderate salinity (10-20 eq. wt % NaCl) in the minimum temperature range 280-450°C with local fluctuations to more saline fluids (≤40 eq. wt % NaCl).

Post-Main Stage hydrothermal activity is recognized at about 220 Ma with more minor events at about 165 Ma and about 75 Ma, but the importance of reworking and introduction of new ore has not yet been assessed. Pervasive argillic alteration in the roof of the pluton (the china clay deposits) was produced by Tertiary supergene fluids, but at least some vein-associated argillic alteration had a hydrothermal origin. The surface above the Cornubian batholith was probably maintained at a relatively low altitude throughout its long evolution. (Authors' abstract)

JAIRETH, S., SANTOSH, M. and MOHAN, P.C., 1982a Fluid inclusion thermometry of quartz from Odara pegmatite, Kerala: Proc. Indian Acad. Sci. (Earth Planet. Sci.), v. 91, no. 2, p. 143-152. First author at Centre for Earth Sci. Studies, Trivandrum 695 010, India.

Using a heating stage and a decrepitometer fluid inclusions in quartz from various zones of an ideally-zoned rare metal pegmatite (Odara pegmatite, Kerala) have been studied using homogenization and decrepitation techniques. Microscopic study of the doubly-polished sections revealed various genetic types of inclusions with different phase-ratios. Decrepitation experiments with mineral fragments showed that the mineral had undergone a complex temperature-growth regime, with major temperature range between 140 and 400°C. Fluid inclusion studies indicate that rare metal mineralization in Odara pegmatite is caused by a boiling, saline hydrothermal fluid at temperatures between 200 and 320°C. (Authors' abstract)

JAIRETH, S., SANTOSH, M. and MOHAN, P.C., 1982b, Physico-chemical conditions of formation of rare metal mineralization in Odara pegmatite of Kerala (abst.): [Proceedings & Abstracts], National Workshop on Fluid Inclusion Studies, 22-23 March, 1982, Indian Inst. Tech., Bombay, p. 32 (unpaginated). Authors at Dept Earth Sci., Univ. Roorkee Roorkee 247 672. See previous item.

JAMBON, A., BRAUN, O. and WEBER, H., 1982, Solubility of noble gases in a basalt melt. Preliminary results at 1300°C, 1 bar (abst.): EOS, Trans. Am. Geopys. Union, v. 63, p. 451.

JOCKWER, N., 1981, The nature and quantity of water contained in Zechstein salt and its liberation and migration in a thermal field of radioactive waste in definitive storage: Ph.D. dissertation, Tech. Univ. Clausthal, W. Germany; GSF - Bericht T 119, 134 pp (in German).

For abstract see Jockwer, 1981, Fluid Inclusion Research--Proceedings of COFFI, v. 14, p. 98. (E.R.)

JOHAN, Z., LE BEL, L, ROBERT, J.L. and VOLFINGER, M., 1982, Role of reducing fluids in the origin of chromite deposits from ophiolitic complexes (abst.): Geol. Assoc. Canada/Min. Assoc. Canada Program with Abstracts, v. 7, p. 58. Authors at GIS BRGM-CNRS, 1A, rue de la Férollerie 45045 Orleans Cedex, France.

Chromite deposits from ophiolitic complexes of different ages (Saudi Arabia, Cyprus, China, New Caldeonia) have been studied. The following mineral assemblage of silicate inclusions in massive chromite was observed: olivine (Fo 93-97, rich in Ni), orthopyroxene (En 94-95), clinopyroxene (Fs 1-3, with up to 1.2% Na_2O), chromium-rich pargasite (poor in K and Ti), purely sodic nepheline, sodium analogue of phlogopite (Ti-rich, containing up to 1 Ti per formula unit), albite and jadeite. In some cases, these silicates are associated with fluid inclusions (5% NaCl equiv., presence of CO_2, CH_4, C_2H_4, C_2H_6). The equilibrium temperature (Wood and Banno) calculated for coexisting opx and cpx inclusions in massive chromite is 1050°C (±20°), approaching the maximum of thermal stability of pargasite. Massive chromite is a remarkable concentrator of PGE and frequently contains minute inclusions (<5 microns) of iridosmine and laurite, sometimes associated (New Caledonia) with native nickel enriched in platinoids (Ir 10, Os 1.4, Ru 1.0, Cu 0.7 wt.%) or in copper (up to 7.6 wt.% of Cu). The composition of these alloys (Fe <1.1 wt.%) implies an oxygen fugacity between 10^{-9} to 10^{-14} atm. (1100°C). PGE minerals are systematically associated with clinopyroxene. All these observations suggest that chromite originates from a magmatic liquid strongly enriched in volatiles (Na, K, Ni, Cu, PGE, Cl, H_2O, S ...). Inclusions of alloys indicate that the precipitation of chromite may be related to a decrease in oxygen fugacity of the fluid phase. Experimental runs performed at 1000°C and 2 to 5 kbars of water pressure showed that this hypothesis is highly plausible. Chromite may be easily formed by the interaction of a chloride-rich reducing fluid with magmatic liquid. Such a process leads to the extraction of chromium from the magmatic liquid. (Authors' abstract)

JOHANSSON, Å. and RICKARD, D.T., 1982, The Variscan lead-zinc-fluorite veins of southern Sweden: Bull. BRGM, Sec. II, v. 2, no. 2, p. 133-142. Authors at Ore Res. group, Geol. Inst., Stockholm Univ., S-106 91 Stockholm, Sweden.

Preliminary fluid inclusion data yield T = ~150°C and salinities of 0-25% NaCl. (E.R.)

JOHN, D.A., MOORE, W.J. and ERICKSON, A.J., Jr., 1982, Contrasts in magmatic-hydrothermal systems in the central Wasatch Mountains, Utah (abst.): Geol. Soc. Am. Program with Abstracts, v. 14, p. 316. First author at U.S. Geol. Survey, Menlo Park, CA 94025.

In the central Wasatch Mountains, Utah, successively deeper levels of middle Tertiary stocks are exposed east to west along the Uinta axis. Petrographic and fluid-inclusion studies indicate systematic variations in mineralization and derivative hydrothermal systems associated with these stocks. Quartz crystals in the western, most deeply eroded stocks (Little Cottonwood, Alta) contain only very small (<10 μm) liquid-rich two-phase fluid inclusions. Mineralization is limited to small copper-bearing skarns around the Alta stock and later(?) quartz-molybdenite stockwork veining within the Little Cottonwood. To the east, fluid inclusions record progressively more saline fluids at shallower levels of erosion. Both the Clayton Peak and Flagstaff Mountain stocks locally contain moderately saline (halite-bearing) fluid inclusions in unaltered rock. Neither stock formed significant mineralization. Nash (1973, Geochemical studies in the Park City District: I: Ore fluids in the Mayflower mine: Economic Geology, v. 73, p. 34-51; and unpub. data) reports early high-temperature high-salinity fluids in veins cutting both the Mayflower and Ontario stocks (325 - >550°C, 34 - >48 wt percent NaCl equivalent). These fluids evolved into solutions that deposited the important Ag-Pb-Zn ores of the Park City district. The easternmost and shallowest intrusion, the Park Premier stock, intrudes highly fractured volcanic rocks and contains the most saline inclusions (>75 wt percent NaCl equivalent) in both veins and quartz phenocrysts. No economic mineralization has been recognized in or near this stock. The progressive eastward increase in salinity of hydrothermal fluids may be the result of decreasing load pressure allowing separation of an initially low- to moderate-salinity fluid (i.e., 10 wt percent NaCl) into two fluids (high and low salinity) in the eastern stocks. (Authors' abstract)

JOSEPH, N.L., 1982, Epithermal veins in the Silver Bell district, Pima County, Arizona: MS thesis, Univ. Arizona, Tucson, Arizona, 49 pp.

Indexed under Fluid Inclusions. (E.R.)

JUSTICE, M.G., Jr., GRAHAM, E.K., TRESSLER, R.E. and TSONG, I.S.T., 1982, The effect of water on high-temperature deformation in olivine: Geoph. Res. Letters, v. 9, no. 9, p. 1005-1008. First author at Dept. Geosci., The Pennsylvania State Univ., University Park, PA 16802.

Numerous natural single crystal specimens of olivine were examined to assess the levels of intrinsic water (hydrogen) concentration and to measure their plastic deformation characteristics within controlled environments in constant strain-rate experiments. Our efforts to characterize the "water" content of the natural specimens, as well as to artificially "wet" single crystals, have indicated that the olivine structure can retain "water" in very small amounts only (a maximum of 55 $H/10^6$ Si was observed*). Moreover, compressional creep deformation experiments at differential stresses between 10 and 450 bars, with strain-rates from 10^{-6} to 10^{-5} sec^{-1} under zero confining pressure, and at a temperature of 1575°C, demonstrate no loss in strength for single crystal specimens deformed in "wet," relative to "dry," experimental environments. Our "wet" environments were obtained from an H_2O-H_2 gas mixture with controlled oxygen fugacity within the olivine stability region, whereas "dry" conditions were obtained by using a CO_2-CO gas flow. The results of this study, as well as those from other recent investigations, suggest strongly that the "water weakening" effect, which has been observed in natural olivine and dunite, is most likely due to the increase of oxygen partial pressure resulting from the high temperature decomposition of H_2O, rather than the hydrolysis of crystal bonds. (Authors' abstract)

*Equiv. to 3.6 ppm H_2O. (E.R.)

KADIK, A.A. and MAKSIMOV, A.P., 1982, Genesis of andesite magmas: problems of water and temperature regimes: Geokhimiya, no. 6, p. 797-821 (in Russian; English abstract). Authors at Inst. Geochem. and Anal. Chem., Moscow, USSR.

Pertinent to melt inclusion studies; bears also some reference Th of melt inclusions. (A.K.)

KADIK, A.A., SHILOBREYEVA, S.N., AKHMANOVA, M.V., SLUTSKIY, A.B. and KOROBKOV, V.I., 1981, Solubility of CO_2 in melts of acid composition for the case of the albite--silica system (65:35): Geokhimiya, no. 1, p. 63-70 (in Russian; translated in Geochem. Int'l., v. 18, no. 1, p. 42-48, 1982). Authors at V.I. Vernadskiy Inst. Geochem. & Anal. Chem., Acad. Sci. USSR, Moscow.

Translated in Fluid Inclusion Research--Proceedings of COFFI, v. 14, p. 271-275. (E.R.)

*KAIVULA, John, 1981, Amber; doorway to ancient forests: Bull. Southern Calif. Paleo. Soc., v. 13, no. 5-6, p. 80-88.

A review of the gaseous, fluid, solid, and paleontologic inclusions in amber. (E.R.)

*Probably misprint for Koivula. (E.R.)

KALITA, Ye.D. and KHRAPOV , A.A., 1982, Formation conditions of fluorite deposits of Transbaikalia and Mongolia, in N.P. Ermakov, ed., Thermobarogeochemistry in Geology - Materials of the Sixth All-Union Symposium on Thermobarogeochemistry: Vladivostok, Far East Sci. Center, Acad. Sci. USSR Pub. House, p. 100-107 (in Russian).

For abstract, see entry Kalita, Mel'nikov, Kandinov and Khrapov in Fluid Inclusion Research--Proceedings of COFFI, vol. 13, 1980, p. 110-111. (A.K.)

KALJUZHNY, V.A., VYNAR, O.N., KOVALISHIN, Z.I., ZINCHUK, I.N. and MATVIENKO, A.D., 1982, Geochemical specialization of hydrothermal fluids of polymetallic and gold manifestations in the Ukraine(with reference to data on fluid inclusions) (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 201-203. Authors at Inst. Geol. & Geochem. of Fuels Min., L'vov, USSR.

Mineral-forming hydrothermal fluids are complex physico-chemical systems. According to the analysis of fluid inclusions the hydroisotherms contain (in addition to water) such volatiles as carbon dioxide, methane, nitrogen, heavy hydrocarbons and other gases. Saturating equally the water solution the above mentioned substances enhance the geochemical (metallogenic) specialization of the mineralizing fluid under certain conditions of geological environment and varying parameters of concentration, pressure and temperature. Carbon-dioxide-water, methane-water and methane-carbon-dioxide-water hydrothermal fluids have been found according to the inclusions in minerals in relation with ore manifestations of certain types on the territory of the Ukrainian S.S.R. (Donbass, the southern part of the Ukrainian Shield, Zakarpatjie).

The carbon-dioxide-water fluids with a high CO_2 content (about 50-60 wt.%) are typical for the polymetallic deposits of Donbass. The originally homogeneous fluid was subject to boiling under active tectonic conditions, when the temperatures and pressures were decreasing (from 340-300° to 150-90°C and from $1000 \cdot 10^5$ Pa to $150 \cdot 10^5$ Pa and even lower, respectively). A direct correlation has been observed between the degree of CO_2 saturation of the mineralizing fluid and the scale of polymetallic (gold) mineralization. The highest CO_2 content (up to 91.3 ml per 1 kg of sample) occurs typically in the largest veined bodies with a fully expressed mineralization, located in the brachyanisynclinal (sic) structures of the Main Anticline of Donbass. Minor lode zones located away from the anticline arch lack the sulphides and contain low amounts of CO_2 (28.6-8.6 ml per kg). The same relationship is preserved in other hydrothermal formations of Donbass.

The quartz veins among the granites of the Kirovograd block of the Ukrainian Shield reveal a poor sulphide mineralization accompanied by the low-grade gold manifestations. The ore-forming fluids are those of the carbon-dioxide-water type; they were enriched in nitrogen and methane in the post-ore stage. The total CO_2 content in the inclusions in quartz are much lower than those in the ore veins of Donbass. However, there is a common tenedency of an increase of the CO_2 relative amount in the inclusions in gangue minerals with increased ore mineralization (gold) volume.

Mineralizing fluids with a relatively low CO_2 content and a higher CH_4 and N_2 content are encountered in the polymetallic ore manifestations of Zakarpatjie. The fluids are of a transient composition from carbon-dioxide-water to methane-water. A low absolute gas-saturation of the fluids is a consequence of shallow depths of crystallization. The low-grade polymetallic ores deposited at temperatures ranging from 230 to 220°C; a relatively high CO_2 content in the fluids is typical of gold manifestations.

Ore mineralization of quartz and quartz-carbonate veins of metamorphic-hydrothermal genesis is presented by rare grains of sulphides and fine-dispersed gold (Zakarpatjie). The mineralizing fluids have a specific high methane-content.

Therefore, the kinds of geochemical (metallogenic) specialization of the ore-forming fluids found in the hydrothermal polymetallic formations of the Ukraine, are important indicators of genesis and location of the deposits under discussion. Two extreme branches of the geochemical process have been identified occurring (1) with very high CO_2 concentrations and (2) with the CH_4 being predominant at the background of low gas contents. (Authors' abstract)

KALYUZHNYI, V.A., 1982a Principles of knowledge about mineral-forming fluids: "Naukova Dumka" Publ. House, Kiev, 240 pp., 1000 copies printed, price 2 rbls. 20 kopecks (in Russian). Author at Inst. Geol. and Geochem. of Mineral Fuels of Acad. Sci. of Ukr. SSR, L'vov, Naukova Str. 3A, Ukrainian SSR. See Translations.

KALYUZHNYI, V.A., 1982b Methods of determination of chemical composition and pH of liquid phase of individual inclusions and problems of interpretation of the results, in Use of methods of thermobarogeochemistry during prospecting and studies of ore deposits, N.P. Laverov, ed.: Moscow, "Nedra" Publ. House, p. 47-58 (in Russian).

The author discusses refractometric and cryometric methods of determination of total concentration of salts in inclusion solutions. From refractive indices of inclusion solutions and results of water leachates the average ion concentrations in fluid may be calculated; synthetic standard leachates are used. Dms extracted from inclusions are investigated by optical, X-ray and microspectrographic methods; they characterize the composition of main components of inclusion fluids. Mechanical method is used for extraction of inclusion solution from single inclusions by drilling with needle of hard alloy or with abrasive material grain in a humidified chamber under microscope. Quantitative and qualitative composition of solution from inclusions of >1 mm^3 are determined by ultramicrochemical analysis. Special devices for experiment with microscopic volumes of solution are used. (Author's abstract translated by A.K.)

KALYUZHNYI, V.A. and VOZNYAK, D.K., 1982, Analysis of genetic information obtainable from altered inclusions, in Use of methods of thermobarogeochemistry during prospecting and studies of ore deposits, N.P. Laverov, ed.: Moscow, "Nedra" Publ. House, p. 161-175 (in Russian).

Alteration of inclusion habit may be caused by precipitation of substance from the inclusion volume or by redistribution (recrystallization) of the inclusion wall substance through the inclusion fluid. The authors illustrate this by specific Volynian topazes. Opening of inclusion vacuole may lead to opening of it to the space surrounding the crystal (called decrepitation, exploded inclusions), or only to the formation of fissures around inclusion, (called breaking of inclusions). The latter may be caused either by T increase or by P decrease outside of crystal. Th of parent inclusions with small haloes of daughter inclusions formed due to healing of fissures are close to Th of inclusion before breaking (but higher or lower, depending on the initial filling degree of inclusion). Th of parent inclusions, homogenizing in L phase, are always higher than Th of inclusions after breaking. Homogenization of parent inclusion in L proves the same type of homogenization before breaking, but homogenization in G does not prove the same type of homogenization before breaking. Studies of daughter inclusions may provide information about true T of fissure healing, and the fact of healing proves the ability of filling fluid to transport the mineral substance (important for non-aqueous solutions). The authors discuss also refilling of inclusions (see for this question Kalyuzhnyi, 1982, Translation Section, this volume) and describe the migration of inclusions in thermal gradients. (Abstract by A.K.)

KALYUZHNYI et al. - See also KALJUZHNY

KANE, R.E., 1982, The gemological properties of Chatham flux-grown synthetic orange sapphire and synthetic blue sapphire: Gems & Gemology, Fall 1982, p. 140-153. Author at Gem Trade Lab., Inc., Los Angeles, CA.

Recent rumors in the trade and inquiries to the various offices of GIA's Gem Trade Laboratory, Inc., concerning the commercial availability of faceted flux-grown synthetic blue sapphires prompted the writing of this article. Blue as well as orange flux-grown synthetic sapphires are now commercially available from Chatham Created Gems, Inc., in limited quantities as rough crystal groups and single crystals; they have not yet been marketed as faceted gems. In this article, the author examines the gemological properties [and inclusions] of Chatham flux-grown synthetic orange sapphires and blue sapphires. (Author's abstract)

KANTOR, M.Z., 1982, Genesis of the Tagar deposit and other iron ore deposits in the Middle Priangar'ye: Izvestiya Vyssh. Uchebn. Zaved.-Geologiya i Razvedka, no. 7, p. 49-54 (in Russian). Author at Krasnoyarsk Div. of Siberian Sci.-Research Inst. of Geol., Geophys. and Mineral Raw Materials, USSR.

The Tagar deposit belongs to the magnesia-skarn type, located in a volcanic caldera in a tectonic zone. Early minerals (periclase, spinel) formed at ~900°C, skarns essentially at 520-280°C (Th), magnetite yields Td 380-360°C. (A.K.)

KARANTH, R.V. and PILLAY, V.P., 1982, Fluid inclusion studies in calcites from Lower Narmada Valley, Gujarat State (abst.): [Proceedings & Abstracts], National Workshop on Fluid Inclusion Studies, 22-23 March, 1982, Indian Inst. Tech., Bombay, p. 39 (unpaginated). Authors at Dept. Geol., M.S. Univ. of Baroda

Fluid inclusion studies were made on four representative samples from Garundeshwar in Lower Narmanda Valley, including veins in Deccan basalts and Bagh sandstones. Th 94-154°C. No dms were seen. (E R.)

KARWOWSKI, L. and SLOSARZ, J., L982, Polymetallic mineralization in Paleozoic rocks of Myszkow area, Poland (genesis and zonation) (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 203-204. Authors at Silesian Univ. & Geol. Inst., Sosnowiec, Poland.

Polymetallic mineralization of Paleozoic rocks in Myszkow area was recognized in altered rocks from boreholes at depth of 150-1000 m. Paleozoic rocks occur under Triassic sediments with stratiform zinc-lead ores.

In association with these alterations occurs multiphase hydrothermal mineralization of polymetallic character with the following important paragenetic assemblages: Quartz-Feldspar (Cu, Fe, Bi - sulphide), Quartz-Molybdenite (chalcopyrite, pyrite), Quartz-Magnetite-Bornite (chalcopyrite, sphalerite), Feldspar-Molybdenite (chalcopyrite), Pyrite-Sphalerite-Galena (molybdenite, tetrahedrite, Bi-minerals), Baryte-Fluorite (Fe, Cu, Pb-sulphides), and Carbonates-Galena-Sphalerite.

Early stages of mineralization started in high hydrothermal conditions (400°C), and relatively concentrated fluids (Na^+, K^+, Cl^- and F^-). Fluid inclusions in succeeding paragenetic assemblages point to gradual temperature decrease and concentration of ore-forming solutions. The activity of solutions is finished in temperature below 100°C.

There was discovered concentric primary thermic and mineralogical zonation in Myszkow area, that was probably connected with shape of a deeper intrusive body. (From the authors' abstract)

KASTRYKINA, V.M. and FIRSOVA, S.O., 1982, Characteristics of composition of metamorphosing fluid, p. 174-179, in Acid-basic properties of chemical elements, minerals, rocks and natural solutions: "Nauka," Moscow, 216 pp., 110 copies printed, price 2 rbls 50 kopecks (in Russian).

The Ladoga complex (Baltic shield) consists of metamorphic carbonates with tremolite, diopside, defernite, amphibole and amphibole-pyroxene schists and metapelites with andalusite, sillimanite, staurolite, garnet (T 400-750°C, P 4 kbar). The gases found in fluid inclusions are as follows: H_2O 0.47, CO_2 0.23, CO 0.05, CH_4 0.002, H_2 0.16, N_2 0.081 moles, $CO/CO_2 = 0.3$, $H_2/H_2O = 0.38$. The Sutama complex (Aldan shield) contains eclogite-like and high-Mg ultrabasic schists, high-Al gneisses (T 850-1030°C, P 9-10.5 kbar), and contains in inclusions the following gases: H_2O 0.22, CO_2 0.10, CO 0.10, CH_4 0.01, H_2 0.27, N_2 0.30, CO/CO_2 - 1.1, $H_2/H_2O = 1.24$, i.e. for moderate P fluid is oxidized, for high P - reduced. (Abstract by A.K.)

KAVILADZE, M.Sh., AREVADZE, D.V., YAROSHEVICH, V.Z. and GUBIYEV, N.V., 1982, Methods of studies of isotope composition of water from fluid inclusions in minerals, in Use of methods of thermobarogeochemistry during prospecting and studies of ore deposits, N.P. Laverov, ed.: Moscow, "Nedra" Publ. House, p. 102-108 (in Russian).

The results of studies of isotope composition of water are presented, including: 1) data on methods of decomposition of small amounts of water to elemental hydrogen and oxygen with use of zinc and xenon bifluoride, 2) methods of release of fluids from G/L inclusions by mechanical and thermal modes for distinguishing various genetic groups of inclusions. During mechanical opening a change of isotope composition is observed, connected with adsorption of water vapor on ground mineral. (Authors' abstract translated by A.K.)

KAY, E.A., 1982, A geochemical and fluid inclusion study of the arsenopyrite-stibnite-gold mineralization, Moreton's Harbour, Notre Dame Bay, Newfoundland: MS thesis, Memorial Univ. Newfoundland, St. John's, NF, Canada.

Indexed under Fluid Inclusions. (E.R.)

KEPEZHINSKAS, K.B. and TOMILENKO, A.A., 1982, Composition of fluid inclusions in minerals of the cordierite-anthophyllite wall-rocks of ores and its barren varieties: Zapiski Vses. Mineral. Obshch., v. 111, no. 5, p. 546-551 (in Russian). Authors at Inst. Geol. Geophys. of Siberian Br. of Acad. Sci. USSR, Novosibirsk, USSR.

The samples came from sulfide deposits of Finland and India. P inclusions in quartz, plagioclase, cordierite and garnet are either of LCO_2+LH_2O type or of LCO_2+LH_2O+GCO_2 type. LH_2O occupies up to 20 vol. % of inclusion. S inclusions in quartz have compositions: LH_2O, GCO_2, GCH_4, LCO_2+LH_2O, LH_2O+G, LH_2O+LCO_2+GCO_2. By gas chromatography of samples of anthophyllite (a) and quartz (q) the following gases in inclusions were found (all in mg per kg): CO_2 3.2-15.6 (a), 2.9-16.0 (q); CO 0.5-8.8 (a), 0.0-0.8 (q); CH_4 0.09-0.38 (a), 0.00-0.29 (q); H_2 0.0-1.7 (a), 0.0-0.3 (q); H_2O 48-571 (a), 26-206 (q); N_2 0.0-0.34 (a), 0.0-0.37 (q); ratio CO_2/H_2O 0.01-2.49 (a), 0.02-0.12 (q). The gas analyses yield the following conclusions: 1) various G compositions are present in quartz and anthophyllite from the same sample, 2) fluids are of CO_2-H_2O type plus some CH_4 and subordinate H_2 and N_2, 3) increased CO_2 (and CO) is typical of inclusions in ore bodies, when compared with barren rocks. Presence of some G components (CO_2, CH_4) was confirmed by cryometry; P at rock formation T, calculated from cryometric data, are in ranges 2-5 kbar. (Abstract by A.K.)

KERRICH, Robert, 1982, Geochemistry of Archaean lode gold deposits (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 329.

KERRICH, R. and HODDER, R.W., 1982, Archean lode gold and base metal deposits: evidence for metal separation into independent hydrothermal systems: Geology of Canadian Gold Deposits, Proc. CIM Symp. 1980, R.W. Hodder and William Petruk, eds.: Spec. Vol. 24, Can. Inst. Min. and Metal., p. 144-160. Authors at Dept. Geol., Univ. Western Ontario, London, Ontario, Canada.

Archean lode gold deposits of both vein and chemical sedimentary types typically have major enrichments of certain rare elements, including Au, Ag, As, Sb, B, W, Se, Te and Bi, coupled with low or negative enrichments of the more abundant and mobile base metals, Cu, Pb and Zn. On the other hand, in massive base metal sulphide deposits Au, Ag, Cu, Zn and in some instances Pb are all enriched by a factor of 200 to 2000 compared to background and there is no large separation of gold relative to the base metals.

The fluids from which gold was precipitated in veins were at temperatures of 320 to 480°C, at lithostatic pressure, had significant CO_2, and Na ≈ K; whereas the fluids which generated base metal deposits were at 250-300°C, at hydrostatic pressure, had $CO_2 << H_2O$ and Na>>K.

Many lode gold deposits are characterized by K, CO_2 and Si additions to their enveloping rocks, whereas base metal deposits typically have a fixation of Fe, Mg, Si and S in footwall rocks. Lode gold deposits may also have a relatively large halo of low-temperature oxidative, sodic spilitization in enclosing volcanic rocks, where seawater has later streamed into cooling stocks or flows that have initially acted to focus gold mineralizing fluids along thermal contraction fractures. The submarine environment is one hydrologically appropriate for the mixing of two initially independent hydrothermal systems, and the blending of their separate characteristics. Hence, lode gold and base metal massive sulphide deposits appear to be products of two distinctly different crustal and hydrological regimes. The former involves a high-temperature, high-pressure discharge of fluids which probably were generated during dehydration accompanying burial and progressive accumulation of volcanic-sedimentary sequences, with an additional influence of marine water in the near-sea-floor environment. The latter represents thermally driven convection of ocean water at lower temperatures and under hydrostatic conditions.

Auriferous fluid systems with only minor base metal content could plausibly be generated during dehydration accompanying burial and metamorphism, when the water-to-rock ratio is low and halogen availability is limited by crustal abundance (~60 ppm Cl). These two factors may constrain the uptake of the abundant base metals into fluids, but the solubility of rare elements is not constrained by limited fluid; and preferential uptake of Au along with other rare elements may be promoted if such elements compete more successfully for the limited halogens than the base metals, and/or have an alternative complexing agent such as CO or CO_3^{2-}. (Authors' abstract)

KHARITONOV, V.P., DEMIDOV, V.P., MOSHEVA, I.Yu., TESLENKO, V.V. and RAKOV, E.G., 1982, Interaction of sodium fluoride with aqueous vapor: Zhurn. Neorg. Khimii, v. 27, no. 10, p. 2687-2688 (in Russian). First author at Perm Div. of State Inst. of Applied Chemistry, Perm, USSR.

In the T range 900-995°C and PH_2O 0.03-0.45 atm the reaction of powdered NaF with aqueous vapor was studied; gaseous NaOH and HF are the reaction products. The reaction may be significant in studies of F-bearing melt inclusions. (A.K.)

KHARLAMOV, Y.S., 1978, Inclusions of melt in minerals from iron ores and carbonatites of the Kovdor pluton: Akad. Nauk SSSR Doklady, v. 239, no. 1, p. 169-172 (in Russian; translated in Doklady Acad. Sci. USSR, Earth Sci. Sects., v. 239, no. 1, p. 25-28, 1980).

Abstracted in Fluid Inclusion Research--Proc. of COFFI, v. 11, p. 101, 1978. (E.R.)

KHARLAMOV, Ye.S., 1980, Nature of iron-ore carbonatite deposit Kovdor (from thermobarogeochemical data of inclusion studies): Ph.D. thesis, Geol. Fac. of the Moscow Univ., USSR. Author at Inst. of Ore Deposits, Petrography, Mineralogy and Geochemistry of Acad. Sci. USSR, Moscow (in Russian).

KHASANOV, A.Kh., 1982, Genesis and age relations of acid metasomatites and gold ore formations in Gissaro-Alay (Central Tadzhikistan): Akad. Nauk SSSR Doklady, v. 262, no. 3, p. 686-688 (in Russian). Author at Tadzhik State Univ., Dushanbe.

Gold ores belong to skarn-gold-ore and quartz-sulfide-gold-ore formations. Skarn ores formed in pyroxene, quartz-garnet and garnet-pyroxene skarns on the contacts of small granitoid intrusions: Chinarsay, Voruy, Rarz, Sarymat etc., in zones of feldspar, amphibole, dolomite metasomatism and berezitization (Th 400-550°C, P 600-1000 bars, $Cl-SO_4-HCO_3$ solutions). Ore minerals (scheelite, arsenopyrite, native gold, Cu sulfies etc.) formed at Th 400-75°C from solutions changing from HCO_3-S to $Cl-HCO_3$ type. Quartz-sulfide-gold ores formed at 250-110°C (Th), from $SO_4-Cl-HCO_3$ solutions bearing K, Na, Ca, Mg plus gases: N_2, H_2, CH_4, CO_2. (Abstract by A.K.)

KHAZOV, R.A., KHAZOVA, V.I. and KAYRYAK, A.I., 1982, Fluorite mineralization in the Baltic Shield: Akad. Nauk SSSR Doklady, v. 263, no. 4, p. 964-966 (in Russian). First author at Inst. Geol. of Karelian Div. of Acad. Sci. USSR, Petrozavodsk, USSR.

Fluorite from skarn-greisen zone of the W. wing of the Uksin structure has Td 260-320°C. (A.K.)

KHETCHIKOV, L.N. and DOROGOVIN, B.A., 1982, Experimental data on formation conditions of two types of inclusions in quartz: Akad. Nauk SSSR Doklady, v. 267, no. 6, p. 1456-1457 (in Russian). Authors at Inst. of Lithosphere of Acad. Sci. USSR, Moscow.

Fine-grained quartz from many gold-ore subsurface deposits and some varieties of chalcedony-like quartz bear specific inclusions filled by amorphous (solid?) and G phases, sometimes even without G. The inclusions have tabular or spherical habit, freezing down to -100°C causes no changes, at +120 to +180°C one-phase inclusions develop G bubbles in them; the G bubbles join at 350-400°C to form one bubble. On cooling G bubbles disappear. Similar inclusions were obtained in synthetic quartz grown from soda solutions. In those runs the soda silica-bearing solutions split with formation of a light phase in upper part of autoclave and heavy, glassy phase in the bottom. Quartz from upper part of autoclave bears usual G/L inclusions, from the bottom - the inclusions similar to the above described ones. The paper describes the behavior of the synthetic inclusions on heating.

Inclusions in quartz crystals grown from albite-oligoclase + quartz in NH_4F 5% water solution, the following trapped minerals were found, identified by micro-X-ray-spectral analysis: chiolite, cryolite, villiaumite, orthoclase, nepheline. This proves that natural crystals with inclusions bearing polyphase inclusions, e.g., Volynian topaz, might crystallize from dilute solutions. (Abstract by A.K.)

KHITAROV, D.N., 1982, Importance and the present state of methods of analysis of bulk composition of liquid phase of inclusions, in Use of methods of thermobarogeochemistry during prospecting and studies of ore deposits, N.P. Laverov, ed.: Moscow, "Nedra" Publ. House, p. 25-31 (in Russian).

The author reviews essentially literature data on various methods of fluid composition determination: water leachate, cryometry, refractometry and ultramicrochemical analysis of individual opened inclusions, concluding on the usefulness and importance of the water leachate method for geological prospecting works. (A.K.)

KHITAROV, D.N., PASHKOV, Yu.N. and NAUMOV, V.B., 1982, Present-day state of methods for thermobarogeochemical studies, in N.P. Ermakov, ed., Thermobarogeochemistry in Geology - Materials of the Sixth All-Union Symposium on Thermobarogeochemistry: Vladivostok, Far East Sci. Center, Acad. Sci. USSR Pub. House, p. 125-130 (in Russian).

A review of presently used investigating methods with some recommendations; see also Fluid Inclusion Research--Proceedings of COFFI, vol. 11, 1978, p. 104. (A.K.)

KHITAROV, D.N., SHMARIOVICH, Ye.M., ASHIKHMIN, A.A. and TIKHOMIROVA, N.U., 1982, Solutions of gas-liquid inclusions in hydrothermal molybdenum-uranium deposits: Sovetskaya Geologiya, no. 12, p. 109-115 (in Russian). Authors at Ministry of Geology of the USSR, Moscow.

Main ions consist of HCO_3, Cl, Na, Ca, sometimes Mg; Th of inclusions are in range 150-300°C, pH calculated for T range 150-200°C is 5.3-7.6. Td varies from 210 to 300°C (quartz, calcite and ankerite). Total H_2S is in range <0.04-0.30, SO_4 <0.01-0.73, CO <0.03-0.30, CH_4 <0.01-0.30, H_2 <0.01-0.60 (all in moles per kg of H_2O), total concentration of components in solutions 5-48%. The authors calculated activities of H_2S, S^{2-} and SO_4, and hydrogen fugacity (44 to 40* Pa, mean value 141 Pa) and plotted the fluid inclusion results on the diagram $-lgfH_2$ vs pH with fields for Fe and S ionic forms, obtaining a compact field for solutions in U-Mo and U-P deposits of the studied ore province (name is not given). From the above data and appropriate reactions the uranium concentration in mineral-forming fluids was calculated as approximately equal $3 \cdot 10^{-2}$ g/l. (Abstract by A.K.)

*A misprint for 400?. A.K.

KHITAROV, N.I., MALININ, S.D., LEBEDEV, Ye.B. and SHIBAEVA, N.P., 1982, Partitioning of Zn, Cu, Pb and Mo between fluid phase and silicate melt of granite composition at elevated temperatures and pressures: Geokhimiya, no. 8, p. 1094-1107 (in Russian; English abstract). Authors at Inst. Geochem. and Anal. Chem., Moscow, USSR.

The paper presents the partitioning of Zn, Cu, Pb and Mo by NaCl and $NaHCO_3$ solutions at 700, 800, and 900°C, P = 2 kbar from granitic melt. (A.K.)

KHODAKOVSKIY, I.L. and DOROFEYEVA, V.A., 1981, The dielectric constant of water and its derivatives with respect to temperature and pressure in the ranges 0-300°C and 1-5000 bar: Geokhimiya, 1981, no. 8, p. 1174-1184 (in Russian; translated in Geochem. Int'l. v. 14, no. 4, p. 129-141, 1982).

KHODAKOVSKIY, I.L., DOROFEYEVA, V.A., MELNIKOVA, G.L., GERANIN, A.V. and RY'ZHENKO, B.N., 1981, Thermodynamic parameters of liquid water at 0-300°C and pressures up to 10,000 bar: Geokhimiya, no. 2, p. 208-220 (in Russian; translated in Geochem. Int'l., v. 18, no. 1, p. 135-147, 1982).

Abstract in Fluid Inclusion Research--Proceedings of COFFI, v. 14, p. 106. (E.R.)

KHODAKOVSKIY, I.L. and SHIKINA, N.D., 1981, The role of carbonate complexes in mercury transport in hydrothermal solutions (experimental studies and thermodynamic analysis): Geokhimiya, 1981, no. 5, p. 671-682 (in Russian; translated in Geochem. Int'l., v. 18, no. 3, p. 32-43, 1982).

KHOTEEV, A.D., 1982, Methods and devices for decrepitation studies, in Use of methods of thermobarogeochemistry during prospecting and studies of ore deposits, N.P. Laverov, ed.: Moscow, "Nedra" Publ. House, p. 76-85 (in Russian).

The laboratory problems of decrepitation analysis, mechanism of opening of G/L inclusions on heating, and influence of sensitivity of the decrepitometers on the final result of analysis are discussed. The block diagram of the decrepitometer and peculiarities of construction of working units are presented. Certain methods of control of the decrepitometer are given. (Author's abstract translated by A.K.)

KHRENOV, A.P., 1982, Dynamics of eruptions and processes of magma crystallization: "Nauka," Moscow, 132 pp., 700 copies printed, price 1 rbl. 70 kopecks (in Russian). Author at Volcanolog. Inst. of Far-East Sci. Center of Acad. Sci. USSR, Petropavlovsk Kamchatskiy, USSR.

Th of melt inclusions in megacrystals of plagioclase from lavas of the Southern Break of the Tolbachik Great Fissure Eruption are in ranges 1080-1100°C or 1140-1150°C, T interval of melting of inclusion filling ≤40°C, indicating a very low P during plagioclase crystallization. (A.K.)

KINNAIRD, J.A., BOWDEN, P. and LETERRIER, J., 1982, Mineralization of the biotite granite of the Ririwai complex, Nigeria (abst.): J. Geol. Soc. London, v. 139, part 1, p. 97.

The centrally situated biotite granite of the Ririwai ring complex varies considerably in texture and mineralogy. Related to the biotite granite are two phases of mineralization. The first, a dispersed niobium-rich phase in which the granite is texturally modified, is followed by an economically more important vein-controlled zinc-tin phase of mineralization with associated wallrock alteration. Variable mica compositions and feldspar structural states probably reflect changes in the composition of the mineralizing fluids. Rb-Sr isotopic studies on the granite and the late-stage cross-cutting lode system suggest that isotopic homogenization continued to low temperatures. Available fluid inclusion data from the mineralized lode indicates a range of depositional temperatures of 250-400°C. (Authors' abstract)

KITA, Itsuro, MATSUO, Sadao and WAKITA, Hiroshi, 1982, H_2 generation by reaction between H_2O and crushed rock: an experimental study on H_2 degassing from the active fault zone: J. Geoph. Res., v. 87, no. B13, p. 10,789-10,795. First author at Res. Inst. Underground Resources, Mining College, Akita Univ., Akita 010, Japan.

Granite and quartz were crushed under moist conditions in the temperature range of 25-270°C, in order to obtain the information on the mechanism operative for H_2 degassing along active faults. It was found that the amounts of H_2 gas released by crushing granite and quartz increased with temperature up to around 200°C and then decreased suddenly. The results indicate that H_2 gas is generated by a chemical reaction between water and such radicals as Si · and Si-O · formed on the fresh surfaces when the Si-O-Si bonds are destroyed by crushing and that the existence of a maximum for amount of H_2 gas is due to the decrease of the lifetime of Si-O · radical at the temperature higher than about 200°C. The results lend credence to the possibility that H_2 gas is generated in the temperature range of 25-270°C along the active fault through the reaction between groundwater and the fresh surfaces of underground rocks formed by the fault movements. (Authors' abstract)

KITAEV, N.A., 1982, Zones of gold-ore mineralization in the Eastern Transbaikalia: Geologiya i Geofizika, no. 2, p. 53-60 (in Russian). Author at Inst. Geochem., Irkutsk, USSR.

Vein gold-ore mineralization in terrigeneous-volcanic deposits, connected with Middle Jurassic-Lower Cretaceous tectonic-magmatic activization (deposit name not given) is divided into several depth zones. The subsurface zone of Au-Ag Hg-Sb-sulfide type formed from chloride-alkaline solutions rich in CO_2 and SiO_2, Th 285-70°C, P 30-40 atm. Subvolcanic (lower than the previous) zone with Au, electrum, quartz, tourmaline, pyrite formed at Th 395-70°C, P 750-650 atm; moderate-depth zone with Au-sulfide-poor mineralization and Au-bearing albite-actinolite-apatite-biotite metasomatites formed at Th 500-300°C, P ~1000 atm with variable CO_2 concentrations. (Abstract by A.K.)

KITAMURA, Masao, KOUCHI, Akira, HOSOYA, Syoichi and SUNAGAWA, Ichiro, 1982, Growth and dissolution of $NaClO_3$ crystal in aqueous solution: Mineral. J., v. 11, no. 3, p. 119-137. First author at Dept. Geol. & Mineral., Faculty of Sci., Kyoto Univ., Sakyo-ku 606, Japan.

Growth and dissolution rates of {100} faces of $NaClO_3$ crystals of about 0.5 mm across have been measured, along with in-situ observations of both processes, under a wide range of well-controlled super- and undersaturations, 1.1~49%, and 1.6~4.5%, respectively. Dissolution mechanism is also briefly discussed, in which the importance of interface kinetics is stressed. The observations on the recovery process from rounded to facetted morphologies and on the occlusion of liquid inclusions are described as well. (From the authors' abstract)

KLEIN, C.W., McNITT, J.R., SANYAL, S.K., CHE, M., TOLENTINO, B.S., ALCARAZ, A. and DATUIN, R., 1982, Geochemistry of the Palimpinon geothermal field, southern Negros, Philippines: Geothermal Resources Council, Transactions, v. 6, p. 285-288. First author at GeothermEx, Inc., California, USA.

Areal patterns of aquifer fluid chemistry at Palimpinon are consistent with patterns of gas chemistry in indicating that the principal source of deep fluid feeding the production zones of existing wells lies to the south of the central part of the reservoir. Enthalpy-chloride mixing relationships indicate a deep parent fluid at about 310°C with about 3,800 mg/l Cl. Boiling and mixing processes have produced variations of chloride within the reservoir from about 3,000 to 4,100 mg/l. Fluids at the western end of the reservoir appear to have evolved principally through mixing of the deep fluid with dilute recharge, whereas along the eastern fringe of the central area mixing has followed concentration by boiling. The least evolved fluids are trapped by wells which lie along a N-S trend which enters the central part of the reservoir from the south. This trend is fairly well defined by contours of the chemical geothermometers, Na/K, and Cl. It may be related to structures along which the principal upwelling into the reservoir, and/or feeding from the south, is occurring. (Authors' abstract)

KNAUTH, L.P., 1982, The origin of water in salt (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 532-533. Author at Dept. Geol., Arizona State Univ., Tempe, AZ 85287.

Water occurs in domal and bedded salt deposits in variable amounts ranging from a trace constituent in pure halite crystals to actual brine pockets and major "leaks" in salt mines. The isotopic composition of this water varies enormously and can be used to determine its origin.

One type of leak in four Gulf Coast salt mines has water with $\delta^{18}O$ values between +7.6 and +11.5, and δD values between -2 and -28. These have been interpreted as formation waters which penetrated the salt during diapiric rise of the salt stock. Others fall on the meteoric water line and are clearly meteoric waters which have penetrated the salt. In some cases this may be related to mining activities, but in others to geological variables within and around the salt dome. Trace water in domal halite also has a wide range of O^{18}-rich isotopic compositions which can similarly be interpreted in terms of the origin of the water. In some cases this information can be applied to the origin of caprock and anomalous zones in the salt.

The trace water content of typical halite in bedded salt is at least ten times larger than the average water content of domal salt. δO^{18} and δD in bedded salt from the Paradox basin range from -1 to +10, and -10 to +90, respectively. These data may indicate that fluid inclusions in this halite are various mixtures of connate evaporite water and formation water that have penetrated the salt.

The selection of a salt nuclear waste repository depends upon the degree to which a salt deposit might be penetrated by external waters. The present isotopic signature of water in salt as meteoric, formation, or connate water provides a powerful means of evaluating whether the salt has been previously penetrated by water and whether it might be in the future. (Author's abstract)

KNAUTH, L.P. and EPSTEIN, Samuel, 1982, The nature of water in hydrous silica: Am. Min., v. 67, p. 510-520. First author at Dept. Geol., Arizona State Univ., Tempe, AZ 85287.

The nature of water in hydrous silica has been investigated by measuring the hydrogen isotopic composition of successive increments of water evolved under vacuum during heating of the silica to 1000°C. Water increments evolved from Monterey diatomite are progressively enriched in deuterium up to 87°C, behaving isotopically like free, structurally nonessential water subjected to distillation. Between 87° and 218°C successive water increments have constant δD values, suggesting a bound water component. Above 218°C water with relatively lower δD values is outgassed, and this water is interpreted as hydroxyl.

Isotope exchange experiments at 25°C and 100°C in which the silica is exposed to D-enriched water and analyzed as above suggest at least 5 types of water in Monterey diatomite. (1) At least 2 wt.% water occurs as adsorbed or mechanically trapped H_2O which cannot be completely pumped away at 25°C and exchanges readily with D-enriched water. (2) Approximately 3.6 wt.% occurs as H_2O in sites protected from interaction with external water at 23°C, but exchanges isotopically at 100°C. (3) Approximately 0.2 wt.% occurs as surface hydroxyls which exchange at 23°C. (4) Approximately 1.3 wt.% occurs as nonsurface hydroxyls which exchange at 100°C. (5) Approximately 0.9 wt.% water exists as nonsurface hydroxyls which exchange slowly, if at all, with waters external to the silica.

The nonessential and easily exchangeable water fraction of diatomite cannot be readily separated from other water in the silica. However, water evolved above 700°C may be derived from hydroxyl groups which have preserved a geologically useful isotopic record.

Applications of this analytical procedure to other hydrous minerals may help to refine the stoichiometry of various water components in these minerals. (Authors' abstract)

KOCHETKOV, A.Ya., 1982, New type of copper porphyry ore mineralization: Akad. Nauk SSSR Doklady, v. 267, no. 2, p. 430-432 (in Russian). Author at Inst. Geol. of Yakutian Div. of Siberian Branch of Acad. Sci. USSR, Yakutsk.

One of the massifs of the El'konskiy horst, Aldan Shield, bears stockworks of veinlet-disseminated sulfide mineralization. Td of sulfides range from 200 to 300°C with maxima at 240-250°C (pyrite), 230-240°C (chalcopyrite) and 310°C (bornite). (A.K.)

KOGA, Akito, TAGUCHI, Sachihiro and MAHON, W.A.J., 1982, The use of volatile constituents in geothermal fluids for assessing the type, potential and near surface permeability of a geothermal system: the Broadlands geothermal area, N.Z.: Proc. Pacific Geothermal Conf. 1982 Part 1, Univ. Auckland Geothermal Inst., Auckland, NZ, p. 135-138. First author at Res. Inst. of Indust. Sci., Kyushu Univ., Kasuga 816, Japan.

Volatile constituents surveys were conducted to evaluate the suitability as geochemical indicators in a gassy system; Broadlands, New Zealand. Samples were collected from many places across the system for soil Hg, soil air Hg, CO_2, and Rn and Tn, respectively. The distribution map was compared with the local structure including fault localities and stratigraphy. Comparison was also made with the physical conditions in the aquifer including near surface temperatures and 300 and 600 m isotherms.

Zones of high concentrations of volatile components on the western side of the system appeared to correspond with distinctive geological and physical structures and anomalies, but not so obvious on the eastern side except Hg in soil air. This may result from the thick sequence of low porosity and permeability lacustrine sandstone and siltstone beds (Huka Falls Formation) which occur in the east. (Authors' abstract)

KOGARKO, L.N. and KRIGMAN, L.D., 1981, Fluorine in silicate melts and magmas: "Nauka" Publ. House, Moscow, 128 pp., 1000 copies printed, price 1 rbl. 30 kopecks.

The following Table of Contents shows its use for interpretation of melt inclusions: Structure of silicate melts. Fluorine influence on viscosity of silicate melts. Volume properties of fluoride-silicate melts. Infrared spectra of fluoride-silicate glasses. State of silicate anions in fluoride-silicate melts. Fluorine separation in gas phase. Problems of fluorine geochemistry in magmatic processes. Peculiarities of parageneses of some F-bearing minerals (thermodynamic calculations and experimental studies). Phenomena of immiscibility in fluorine-silicate melts (differentiation of fluorine-bearing alkaline melts and immiscibility in granite F-rich melts). F role as acid mineralizing agent in magmatic processes. (A.K.)

KOGARKO, L.N., LAZUTKINA, L.N. and ROMANCHEV, B.P., L982, Problems of genesis of the eudialyte mineralization: Geokhimiya, no. 10, p. 1415-1432 (in Russian; English abstract).

Eudialyte specimens for studies were taken from agpaitic complexes of Lovozero, Ilímaussaq, Norra Cherr, Pilansberg, Khibiny, Los Island and Koksharovka. Inclusion size in eudialytes ranges from 5 to 120 μm. Inclusions are of crystallized melt, crystal-fluid, G and solid types. In crystallized inclusions 5-6 dms occupy ~95% of vacuole volume, plus G and L 3-7 vol.%. Crystal-fluid inclusions bear 2-3 dms, G occupies 7-15% of vacuole volume. Dms are the same minerals as in rocks: K-feldspar, nepheline, pyroxene, eudialyte, lamprophyllite (identification by electron microprobe). Th in melt or hydrous melt, measured for specimens from Lovozero, and from mountains Engporr-Ninchurt, Vavnbed, Karnasurt, Kedykverpakhk and Parga, are in ranges 720-900°C (16 specimens). The highest Th are for porphyroid luiavrites (820-900°C); most specimens yielded Th 860-820°C, and coarse-grained eudialytites bear in inner cores of eudialyte crystals melt inclusions with Th ~820°C, and in outer cores - crystal-fluid inclusions with Th 720-770°C. Nepheline from eudialyte-bearing rocks yielded Th 830-850°C, aegirine 800-830°C, microcline 810-860°C. The close Th values suggest anchieutectic composition of parent melt. (Abstract by A.K.)

KOGARKO, L.N. and ROMANCHEV, B.P., 1982a, Phase equilibria in alkaline melts: Zapiski Vses. Mineral. Obshch., v. 111, no. 2, p. 167-182 (in Russian). Authors at Inst. of Geochem. and Anal. Chem., Moscow, USSR.

The paper presents results of melt inclusion studies, rock melting and crystallization experiments with synthetic components, which were performed for effusive alkaline-basalt series of oceanic islands, ultrabasic rocks and carbonatites of rift zones in E. Africa and intrusive massifs of nepheline syenites of the Kola Peninsula. The E. African rocks yielded Th 1260-1220°C (alkaline picrites) → 1240-1140°C (olivine melanephelinites) → 1080-1020°C (melanephelinites) → 1030-840°C (nephelinites) → 810-760°C (phonolites). Dm in inclusions are typical of the following (next) member of the mineral paragenesis in descending the rock sequence presented above. The rocks from St. Helen Island formed at Th 1300-1280°C (ankaramites) → 1280-1240°C (ankaramite-basalts) → 1260-1200°C (olivine basalts) → 1230-1050°C (trachybasalts) → 1040-1000°C (trachyandesites) → 980-920°C (trachytes); the rocks from Gran Canaria - 1330-1260°C (ankaramites) → 1290-1200°C (ankaramite-basalts) → 1280-1080°C (olivine alkaline basalts) → 1100-980°C (ordanchite); less alkaline series from Gran Canaria ankaramite → phonolite 1300-900°C; effusive series from Tristan da Cunha ankaramite → trachytes 1300-990°C. The rocks formed under relatively dry conditions. Experiments with rock melting of the above locations and from Ilímaussaq, Lovozero and Khibiny were made under atmospheric and elevated P, and liquidus and solidus curves were plotted. E.g. Th in the earliest mineral - nepheline - were as follows for the rocks: from Khibiny - 980°C, from Lovozero - 970°C and from Ilímaussaq - 900°C, being also very close to liquidus T of the intrusions. Five rocks with distinct immiscibility in inclusions were found: in nephelinites and phonolites of the carbonatite complexes Oldoyniyo-Lengai and Quarakha in E. Africa, in ordanchites from Gran Canaria, in phonolites from St. Helen, in sodalite- and nosean syenites of the Lovozero and in villiaumite-bearing nepheline syenites from Khibiny and Lovozero. Nepheline from volcano Oldoyniyo-Lengai bears inclusions of glass and microcrystalline carbonate aggregate of globular habit, which melted with formation of two immiscible melts at 800 and 840°C. Above those T the equilibrium (melt+melt+gas) was observed. By water leachate(sic) the microcrystalline aggregate was determined to be a mixture of Na, Ca and K carbonates, and apatite. Ordanchites bear inclusions, in pyroxene, apatite, plagioclase and hauyne, which contain nosean melting at ~1000°C with formation of two immiscible melts; at 1040°C apatite and magnetite melted; during pyroxene melting the amount of immiscible salt melt decreased until complete disappearance of immiscibility at 1060°C. The immiscibility found may suggest the possible immiscibility origin of minerals of the nosean-hauyne group in rocks of the ordanchite type. Phonolites and trachytes from St. Helen bear in feldspar and sodalite inclusions with dms: halite and sodalite, which form immiscible melts at 880-850°C; up to 1000°C those inclusions did not homogenize. Inclusions with dense CO_2 in olivine and augite yielded P 1.9-5.8 kbar (Th 1280-1300°C) for ankaramites from Gran Canaria, St. Helen and Tristan da Cunha. Also behavior of ore elements in alkaline magmatic process is discussed. (Abstract by A.K.)

KOGARKO, L.N. and ROMANCHEV, B.P., 1982b, Differentiation of alkaline magmatic series of S. Atlantic islands, in N.P. Ermakov, ed., Thermobarogeochemistry in Geology - Materials of the Sixth All-Union Symposium on Thermobarogeochemistry: Vladivostok, Far East Sci. Center, Acad. Sci. USSR Pub. House, p. 73-79 (in Russian).

For abstract, see Fluid Inclusion Research--Proceedings of COFFI, vol. 11, 1978, p. 105-106. (A.K.)

KOKIN, A.V., 1982, Coincidence of stage of mineral formation with temperatures of polymorphism of water and quartz in hydrothermal deposits of Yakutia: Akad. Nauk SSSR Doklady, v. 262, no. 1, p. 198-201 (in Russian). Author at Allakh-Yun' Geol.-Prosp. Expedition of Yakutian Production-Geol. Enterprise.

Total of 3594 samples of quartz, sulfides and gold were decrepitated and T of maximum P increment was measured. Statistical elaboration of the results yielded seven T maxima of fluid-saturation of minerals (in °C): 50 ± 11, 85 ± 7, 160 ± 13, 222 ± 18, 265 ± 17, 340 ± 9, 430 ± 17, similar to T of polymorphic changes of L water: 40, 85, 165, 225, 270, 340, 410°C(sic). (A.K.)

KOLESNIKOV, P.P., NAYBORODIN, V.I., PRISTAVKO, V.A. and BORKHODOEV, V.Ya., 1982, Distribution of chlorine in Late-Mesozoic granitoids and ore deposits in the North-East of the USSR: Izvestiya Akad. Nauk SSSR - Ser. Geol., no. 5, p. 35-45 (in Russian). Authors at North-East Complex Sci.-Res. Inst. of Far-East Sci. Center of Acad. Sci. of USSR, Magadan.

S inclusions in minerals of Peresyp granitoid intrusive in the Okhotsk complex have Th 550-700°C and they bear chlorides of alkaline and alkaline earth metals. (A.K.)

KOLKER, Allan, 1982, Mineralogy and geochemistry of Fe-Ti oxide and apatite (nelsonite) deposits and evaluation of the liquid immiscibility hypothesis: Econ. Gol., v. 77, p. 1146-1158. Author at U.S. Geol. Survey, National Center, Mail Stop 917, Reston, VA 22092.

Modal mineralogy determined for 32 Fe-Ti oxide and apatite rocks from localities in Virginia, New York, Quebec, Norway, and Sweden largely supports the 2:1 oxide:apatite ratio suggested as a eutectic mixture by Philpotts (1967). A fairly consistent suite of accessory minerals, including biotite, clinoamphibole, spinel, zircon, and sulfides, is present. Some silicate accessory minerals tend to form glomeroporphyritic intergrowths in an equigranular matrix of nelsonite, suggesting that the accessories are xenocrysts that have been trapped in an oxide-apatite liquid. This liquid may represent an extreme case of partitioning of high charge-density cations into a low silica, phosphorus-enriched immiscible melt.

Temperature and oxygen fugacity estimates for oxide pairs in nelsonites range from 600° to 1,000°C and 10^{-20} to 10^{-11} atm fO_2 and bracket an equilibration path that is close to the FMQ buffer curve. Several stages of exsolution are evident in Fe-Ti oxides of some deposits. Nelsonites contain fluorapatite that is enriched in light lanthanides. The occurrence of nelsonite "dikes" in Roseland anorthosite and associated rocks of the Roseland-Piney River district of Virginia is explained by the infilling of fractures with nelsonite liquid that has settled out of an overlying ferrodiorite pluton. (Author's abstract)

KOLONIN, G.R., 1982, On technique of determination of oxidation-reduction conditions of hydrothermal ore formation, in N.P. Ermakov, ed., Thermobarogeochemistry in Geology - Materials of the Sixth All-Union Symposium on Thermobarogeochemistry: Vladivostok, Far East Sci. Center, Acad. Sci. USSR Pub. House, p. 156-164 (in Russian).

For abstract, see Fluid Inclusion Research--Proceedings of COFFI, vol. 13, 1980, p. 127-128. (A.K.)

KOLPAKOVA, N.N., 1982a Laboratory and field studies of ionic equilibria in the Sb_2S_3-H_2O-H_2S system: Geokhimiya, no. 1, p. 47-55 (in Russian.)

KOLPAKOVA, N.N., 1982b Determination of hydrogen sulfide in the fluid inclusions of the gangue minerals: Geokhimiya, no. 2, p. 271-276 (in Russian).

Potentiometric technique of determination of sulfide sulfur in the fluid inclusions of the gangue minerals has been developed. The technique is based upon the measurement of potential of the sulfide-silver electrode in the alkaline (pH 11 to 12) water extractions. A sensitivity limit of the electrode is 10^{-7} M total sulfide sulfur. More than a hundred determinations of concentrations of sulfide sulfur in the fluid inclusions were made. Maximum concentrations (10^{-1} to 10^{-2} M total sulfide sulfur) were determined in gangue minerals associated with antimonite. Concentrations as large as 10^{-2} to $10^{-2.5}$ M total sulfide sulfur are typical for the base-metal deposits. Low concentrations of hydrogen sulfide were observed in quartz and cassiterite of the high-temperature quartz-cassiterite deposits. (Author's abstract)

KOLTUN, L.I. and PIZNYUR, A.V., 1982, Genetic models of endogene ore formations: Mineralog. Sbornik, v. 36, no. 2, p. 115-116 (in Russian; English abstract). Authors at L'vov Univ., L'vov, Ukrainian SSR.

Note about the Novosibirsk meeting "Genetic models of endogene ore formations" (20-22-V-1981), where some fluid inclusion lectures were presented. (A.K.)

KONNERUP-MADSEN, J. and ROSE-HANSEN, J., 1982, Volatiles associated with alkaline rift activity: fluid inclusions in the Ilímaussaq Intrusion and the Gardar granitic complexes (south Greenland), in R. Kruelen and J. Touret (guest eds.), Current Research on Fluid Inclusions: Chem. Geol., v. 37, p. 79-93. Authors at Inst. Pet., Univ. Copenhagen, DK-1350 Copenhagen K, Denmark.

Fluid inclusions in minerals from Si-oversaturated and Si-undersaturated alkalic igneous complexes belonging to the Precambrian Gardar Rift Province in South Greenland contain distinctly different carbon-bearing gases: granites and quartz syenites are characterized by CO_2 and only minor CH_4 whereas agpaitic nepheline syenites are dominated by hydrocarbons (essentially CH_4) and contain only insignificant amounts of CO_2 and/or CO. In the alkaline Ilímaussaq Intrusion the hydrocarbon-rich gases may well reflect equilibration with graphite at magmatic temperatures and at oxygen fugacities approaching those defined by the synthetic MW buffer reaction. In general, formation of hydrocarbon gases in agpaitic nepheline syenites is considered to reflect the fulfillment of three basic conditions: (1) low oxygen fugacities; (2) a wide temperature range of crystallization and a low-temperature solidus; and (3) retention of volatiles during crystallization. The characteristic carbon-bearing vapor associated with continental alkaline igneous activity is, however, considered to be CO_2. (Authors' abstract)

KONONOV, V.I. and POLYAK, B.G., 1982, Identification of the juvenile component in modern hydrothermal systems: Geokhimiya, no. 2, p. 163-177. Authors at Geol. Inst., Acad. Sci. USSR, Moscow, USSR.

Localized plutonic heat and mass flow occurs in any large hydrothermal system, and the geochemical evidence of this should be found in products of hydrothermal and volcanic activity. However, traditional studies of the gas and salt compositions of thermal fluids do not give unambiguous proof of the the presence or absence of juvenile components. Evidence of the present-day flow of mantle material to the surface of the Earth can be found from the isotope geochemistry of hydrogen, oxygen, carbon, sulfur, strontium, argon, and helium. Unambiguous conclusions are provided in this respect only by the helium. The helium present in thermal fluids derived from the present-day mantle clearly points to a juvenile component and reduces the uncertainties in interpreting the isotope compositions of the other elements. The best way of solving the problem is to analyze all the isotope data in conjunction with the thermal and material balances. (Authors' abstract)

KOONS, P.O., 1982, An experimental investigation of the behavior of amphibole in the system Na_2O-MgO-Al_2O_3-SiO_2-H_2O at high pressures: Contrib. Mineral. Petrol., v. 79, p. 258-267.

KOPP, O.C., 1982, Comment on "Problems in determination of the water content of rock-salt samples and its significance in nuclear-waste storage siting:" Geol., v. 10, no. 6, p. 330.

A comment on paper by Roedder and Bassett, 1981 (see abstract in Fluid Inclusion Research--Proceedings of COFFI, v. 14, p. 175, 1981). (E.R.)

KORZHINSKIY, M.A., 1981, Apatite solid solutions as indicators of the fugacity of HCl^0 and HF^0 in hydrothermal fluids: Geokhimiya, 1981, no. 5, p. 689-706 (in Russian; translated in Geochem. Int'l., v. 18, no. 3, p. 44-60, 1982). Author at Inst. Exper. Min., Acad. Sci. USSR, Chernogolovka, USSR.

Ag-AgCl and CaF_2-$Ca(OH)_2$ buffers have been used at 500-700°C and 4 kbar to examine the dependence of the anion composition of apatite Ap on the fugacities (activities) of HCl^0 and HF^0 in hydrothermal fluid. It is found that there is a linear relationship between XCl-Ap and $aHCl^0$. The proportion of OH in Ap increases with temperatures in the HCl-H_2O-Ap system and in the HF-H_2O-Ap one at $aHCL^0(aHF^0)$ = const. In the HCl-HF-Ap system at $aHCl^0/aHF^0 = 1$, the coexisting Ap is clearly fluorian. The proportion of chlorine in Ap relative to fluorine increases with temperature. The pressure has only a slight effect on the distribution of the components in the HCl-HF-H_2O-Ap system. (Author's abstract)

KORZHINSKY, D.S., PERTSEV, N.N. and ZOTOV, I.A., 1982, Transmagmatic fluids and magmatic ore formation - a problem of mineralization mantle source (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 28-29.

KOSALS, Ya.A., 1982, Crystallization temperatures of granitoids and their rare-metal ore capacity, in N.P. Ermakov, ed., Thermobarogeochemistry in Geology - Materials of the Sixth All-Union Symposium on Thermobarogeochemistry: Vladivostok, Far East Sci. Center, Acad. Sci. USSR Pub. House, p. 38-48 (in Russian).

Considerations based on earlier published melt inclusion data. (A.K.)

KOSALS, Ya.A. and TEMNIKOV, Yu.I., 1982, Pegmatite-bearing granitoids of the Transbaikal region: Trans. Inst. Geol. Geoph. SB AS USSR, v. 519, 300 pp. (in Russian).

Petrochemical and geochemical features of granitoids of various ore concentration (pegmatite-bearing, tin-tungsten-bearing and rare metal) are discussed. Comparative geochemical characteristic of rare-metal pegmatites, lithium-fluorine granites and ongonites is presented. Thermobarogeochemical data on the temperature conditions of granitoid and pegmatite crystallization of various deep formations and facies are summarized. (From the publisher's abstract)

KOSKI, R.A. and COOK, D.S., 1982, Geology of the Christmas porphyry copper deposit: Gila County, Arizona, in S.R. Titley, ed., Advances in Geology of the Porphyry Copper Deposits, Southeastern North America, p. 353-374.

Includes some reference (p. 370) to inclusion data. (E.R.)

KOSUKHIN, O.N., 1982, Certain peculiarities of processes of chamber pegmatite formation, in N.P. Ermakov, ed., Thermobarogeochemistry in Geology - Materials of the Sixth All-Union Symposium on Thermobarogeochemistry: Vladivostok, Far East Sci. Center, Acad. Sci. USSR Pub. House, p. 111-114 (in Russian).

For abstract, see Fluid Inclusion Research--Proceedings of COFFI, vol. 11, 1978, p. 111-112. (A.K.)

KOTEL'NIKOV, A.R., BYCHKOV, A.M. and CHENAVINA, N.I., 1981, The distribution of calcium between plagioclase and a water-salt fluid at 700°C and P_{fl}=1000 kg/cm^2: Geokhimiya, 1981, no. 5, p. 707-721 (in Russian; translated in Geochem. Int'l., v. 18, no. 3, p. 61-75, 1982).

KOTOV, N.V., DOMNINA, M.I., VOROB'YEV, P.V., KOVNURKO, G.M. and GALIBIN, V.A., 1981, Experimental determination of the composition of the albitizing solution during hydrothermal transformation of granite in the presence of NaF: Geokhimiya, no. 9, p. 1353-1361 (in Russian; translated in Geochem. Int'l., v. 18, no. 4, p. 47-54, 1982).

Abstract in Fluid Inclusion Research--Proceedings of COFFI, v. 14, p. 113-114. (E.R.)

KOTOV, N.V., KOL'TSOV, A.B., ZAKHAREVICH, K.V., DONSKIKH, A.V., KUZNETSOV, V.P., KOL'TSOVA, A.G. and GALIBIN, V.A., 1982, Thermodynamic conditions during the formation of gold ore-bearing metasomatites in blackschist rocks of western Uzbekistan: Vestn. Leningr. Univ., Geol., Geogr., no. 3, p. 13-19 (in Russian).

Metasomatism of the Ordovician shales in an area of Uzbek Au-ore occurrence proceeded with the formational succession sericitized rocks → albitized rocks → argillites. The mineralogical compositions are quant. estd. from chem. analyses of the metasomatites, based on the actual compns. of muscovites, chlorites, and carbonates, as determined by X-ray, chem., and optical methods. In the upper, near-surface part of the ore occurrence sericitized rocks are enriched in muscovite and quartz and argillites in kaolinite. Th of quartz suggest that sericitization occurred at ~350° and kaolinite formation was at 225-75°. The ion composition and degree of mineralization of the liquids in fluid inclusions were estd. from the calcining and anal. of distd.-water exts. from finely crushed samples. The information from the fluid-inclusion and mineralogical-petrol. studies is used to plot the course of mineral formation during argillization, in a temp. vs. log [KCl]/[HCl] mineral-stability diagram. The non-steady-state thermodn. regime near the ground surface produced the sepn. of fluid mineralized phases enriched in acidic volatile components. Boiling of the fluid led to enrichment in CO_2, accounting for massive pptn. of quartz in near-surface parts of the ore occurrence. (CA 98: 19800f)

KOTRA, R.K., 1982, Organic compounds in three Antarctic meteorites: Meteoritics, v. 17, p. 238-239.

KOTRA, R.K. and GIBSON, E.K., Jr., 1982, Direct analysis of fluid and vapor inclusions using laser microprobe-gas chromatography (abst.): EOS, Trans. Am. Geophys. Union, v. 63, p. 450. First author at Lockheed, C23, NASA/Johnson Space Center, Houston, TX 77058.

A technique for the direct chemical analysis of trapped fluids and vapors in rocks and minerals has been developed. A Nd-glass laser microprobe has been coupled to a gas chromatograph. The system permits the analysis of individual inclusions or surrounding matrix by selectively opening inclusions or heating the matrix by pulsing the laser under controlled conditions. A helium stream sweeps the released gases into a chromatographic column and the ultra-sensitive helium ionization detector of the gas chromatograph is used for the identification and quantitation. Parts per billion and less levels of permanent gases, hydrocarbons, and water can be detected.

Studies on terrestrial basalts, meteorites, tektites and other mineral phases will be discussed. Analysis of trapped inclusions of the Hualala (sic) basalt, Hawaii, indicates the presence of trapped CO_2 along with CO and O_2. Additional potential applications of the newly developed technique which will also be discussed include the analysis of fluid inclusions in meteorites and analysis of cosmic dust particles. (Authors' abstract)

KOTRA, R.K., GIBSON, E.K. and URBANCIC, M.A., 1982, Release of volatiles from possible Martian analogs: ICARUS, v. 51, p. 593-605. First author at Lockheed EMSCO C-23, NASA Johnson Space Center, 1830 NASA Rd. 1, Houston, TX 77058.

Viking data suggest the presence of volatile-rich materials in the Martian regolith. The thermal stabilities of mineral phases and their volatile release profiles were studied in detail in our laboratory. Thermal analysis, combined with mass spectrometry, was applied to the study of the behavior of carbonates, sulfates, hydrates, and clays. The results indicate that these techniques are useful in the preliminary mineralogical characterizations of volatile-rich minerals. However, our results also indicate that great care must be taken in the incorporation into planetary probes of such methods as heating rates, pressure, composition of atmospheres, grain size, etc., because these factors affect volatile release. (Authors' abstract)

KOVALENKER, V.A., 1982, Tin minerals and their parageneses from a subsurface gold ore deposit: Geol. Rudn. Mest., v. 24, no. 1, p. 31-41 (in Russian). Author at IGEM, Moscow, USSR.

The studied deposit (name not given) occurs in the Chatkalo-Kuramin area, Middle Tyan'-Shan'. Th of inclusions in quartz, barite, carbonates and sphalerite are about 300-250°C in the beginning of each of four stages of the deposit formation, and 130-90°C in the end of the stages(sic). Periodic boiling of parent solutions was noted. (A.K.)

KOVALENKO, V.I., ANTIPIN, V.S., NAUMOV, V.B., IVANOVA, G.F. and VLADYKIN, N.V., 1982, Mineralogical criteria of connection of rare-metal ore mineralization with acid magmatism, p. 30-38, in Mineralogical criteria for the relationship between magmatism and ore mineralization - Proceedings of the XIth General IMA Meeting, Novosibirsk 4-10 September 1978, "Nauka," Leningrad, 144 pp., 1400 copies printed, price 1 rbl. 70 kopecks (in Russian, English abstract).

Th of melt inclusions for ongonites was from 1020 to 580°C, for granites 950-600°C, Th range for pegmatites 750-250°C (750-550°C melts, 650-400°C brines), for greisens 570-280°C, ore rare metal parageneses 500-250°C. P during formation of granites and pegmatites may reach 5.5 kbar. (A.K.)

KOVALEV, K.R., KOCHETKOVA, K.V., KORNEVA, T.A. and GAS'KOV, I.V., 1982, Temperature of metamorphogenetic mineral formation of the Kholodnyi ore field, in Geol. Mestorozhd. Tsvetn. Met. Skladchatogo Obramleniya Sib. Platformy, A.V. Van and V.I. Sotnikov, eds.: Izd. Nauka, Sib. Otd., Novosibirsk, p. 86-99 (in Russian).

The rocks within the title ore field include graphite-contg. black schists, garnet-contg. porphyroblastic metamorphogenic-metasomatic formations without graphite, orthoamphibolites, phyllitic schists, marbles, quartzites, metabasites, and chlorite-talc-carbonate schists. Anal. of mineral parageneses, DTA of graphites, geothermometric data of coexisting mineral pairs, Th of fluid inclusions, and the compns. in general of the principal rock-forming minerals show that the sedimentary rocks, syngenetic silicate-sulfide ores, and igneous rocks of the ore field were metamorphosed under epidote-amphibolite facies conditions at temps. generally ≤600°. Porphyroblastic garnet-biotite-amphibole and garnet-biotite rocks formed by prograde regional metamorphism have similar temps. of formation as muscovitic metasomatites originating during the early high-temp. stage of retrograde metamorphism. (CA 97: 185746s)

KOWALLIS, B.J. and WANG, H.F., 1982, Microcrack study of granitic cores from Illinois deep borehole UPH-3 (abst.): EOS, Trans. Am. Geophys. Union, v. 63, p. 441. First author at Dept. Geol., Bringham Young Univ., Provo, UT 84602.

Microcracks were examined in 5 granite samples ranging in depth of origin from 696 m to 1572 m by optical and scanning electron microscope observations and by elastic property measurements. The samples were obtained from the continuous crystalline core from UPH-3 which varies from fine-grained granite at the top through medium-grained granite. Cracks and fractures can be seen with the unaided eye in most of the core. Many of the larger fractures are coated or filled with secondary minerals. Long, narrow, tapered cracks which are open have not been observed in other midcontinent granites. These narrow cracks have sharp, matching edges, and appear to be fresh. They are attributed to stress relief due to removal of the core by drilling. This interpretation is supported by measurements of velocity and strain as a function of confining pressure. The velocity and static bulk modulus at 1-bar pressure were smaller for samples originating from greater depths, indicating progressively greater stress relief cracking for deeper samples. The crack spectrum derived from the strain measurements showed that the majority of the crack porosity was for cracks with closure pressures below the lithostatic load. The crack spectra derived from velocity inversion and from scanning electron microscope measurement showed the same general features of the strain spectrum. A comparison of the spectra is made to show the assumptions and limitations for each method. The conclusion that stress relief microcracks occur with greater concentrations for greater depths implies that cautious interpretation must be made of laboratory measured physical properties which are sensitive to open microcracks. (Authors' abstract)

KOZŁOWSKI, A., 1982, Hydrocarbons in solutions penetrating sedimentary rocks (on the basis of studies of gas-liquid inclusions), in: Sci.-technical conference "Role of the laboratory studies in prospecting for the deposits of petroleum and gas," October 1982, Serock, p. 233-241 (in Polish). Author at Inst. Geochem. Mineral. Petrogr. of the Warsaw Univ., 02-089 Warnowa, al. Zwirki i Wigury 93, Poland.

The problem of hydrocarbons in mineral-forming solutions was discussed on the basis of the author's earlier published data on inclusions in authigenic quartz from limestones and in sphalerite-wurtzite ores from Cracow-Silesia dolostones, plus new data on inclusions in authigenic quartz crystals from flysch at Marmarosh (so-called Marmarosh diamonds). The latter bear inclusions of two immiscible L up to Th +58.5°C to +70°C; at -84 to -87°C heterogenization occurs with formation L_1+L_2+G without further changes down to -102°C. Homogenization $L+G \rightarrow L$ occurred at -82.0 to -72.1°C. At about -70°C in one L small and rare needle crystals formed and droplets of a second L exsolve, next joining the second L phase. At T close to Th (+60 to +70°C) inclusions very frequently decrepitate. Th of $L+G \rightarrow L$ at ~-80°C suggests that one liquid may be methane (T critical -82.1°C) and crystals may be methane cryohydrate for which the upper T limit is +21.4°C; the small amount of crystals is a result of the scarcity of water in the fluid. At ~70°C P in inclusions should exceed 800-900 bars, on the basis of the common decrepitation; CH_4 density should be in the range ~0.3 g per cm^3. The second L cannot be either CO_2 or H_2S, due to the T of the triple points which were overstepped in the freezing runs, and still remains an enigma; the tentative supposition based on the common composition of natural gas is that it may be N_2. The freezing runs were made at Roedder's and Creede Labs in USGS. (Abstract by A.K.)

KOZLOVSKY, Y.A., 1982, Kola super-deep: interim results and prospects: Episodes, v. 1982, no. 4, p. 9-11.

KRǍSTEVA, Margarita and RAŠKOVA, Diana, 1982, Mineral thermometry studies of apatite, quartz and calcite from the deposits in the Rosen ore field: Geohim., mineral.i petrol. (Bulgaria), no. 16, p. 47-53 (in Russian; English abstract).

A regular temperature variation from NW to SE has been found to be generally valid in all deposits. Th values show that the minerals studied and the associated ore mineralization (copper-molybdenum) were formed under medium- and low-temperature hydrothermal conditions. Th of apatite is highest - 280-270°C, of quartz it is 290-70°C, and of calcite (white) - 130-70°C and calcite (pink) - 300-260°C. Th of fluid inclusions is measured on a Kofler-type (± 1°C) thermal stage. (Authors' abstract)

KRENTZ, Ottomar, & THOMAS, Rainer, 1982, Fluid inclusions in quartz from metamorphic rocks of the western Erzgebirge and their dependence on regional metamorphism: Z. geol. Wiss. Berlin, v. 10, no. 11, p. 1425-1437 (in German; English summary).

The paper contains results of fluid inclusion research done in 15 samples of metapelitic rocks (mica schists, phyllites) of probably Cambrian age from the western part of Erzgebirge-anticlinorium (southern part of G.D.R.). The results clearly show a dependence between P/T-conditions of regional metamorphism and thermobarometric data. The latter agree with the observed mineral association, characterized by the presence of chloritoid. According to this data, garnet-mica-schists, belonging to the

Raschau-suite (Raschauer Folge), crystallized between 550-600°C; phyllites, belonging to the Thum-series (Thumer Serie) and Weisselster-suite (Weisselster-Folge) crystallized between 360-400°C. A second group of fluid inclusions, characterized nearly 500°C, was found in four samples and is interpreted as belonging to a later thermal event. (Authors' abstract)

KREULEN, R. and SCHUILING, R.D., 1982, N_2-CH_4-CO_2 fluids during formation of the Dôme de l'Agout, France: Geochimica Cosmo. Acta,. v. 46, p. 193-203. Authors at Inst. Earth Sci., Dept. Geochem., Univ. Utrecht, P.O. Box 80.021, 3508 TA Utrecht, The Netherlands.

The Dôme de l'Agout consists of an ellipsoidal mass of gneisses and migmatites emerging from a large area of chlorite-sericite schists. Fluid inclusions in syn-metamorphic quartz segregations are typically one-phase at room temperature. Analyses by gas chromatography indicate that their main constituents are N_2, CH_4 and CO_2; such compositions are confirmed by freezing studies on individual inclusions. Nitrogen contents of the inclusions range from 2 to 72 mol% and tend to increase with increasing degree of metamorphism. CH_4 and CO_2 show an erratic distribution with the exception of the lowest grade samples, which invariably have very high CO_2 contents. The origin of the nitrogen remains unsolved; however, it seems likely that the nitrogen was not produced by mineral reactions in the presently exposed rocks but came from an external source and moved from the center of the dome outwards. (Authors' abstract)

KREULEN, R. and TOURET, J., eds., 1982, Current Research on Fluid Inclusions, special issue Chemical Geol., v. 37, no. 1/2, 214 pp., October 1982 (available from the publisher at $50.75 U.S.).

Contains many of the papers presented at a symposium at Utrecht, The Netherlands, April 22-24, 1981. Individual papers are abstracted in this volume. (E.R.)

KREYTER, I.V., KUZNETSOV, V.V., PUGACHYOVA, I.P., FILATOV, Ye.I., FILATOVA, L.K., CHEKALIN, V.M. and KHODAREV, V.P., 1982, Geology and conditions of formation of the sulfide-polymetal deposit Korbalikha (Rudnyi Altai): Geol. Rudn. Mest., v. 24, no. 5, p. 37-46 (in Russian). First author at Central Sci.-Res. Geol.-Prosp. Inst., Moscow, USSR.

The sulfide-polymetal ores in volcanic-sedimentary rocks yielded the following Th: in sphalerite 210-280°C, in barite 210-270°C, in quartz 250-310°C. Td of pyrite from quartz-pyrite-sphalerite ore was 280-310°C, Td of pyrite-chalcopyrite are 350-410°C. (A.K.)

KUCHER, M.I. and SHASHKIN, V.M., 1982, Isotope composition of carbon from carbon dioxide of intrusive magmatic rocks in the Balygychan-Sugoy region: Akad. Nauk SSSR Doklady, v. 267, no. 2, p. 449-452 (in Russian). Authors at Moscow Geol.-Prosp. Inst., USSR.

The studied massif occurs in one of the submeridional branches of the Okhotsk-Chukotka volcanic belt; the rocks are of Cretaceous age. Isotope studies were made for samples ~20 g washed by HCl for cleaning of possible carbonates. Inclusions were opened by thermovacuum decrepitation. Low-T inclusions were opened before collecting of CO_2 for analysis by preheating to 200 and 500°C; analyzed CO_2 was released at 500-700°C. The obtained values of $\delta^{13}C$ (‰) are as follows: nevadite stock -23.20 to -22.10, granodiorite-porphyry sill -20.99, hornblende diorite stock -19.20 to -18.70, diorite porphyrite sill -26.00, gabbro-diorite-granodiorite Bystrinskiy complex -25.94 to -13.10, leucocratic biotite granite Omsukchan complex -25.04 to -12.10, same rocks of Okhotsk complex -22.30 to -16.72.

Late phase intrusions cause the enrichment of carbon in the light isotope. The obtained $\delta^{13}C$ values suggest the influence of organic carbon on formation of CO_2 in fluids present in high-T inclusions, i.e. formation of acid melts due to melting of terrigeneous rocks of the Verkhoyan'ye complex at the depth 8-10 km, under P ~2 kbars. Certain granites, however, contain significant portion of CO_2 of deep (mantle?) origin. (Abstract by A.K.)

KUHNERT-BRANDSTATTER, M., 1982, Thermomicroscopy of organic compounds, in G. Sheva, ed., Comprehensive Analytical Chemistry, Vol. XVI, p. 329-497.

A very extensive study of all aspects of thermomicroscopy, including stages (Kofler hot stage, Mettler FP 52, Leitz 350, and the Kofler hot bench), the methods, standardization, recognition of mixtures, phase investigations of one- and two-component systems, etc. (E.R.)

KULAKOVA, I.I., OGLOBLINA, A.I., RUDENKO, A.P., FLOROVSKAYA, V.N., BOTKUNOV, A.I. and SKVORTSOVA, V.L., 1982, Polycyclic aromatic hydrocarbons in diamond-associated minerals and possible mechanism of their formation: Dokl. Akad. Nauk SSSR, v. 267, no. 6, p. 1458-1461 (in Russian). Authors at Mosk. Gos. Univ., Moscow, USSR.

Results are presented of the low-temp. spectrofluorometric detn. of the polycyclic arom. hydrocarbons (PAH) in olivine and pyrope, associated with diamond, in kimberlites of Yakutia. The total content of PAH in pyrope and olivine ranges, resp., 174-3931 and 112-136 μg/kg min. The relative concns. of the homologs of $C_{10}H_8$ and phenanthrene ($C_{14}H_{10}$), pyrene, 3,4-benzopyrene, and 1,12-benzoperylene were estd. in these minerals. The high content of PAH in olivine and pyrope indicate a high concn. of H in the crystg. medium, preventing polycondensation of PAH into graphite. The PAH were formed from CH_4, CO, and CO_2. (CA 98: 129392g)

KULAKOVA, I.I., OGLOBLINA, A.I., RUDENKO, A.P., TEPLITSKAYA, T.A. and FLOROVSKAYA, V.N., 1982, Possible mechanism of synthesis of polycyclic aromatic hydrocarbons in processes of endogeneous mineral formation: Akad. Nauk SSSR Doklady, v. 266, no. 4, p. 1001-1003 (in Russian). Authors at Moscow State Univ., USSR.

Experimental polycondensation of CH_4, C_2H_6, C_2H_4, C_2H_2 and C_6H_6 on catalysts (silica gel, aluminum oxide, alumosilicates etc.) prove possibility of this mode of formation of polycyclic aromatic hydrocarbons found in basalts and kimberlites like alkylnaphthalines, alkylphenanthrenes, pirene, etc. (Abstract by A.K.)

KUL'CHETSKAYA, A.A., 1982, Genetic characteristics of gypsum from the Dniester River area (according to the study of its inclusions): Mineral. Zh., v. 4, no. 3, p. 61-66 (in Russian). Author at Inst. Geokhim. Fiz. Miner., Kiev, USSR.

Gypsum crystals from the Tortonian Tirass suite contain fluorite, carbonate, and anhydrite as solid inclusions. Syngenetic growth of calcite and gypsum suggests crystn. from a solution close to being satd. with $CaCO_3$. Syngenetic growth of gypsum and anhydrite indicates crystn. of these 2 phases in equil. The liquid phase of inclusions in the gypsum is an aq. solution with a NaCl concn. close to that of seawater and below that expected for gypsum pptn. The gypsum probably pptd. from a solution with excess Ca^{2+} and SO_4^{2-} ions; the excess of Ca^{2+} ions persisted for a long time in the evaporite basin, whereas SO_4^{2-} ions were in excess only during pptn. of gypsum and anhydrite. The compn. of inclusions (solid, liquid, and gaseous) indicates that gypsum crystd. in the presence of bitumens, also. Gypsum crystd. at 30-40° in a saline basin simultaneously receiving H_2S and bitumens. The crystn. could have occurred at a considerable depth. Anhydrite probably crystd. simultaneously in parts of the basin with higher salinity and temp. (CA 97: 130675n)

KULIKOV, I.V., 1981, Mineralogy and genesis of scheelite-sulfide mineralization of Tyrny-Auz deposit. Abstract of dissertation for degree of candidate geol.-mineralog. science, Moscow, MGRI (in Russian).

See Kulikov, 1980 (Fluid Inclusion Research--Proc. of COFFI, v. 13, p. 138) and following items. (E.R.)

KULIKOV, I.V., 1982a, Multiphase brine inclusions in fluorite and calcite and their genetic significance: Dokl. Akad. Nauk SSSR, v. 264, no. 4, p. 958-961 (in Russian).

Essentially the same material as in the following items. (E.R.)

KULIKOV, I.V., 1982b, Conditions of mineral formation at the molybdenum-tungsten deposit Tyrnyauz: Izvestiya Vyssh. Uchebn. Zaved.-Geologiya i Razvedka, no. 6, p. 24-30 (in Russian). Author at Moscow Geol.-Prosp. Inst., USSR.

For inclusion data see Fluid Inclusion Research--Proceedings of COFFI, vol. 13, 1980, p. 138; vol. 14, 1981, p. 117, 257-258; Mel'nikov, Kulikov and Gromov, vol. 14, 1981, p. 259 and Kulikov, Devyatov and Gromov, 1982, this volume. (A.K.)

KULIKOV, I.V., DEVYATOV, V.Ye. and GROMOV, A.V., 1982, New natural compound-calcium fluoride-chloride: Izvestiya Vyssh. Uchebn. Zaved.-Geologiya i Razvedka, no. 7, p. 120-122 (in Russian). Authors at Moscow Geol.-Prosp. Inst., USSR. (see Translations).

The compound CaFCl was found in inclusions in fluorite from the Tyrnyauz Mo-W deposit (Caucasus). The paper presents properties of CaFCl, including X-ray powder data. See also Kulikov in Fluid Inclusion Research-Proceedings of COFFI, vol. 13, 1980, p. 138; vol. 14, 1981, p. 117, 257-258; Mel'nikov, Kulikov and Gromov, vol. 14, 1981, p. 259; and Kulikov 1982, this volume. (A.K.)

KULIKOV, I.V., DEVIATOV, V.E., MELNIKOV, F.P. and GROMOV, A.V., 1982, On the composition of gas-liquid inclusion solid phases in fluorites: Dokl. Akad. Nauk SSSR, v. 265, no. 4, p. 963-966 (in Russian).

Essentially the same material as in the previous item. (E.R.)

KUMAR, Anil, ATKINSON, Gordon and HOWELL, R.D., 1982, Thermodynamics of concentrated electrolyte mixtures. II. Densities and compressibilities of aqueous NaCl-$CaCl_2$ at 25°C: J. Solution Chem., v. 11, no. 12, p. 857-876. First author at Dept. Chem., Univ. Oklahoma, Norman, OK 73019.

Densities and ultrasonic velocities of NaCl-$CaCl_2$ aqueous mixtures at 25°C have been measured for the ionic strength range $I=0.30-20.0$. Where NaCl solubility permitted, both properties were measured over the range of compositions from pure NaCl to pure $CaCl_2$ at constant I. Apparent molar volumes and apparent molar compressibilities of the mixtures were calculated. The Pitzer form of the specific interaction theory is used to predict the properties of the binary mixtures from the properties of the single salt solutions. It provides a good fit over the full range of ionic strength for apparent molar volumes but a much inferior fit for compressibilities. It is also clear that in the high ionic strength range, explicit mixing parameters must be included for an excellent fit. (Authors' abstract)

KUMAR, M.B., 1982, Subsurface leaks of salt mines in Louisiana (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 537.

KUMAR, M.B. and MARTINEZ, J.D., 1981, Character of brines from the Belle Isle and Weeks Island salt mines, Louisiana, U.S.A., *in* W. Back and R. Létolle (guest eds.), Symposium on Geochemistry of Groundwater--26th Int'l. Geol. Congress, 1982, J. Hydrology, v. 54, p. 107-140.

KURODA, Yoshimasu, HARIYA, Yu, SUZUOKI, Tetsuro and MATSUO, Sadao, 1982, D/H fractionation between water and the melts of quartz, K-feldspar, albite and anorthite at high temperature and pressure: Geochem. J., v. 16, p. 73-78.

KUSAKABE, Minoru, CHIBA, Hitoshi and OHMOTO, Hiroshi, 1982, Stable isotopes and fluid inclusion study of anhydrite from the East Pacific Rise at 21°N: Geochem. J., v. 16, p. 89-95. First author at Dept. Earth Sci., Toyama Univ., Gofuku, Toyama 930, Japan.

Six anhydrite samples from the submarine hydrothermal sulphide/sulphate mineral deposits found along the crest of the East Pacific Rise at 21°N have been examined for filling temperature of fluid inclusions and for $^{34}S/^{32}S$ and $^{18}O/^{16}O$ ratios. The anhydrite was precipitated upon mixing of hot (260-350°C), SO_4^{2-}-poor hydrothermal fluids with cold seawater at various proportions, which is reflected in a large variation in the filling temperatures ranging from 180°C to almost the highest exit temperatures. Seawater sulphate origin for anhydrite-sulphur is indicated by the $\delta^{34}S$ values that are essentially identical with the present-day seawater sulphate value, whereas the $\delta^{18}O$ values are up to 2% higher than the seawater sulphate value. The anhydrites are not in oxygen isotopic equilibrium with the mixed solution at measured exit temperatures of 260 to 350°C. However, this enrichment of ^{18}O may be attributed to partial equilibration of fine-grained anhydrite with solutions at lower temperatures after deposition. Absence of anhydrite at dead vents suggests that SO_4^{2-} slightly enriched in ^{18}O is added to seawater sulphate owing to dissolution of anhydrite after the cessation of high temperature stage of the hydrothermal activity. (Authors' abstract)

KUSHNIR, Jacob, 1982, The composition and origin of brines during the Messinian desiccation event in the Mediterranean Basin as deduced from concentrations of ions coprecipitated with gypsum and anhydrite: Chem. Geol., v. 35, p. 333-350. Author at Geol. Res. Div., Scripps Inst. Oceanography, La Jolla, CA 92093, USA.

Gypsum and anhydrite from the Upper Miocene (Messinian) evaporites of the Mediterranean Basin were analyzed for their coprecipitated-ion compositions. The concentrations of Mg, Na, K, Sr and Cl in gypsum and anhydrite samples were used to calculate the composition of the brines from which these calcium sulfate minerals were deposited, or in which they have undergone recrystallization or phase transformation. (From the author's abstract)

Washed <64 μm grains were analyzed, and a correction made for fluid inclusions by assuming the Cl came from inclusions of fluid with seawater ratios of Na, K and Mg. (E.R.)

KUZNETSOV, A.G., 1982, Use of thermobarogeochemical methods for detailed exploration of the polymetallic deposit Sadon (Northen Caucasus), *in* N.P. Ermakov, ed., Thermobarogeochemistry in Geology - Materials of the Sixth All-Union Symposium on Thermobarogeochemistry: Vladivostok, Far East Sci.

Center, Acad. Sci. USSR Pub. House, p. 141-144 (in Russian).
For abstract, see Fluid Inclusion Research--Proceedings of COFFI, vol. 11, 1978, p. 119. (A.K.)

KUZNETSOV, A.G. and GLUKHOV, Yu.Yu., 1982, Thermobarogeochemical conditions of coal metamorphism in the East Donbass, in N.P. Ermakov, ed., Thermobarogeochemistry in Geology - Materials of the Sixth All-Union Symposium on Thermobarogeochemistry: Vladivostok, Far East Sci. Center, Acad. Sci. USSR Pub. House, p. 10-14 (in Russian).

For abstract, see Glukhov and Kuznetsov, 1978, Fluid Inclusion Research--Proceedings of COFFI, vol. 11, 1978, p. 75-76 (note also the changed title). (A.K.)

KUZNETSOV, N.M., 1982, Equation of state and curve of phase equilibrium in liquid-vapor systems: Akad. Nauk SSSR Doklady, v. 266, no. 3, p. 613-616 (in Russian). Author at Inst. of Chemical Physics of Acad. Sci. of the USSR, Moscow.

The paper bears thermodynamic data on CO_2 and CO. (A.K.)

KUZNETSOVA, S.V. and GOSTYAEVA, N.M., 1982, Studies of gas-liquid inclusions in metasomatic albitites of Precambrian age: Geokhimiya i rudoobrazovaniye, v. 10, p. 27-35 (in Russian). Authors at Inst. Geochem. and Physics of Minerals, Kiev, Ukraine.

Precambrian albitites of the Ukrainian Shield developed in zones of faults, mylonitization and cataclasis; granites and migmatites were albitized. Albitization was preceded by K metasomatism with development of microcline. Albite replaces plagioclase (oligoclase and andesine). Inclusions were studied in albites of the I and II generation, early (premetasomatic) and new quartz, calcite, dark minerals and apatite. Albite I bears L and G/L inclusions of various habit and the largest dimension 1-15 μm, all two-phase inclusions homogenize in L at 400-100°C. Precataclastic albite bears inclusions homogenizing in L at 480-400°C. Albite II bears P and PS inclusion, homogenizing at 440-100°C, with most typical Th interval 260-120°C connected with intensive crystallization of late albite. Th of inclusions in quartz are 480-80°C; part of the inclusions (primary) decrepitated; those that did not leak are secondary. New quartz bears inclusions homogenizing in L, mostly at 220-140°C; rare inclusions homogenized at 360-220 and 140-80°C. Inclusions in calcite yielded Th 340-100°C, in aegirine 370°C, in riebeckite 210°C, in chlorite 295-260°C[sic], in epidote 120°C, in apatite 275-220°C. Potassium metasomatites formed from solutions bearing following ions (in wt. % of total salts): Na 26, K 17, Ca 5.5, Mg 1.5, HCO_3 41, Cl 9; early albitites Na 26.5, K 14.5, Ca 5, Mg 4, HCO_3 39, Cl+F 10.5, SO_4 0.5; late albitites Na 41.5, K 6, Ca 1.2, Mg 1.2, HCO_3 37.5, Cl+F 12, SO_4 0.5. Gases contain N_2 up to 100% vol., CO_2 up to 50% vol., H_2 20-60% vol., O_2 8-40% vol. (Abstract by A.K.)

KYSER, T.K. and RISON, W., 1982, Systematics of rare gas isotopes in basic lavas and ultramafic xenoliths: J. Geoph. Res., v. 87, no. B7, p. 5611-5630. First author at Dept. Geol. & Geoph., Univ. California, Berkeley, CA 94720.

Mid-ocean ridge (MOR) tholeiites and several ultramafic xenoliths from a variety of localities have identical $^3He/^4He$ ratios of 1.3×10^{-5} which indicate that a large portion of the mantle has a constant helium isotopic composition. In contrast, megacrysts from alkali basalts, phenocrysts from andesites, and some nodules have $^3He/^4He$ ratios of 0.3 to 1.3

$\times 10^{-5}$, and submarine tholeiites from Kilauea have ratios greater than 1.3×10^{-5}. The low ratios of some nodules may be due either to loss of ^{3}He by prior outgassing events that lowered the ^{3}He/(U + Th) ratio or to interactions with metasomatic fluids having low ^{3}He/^{4}He or ^{3}He/(U + Th) ratios. Andesites and nodules associated with subduction zones have ^{3}He/^{4}He ratios indicative of mixing between the helium in MOR tholeiites and subducted helium with a low ^{3}He/^{4}He ratio. High ^{3}He/^{4}He ratios of Hawaiian tholeiites, like the ratios measured in materials from other hot spots, reflect a deeper, less depleted source than do MOR tholeiites. Some xenoliths and lavas have greater ^{21}Ne/^{22}Ne and ^{20}Ne/^{22}Ne ratios than does the atmosphere. Correlation of excess ^{21}Ne with ^{4}He in most samples suggests that the ^{21}Ne is nucleogenic. The excesses of ^{20}Ne are probably the result of mass fractionation processes. Hawaiian submarine lavas, which may sample deeper, less depleted portions of the mantle than do MOR tholeiites, not only have high ^{3}He/^{4}He ratios but also low ^{40}Ar/^{36}Ar ratios. Many nodules and megacrysts related to alkali basalts have lower ^{3}He/^{4}He ratios but higher ^{40}Ar/^{36}Ar ratios than do MOR tholeiites because of prior outgassing events that have lowered the ^{3}He/(U + Th) and ^{36}Ar/K ratios. Lavas and nodules associated with subduction zones can have variable ^{3}He/^{4}He and ^{40}Ar/^{36}Ar ratios because of the addition of subducted gases and the disturbance of the relative position of depleted and undepleted portions of the mantle. (Authors' abstract)

LAHIRY Ashoke 1982, Fluid inclusion research--historical background and present status: [Proceedings & Abstracts], National Workshop on Fluid Inclusion Studies, 22-23 March, 1982 Indian Inst. Tech., Bombay p 18-26 (unpaginated). Author at Rajasthan State Min. Dev. Corp. Ltd., Jaipur, India.

A historical review with no references. (E.R.)

LALONDE, A.E., 1981, The Baie-des-Moutons syenitic complex, La Tabatiere, Quebec: M.S. thesis, McGill Univ., Montreal, Canada, 163 pp. (in English).

Indexed under fluid inclusions. (E.R.)

LAMBERT, P., ASHWAL, L.D. and GIBSON, E.K., Jr., 1982, Fluid inclusions in chondrules and history of the meteorite hosts: Origin of Chondrules Meeting, L.P.I., Nov. 1982. First author at N.R.C., SN6/Geol. Branch, NASA-JSC, Houston, TX 77058.

Fluid inclusions have been found in chondrites ALHA 77230 (L4), ALHA 77299 (H3), Bjurbole (L4), Faith (H5), Holbrook (L6), Jilin (H5), Peetz (L6) and St. Severin (LL6). See Adar et al., 1981, this volume. (E.R.)

LAND, L.S. and PREZBINDOWSKI, D.R., 1981, The origin and evolution of saline formation water, Lower Cretaceous carbonates, south-central Texas, U.S.A., in W. Back and R. Létolle (guest eds.), Symposium on Geochemistry of Groundwater--26th Int'l. Geol. Congress, 1982, J. Hydrology, v. 54, p. 51-74.

LANGER, H. and OFFERMANN, H., 1982, On the solubility of sodium chloride in water: J. Crystal Growth, v. 60, p. 389-392. Authors at Inst. Verfahrenstechnik, RWTH Aachean. Turmstrasse 46, D-5100 Aachean, FRG.

In the present experiments the crystal growth rate of sodium chloride from aqueous solution has been studied. In particular, the solubility curve of NaCl/H_2O has been measured. Crystal growth and dissolution experiments were used to determine the saturation temperatures of the given solutions; the corresponding salt concentrations were measured by chemical analysis. (Authors' abstract)

LAPIN, A.V., 1981, Carbonatite differentiation processes: AN SSSR Izvestiya, Ser. Geol., no. 1, p. 38-51 (in Russian; translated in Int'l. Geol. Review, v. 24, no. 9, p. 1079-1089, 1982). Author at Inst. Mineral., Geochem., & Crystallogchem. of Rare Elements.

The role of various factors and processes that lead to the development of the conjugate petrographic series, which form the combination of rocks of the carbonatite stage, are analyzed. The principal factors involved are: 1) temperature conditions for formation of carbonatites; 2) crystallization differentiation and liquid immiscibility; 3) processes of assimilation and hybridism; and 4) behavior of volatile components during genesis of carbonatites. It has been shown that the processes of liquid immiscibility and crystallization differentiation are responsible for the development of the conjugate rock series, consisting of calcite carbonatites and camaphorites. Assimilation of the country rocks determines the appearance of hybridized carbonatite melts, which are characterized by increased amounts of silicate components. It is established that the behavior of the volatile components, especially the accumulation of fluorine and sulfur toward the end of the process of crystallization of the calcite carbonatites and camaphorites, is one of the primary factors of evolution of the material composition and mineral parageneses of these rocks and greatly determines the distribution of rare elements (niobium and tantalum) in them. (Author's abstract)

LARSON, P.B. and TAYLOR, H.P., Jr., 1982, $^{18}O/^{16}O$ relationships in hydrothermally altered rocks of the 22.5 m.y. Lake City caldera, San Juan Mts., Colo. (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 541.

LATTANZI, P., 1982, Fluid inclusions in sphalerite from southern Tuscany, Italy: a reconnaissance study (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstacts, p. 204. Author at Univ. di Firenze, Firenze, Italy.

In southern Tuscany, sphalerite is found in two distinct types of occurrences, as a major mineral in Cu-Pb-Zn-Fe vein- and/or replacement mineralizations, associated with tectonic dislocations and/or felsic intrusive bodies related to the Apenninic orogeny (Mio-Pliocene) or as a minor, late stage, vein mineral in massive stratabound pyrite deposits, which are thought to be volcanogenic and coeval with the associated quartzitic-phyllitic terrains (Paleozoic-Trias?).

Sphalerite from both types of mineralizations shows some constant common microtextural and chemical features. First results of a fluid inclusion study shows also that, apart from small variations, sphalerite-forming fluids were quite similar in both types of deposits. Temperatures fo deposition were in the range 200-300°C, from fluids of low to moderate salinities (2 to 9% weight NaCl equivalent).

These results lend support to the hypothesis that sphalerite in both types of deposits was formed from a single mineralizing event - namely, remobilization of the stratabound ores during Mio-Pliocenic tectonic and magmatic activity. (Author's abstract)

LAVEROV, N.P. (ed.), 1982, Use of methods of thermobarogeochemistry during prospecting and studies of ore deposits: "Nedra" Publ. House, Moscow, 240 pp., 1000 copies printed, price 3 rbls. 20 kopecks (in Russian).

The book contains 31 papers of the prominent Russian fluid inclusion investigators. The papers are mostly the edited versions of lectures presented during the seminar on the same theme as the book title, organized in 1981. The individual papers are abstracted in this volume under the individual authors' names. (A.K.)

LAVRUKHINA, A.K., SAZHINA, N.K., KASHKAROVA, V.G., BARYSHNIKOVA, G.V., IGNATENKO, K.I. and STAKHEYEVA, S.A., 1981, Chemical compositions of olivines from L-group chondrites: Geokhimiya, 1981, no. 7, p. 947-969 (in Russian; translated in Geochem. Int'l., v. 18, no. 4, p. 1-25, 1982). Authors at Inst. Geochem. & Anal. Chem., Acad. Sci. USSR, Moscow, USSR.

The composition of the olivine fraction and of inclusions in olivine grains from four L-group chondrites of different petrological types was studied. In the case of the Krymka (L)3 chondrite it is confirmed that olivine from nonequilibrium chondrites is widely variable in composition. This chondrite contains olivine grains having up to 1.9 wt. % CaO (minimum content 0.1 wt. %), which indicates that the Krymka chondrite was not subject to thermal metamorphism. In the equilibrium chondrites (L4 → L6), the olivine has less than about 0.02 wt. % CaO. The textural features demonstrate thermal metamorphism in these chondrites.

There are inclusions of submicron size in the olivine in all petrological types of chondrite. The chemical compositions of these inclusions in the olivines appear to reflect the origin of the chondrites.

The data on the Fe-Mg ratio of olivine and pyroxenes on the amount of metallic iron and on the contents of nickel and cobalt in the Fe-Ni phase, on the contents of siderophile elements in the bulk sample, and on the amounts of major silicate minerals demonstrate that the Krymka chondrite can be classified as nonequilibrium type L3 chondrite. (Authors' abstract)

LAWLER, J.P. and CRAWFORD, M.L., 1982, Fluid inclusions in the Midwest Lake uranium deposit (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 542. First author at Geol. Res. Dept., Exxon Minerals Co., P.O. Box 2189, Houston, TX 77001.

Fluid inclusions have been investigated in quartz-bearing samples from the Midwest Lake uranium deposit. Preliminary data, collected through microthermometric analysis, suggest the dominant fluid in the alteration envelope around the ore body is low density CO_2. In addition, an oxidizing saline aqueous fluid is present within the ore zone, both above and below the unconformity as indicated by the occurrence of aqueous inclusions with hematite and NaCl daughter crystals. Hematite also occurs along fractures containing CO_2. Some fractures contain aqueous and CO_2 inclusions suggesting the fluids were immiscible at the time of trapping. Separate CO_2 and low salinity aqueous inclusions also coexist along healed fractures. Homogenization temperatures of these coexisting inclusions suggest trapping conditions of 800-1000 bars and 200±25°C. Gneissic samples, some of which are graphitic, collected outside the zone of intense alteration contain CH_4 and CO_2-CH_4 fluids. Aqueous fluids enriched in $CaCl_2$ which contrast with the NaCl rich brines, also occur in some samples. No fluids of any composition were observed which can be unambiguously assigned to preexisting amphibolite facies metamorphic conditions in the basement metapelites. Consequently, we suggest the ore deposition was associated with conditions which favored an oxidizing CO_2-rich fluid. Major ore deposition may have resulted due to unmixing of CO_2 and aqueous brines. (Authors' abstract)

LAZKO, E.M., KOLODII, O.N., LYAKHOV, Y.V., MISNIK, Y.F. and POPIVNYAK, I.V., 1982, A complex interpretation of thermobarogeochemical, space imagery and geological-mineralogical data in predicting postmagmatic mineralization in eastern Zabaikaije (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 204-206. Authors at L'vov State Univ., L'vov, USSR.

The writers used a combination of methods on an area of the intersection of the gold-molybdenum and tin-tungsten belts in the Undina fault zone which is a south-west branch of the Prishilka en echelon part of the Mongol-Okhotsk deep-seated fault.

The investigation results reveal a number of radial concentric volcanic-plutonic dome and caldera structures.

Pneumatolytic-hydrothermal gold mineralization of a low grade sulphide medium-depth formation presented by Late Jurassic lodes are confined to the dome structures. The ores are formed at 450-60°C and 1200-400 atm. Hydrothermal Early Cretaceous mineralization of a shallow low-sulphide formation presented by stockwork and vein zones that formed at 310-50°C and 30-40 atm. is confined to the caldera. Pressure and temperature drop (from 4-6° to 25-30°C per 100 m) gradients from the deep-seated levels towards the surface and from the structure centers toward their peripheries coincide with the regular change of thermoelectric properties of ore minerals.

Investigation data indicate that gold mineralization of different ore formations have originated by similar developing ascending gas-liquid flows associated with local magmatic chambers. Changes of chemical properties, concentrations of salts and gases, densities and aggregate states of solutions during the formation of the pre-ore and post-ore associations had been estimated. The formation of gold parageneses occurred irrespective of the depth of crystallization within the average temperatural range (300-200°C) by means of hydrocarbonate Mg-Ca solutions, with a high activity (as compared with unproductive stages) of alkaline elements and at different partial pressures of carbon dioxide. (From the authors' abstract)

LAZ'KO, Ye.M., SIVORONOV, A.A. and BOBROV, A.B., 1982, Problem of the tonalite layer in the granite-greenstone areas: Izvestiya Akad. Nauk SSSR - Ser. Geol., no. 9, p. 5-15 (in Russian). First author at L'vov Univ., Ukraina.

Migmatites from the area between the rivers Bazavluk and Bazavluchek bear, in quartz, isolated crystallized melt inclusions with Th 680-720°C. (A.K.)

LAZUTKINA, L.N., KOGARKO, L.N. and ROMANCHEV, B.P., 1982, Peculiarities of eudialyte mineralization of the agpaitic nepheline syenites from the Lovozero massif, in N.P. Ermakov, ed., Thermobarogeochemistry in Geology - Materials of the Sixth All-Union Symposium on Thermobarogeochemistry: Vladivostok, Far East Sci. Center, Acad. Sci. USSR Pub. House, p. 63-65 (in Russian).

For abstract, see Fluid Inclusion Research--Proceedings of COFFI, vol. 11, 1978, p. 122. (A.K.)

LEACH, T.M., 1982, An evaluation of fluid inclusions as a geothermal exploration tool, in Proceedings of Pacific Geothermal Conf., Nov. 1982, Univ. Auckland, p. 475-478. Author at Kingston Reynolds Thom & Allardice Ltd. (KRTA), C.P.O. Box 4498, Auckland, New Zealand.

Fluid inclusion studies were carried out during routine petrological analysis of cores from wells drilled in three Philippine geothermal fields. An evaluation of fluid inclusion homogenization temperatures as an exploration tool is outlined. It was concluded that fluid inclusions are a valuable tool during a geothermal exploration program and can be used: 1. during drilling to give an indication of reservoir conditions; 2. in interpretations of heating-up profiles; 3. in petrological evaluation of each well; 4. in reservoir modelling; and 5. in aiding the determination of the stability ranges of certain hydrothermal minerals. (Author's abstract)

LEACH, T.M. and BOGIE, I., 1982, Overprinting of hydrothermal regimes in the Palimpinon geothermal field, southern Negros, Philippines: Proc. Pacific Geothermal Conf. 1982 Part 1, Univ. Auckland Geothermal Inst., Auckland, NZ, p. 179-183. Authors at Kingston Reynolds Thom & Allardice Ltd. (KRTA).

Two major hydrothermal regimes are evident from the alteration mineralogy in the Palimpinon Geothermal Field. A relict mineral zonation consisting of potassic, advanced argillic, phyllic and propylitic zones appears to have formed in response to the intrusion of a large monzodiorite in the western section of the field. A recent mineral zonation, that is interpreted to have formed during the current geothermal system, is superimposed on the relict system and appears to be centered around the eastern portion of the field.

The relict assemblages have many characteristics of a failed or barren porphyry copper system. The relict advanced argillic mineralogy is interpreted to be a magmatic fluid origin and probably has not formed from the present geothermal regime with its predominant meteoric fluid component. The abundant anhydrite being deposited in this geothermal system is interpreted to have originated by redistribution of anhydrite formed initially during the relict magmatic hydrothermal system. Most Philippine systems are similar. (Authors' abstract)

LEAKE, B.E. (Chm.), 1982, Fluids in metamorphism, a Metamorphic Studies Group Meeting, Univ. Glasgow, Scotland, Sept. 23, 1982: Geol. Soc. Newsletter (London), v. 11, no. 4, p. 14-18.

Ten papers were presented, mainly dealing with rock-fluid reactions and fluid movement. All are abstracted in this issue of COFFI. (E.R.)

LE BEL, L. and OUDIN, E., 1982, Fluid inclusion studies of deep-sea hydrothermal sulphide deposits on the East Pacific Rise near 21°N, in R. Kreulen and J. Touret (guest eds.), Current Research on Fluid Inclusions: Chem. Geol., v. 37, p. 129-136. First author at G.I.S., B.R.G.M.-C.N.R.D., 45045 Orléans Cedex, France.

Fluid inclusions were studied in both anhydrite and zinc sulphides from actively forming deposits on the East Pacific Rise near 21°N. A very good correlation exists between the temperatures measured in situ and those obtained from fluid inclusions. Salinities of fluid inclusions in zinc sulphides are equal to that of seawater and support the hypothesis of circulation of seawater in the oceanic crust as the origin of the hydrothermal fluid. Evidence for a thermal gradient inside the chimney walls as well as the thermal evolution of the hydrothermal system can possibly be inferred from the study of fluid inclusions. (Authors' abstract)

LEEDER, O., THOMAS, R. and KLEMM, V., 1982, Thermobarogeochemical studies of minerals and parageneses of tin and fluorine deposits in the south of the German Democratic Republic (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 206. Authors at Freiberg Mining Acad., Freiberg, GDR.

The temperatures of formation, salinity, humidity, solution and gas compositions and H, O and C isotope ratios have been investigated for the minerals of the Late Variscan pneumatolytic Sn-W and hydrothermal fluorite-quartz deposits, as well as of the Mesozoic hydrothermal fluorite-baryte (calcite) deposits in the South of the G.D.R. These investigations were performed partially by new analytical methods. The results evidence minerogenetic relations between the two periods of mineralization within the boundaries of the tectono-magmatic activity of Central Europe which started in the Late Paleozoic. They also provide criteria of location of the above mentioned parageneses in the compatible ore formations. (Authors' abstract)

Le GUERN, F., GERLACH, T.M. and NOHL, A., 1982, Field gas chromatograph analyses of gases from a glowing dome at Merapi Volcano, Java, Indonesia, 1977, 1978, 1979: J. Volcan. and Geotherm. Res., v. 14, p. 223-245. First author at Centre des Faibles Radioactivités, C.N.R.S., 91190 Gif-sur-Yvette, France.

A new field gas chromatograph (FGC) and conventional evacuated bottle (EB) techniques have been used to study high temperature (>600°C) volcanic gases from Merapi Volcano, Indonesia during 1977, 1978, and 1979.

The FGC design allows analysis of H_2O, CO_2, SO_2, H_2S, H_2, COS, CH_4, CO, N_2, Ar, and O_2 in a manner that prevents loss of sulfur and water by condensation, inhibits corrosion from reactions of gases with lead-in tubes, and minimizes atmospheric contamination. The FGC analyses are highly superior to the EB data especially with respect to prevention of sulfur loss from reaction of SO_2 and H_2S. In addition to providing much improved H_2S data, the FGC system minimizes oxidation of H_2 and CO from contaminating atmospheric O_2 because of the elimination of a lengthy time interval between collection and analysis. Thermodynamic calculations indicated small errors for H_2 and CH_4 in the 1978 analyses provided by the proto-type FGC device. A later model FGC provided excellent analyses that were shown by thermodynamic calculations to be nearly equilibrium mixtures, requiring only minor corrections.

The Merapi gases are H_2O-rich (88-95%) containing small amounts of CO_2 (3.5 to 7.5%), SO_2 (0.3 to 1.2%), and H_2S (0.3 to 1.2%). They resemble "excess volatiles" (Rubey, 1955) except for too high a sulfur content. Thermodynamic calculations based on the analyses indicate that the gases were once at temperatures of at least 915°C with O_2 fugacities near quartz-magnetite-fayalite and that they have not been significantly diluted by disequilibrium admixture of meteoric water below these temperatures. This conclusion takes on special importance because stable isotope studies (Allard, 1980, 1982) of Merapi gases have shown that the water is meteoric and that much of the carbon and sulfur could be from sedimentary sources. The Merapi gases, therefore, may be "magmatic" even though they are not "juvenile" but recycled crustal volatiles. (Authors' abstract)

LETNIKOV, F.A., 1982, Evolution of fluid regime of endogene processes during the geological history of the Earth: Akad. Nauk SSSR Doklady, v. 262, no. 6, p. 1438-1440 (in Russian). Author at Inst. Earth's Crust of Siberian Branch of Acad. Sci. USSR, Irkutsk.

On the basis of analyses of ~7600 samples selected from the total of ~14,000 samples analyzed (volatiles of various types of rocks) the following conclusion was made: during the geological history of the Earth the H:C ratio in rocks increases from 4-5 to ~50 (Archean 4-5, Proterozoic

20-23, Paleozoic 28-47, Mesozoic 39; ranges for average values for hyperbasites, basites and granitoids). (A.K.)

LHÉGU, J., JÉBRAK, M., TOURAY, J.C. and ZISERMAN, A., 1982, The fluorite and baryte veins of the Massif central (France): Bull. BRGM, sec. II, v. 2, no. 2, p. 165-177 (in French; English abstract).
Listed under fluid inclusions as key word. (E.R.)

LI, Binglun, WANG, Lyinglan and XIE, Yihan, 1982, Gas chromatographic analysis of fluid inclusions and their geological significance: Scientia Geologica Sinica, 1982, no. 2, p. 220-225 (in Chinese; English abstract). Authors at Inst. Geol., Acad. Sinica, Beijing.

The gas chromotograph ("Sp2305," of Chinese manufacture) was used to study the gases in volcanic and sedimentary-metamorphic iron ores and hydrothermal deposits. The gases obtained were either reducing (high in CO, H_2 and CH_4, and associated with magnetite), or oxidizing (low in these compounds, and associated with hematite. The mole ratio $(CO+H_2+CH_4)/CO_2$ is a useful parameter for evaluating the redox state of the ore fluids, and varies with deposit depth of formation. (Modified by E.R. from authors' abstract)

LI, Binglun, XIE, Yihan and WANG, Yinglan, 1982, A recognition of porphyrite type iron ore deposits in the light of inclusion study, in IGAS, 1982, Research on Geology (I), p. 222-229, Cultural Relicts Pub. House, Inst. Geol., Acad. Sinica (in Chinese; English abstract).

The further research on the inclusions in minerals of volcanic iron deposits from the Ning-Wu region of the middle-lower reaches of the Changjiang (Yangtze) River indicates that a large amount of melt inclusions can be found in pyroxene, apatite, garnet and magnetite of ore-magma type of deposits. However, melt inclusions are rather minor in pyroxene and apatite of deuteric gas-aqueous metasomatic and pegmatoid deposits. The inclusions in magnetite of these deposits decrepitate at high temperature. These data give an evidence for the occurrence of ore-magma and deuteric mineralogenesis in the volcanic iron deposits of the region.

The sequence of crystallization of main minerals in supergene ore-magma deposits is determined as pyroxene, garnet, apatite, magnetite, quartz and calcite. The inclusions formed in the above-mentioned minerals are different in nature. For instance, they are melt inclusions in pyroxene; excepting these, they are gas-liquid-solid polyphase and gas-liquid two-phase inclusions in garnet, apatite and magnetite. Besides, in miarolitic cavities the quartz presents mainly gas inclusions and in calcite, liquid inclusions. The distribution of inclusions shows that the mineralogenetic process of ore-magma deposits began at the "dry"-ore-magmatic stage, and then ended at hydrothermal one. The melt, polyphase, gas-phase and gas-liquid phase inclusions can be found in the pre-existing pyroxene and apatite from deuteric pneumato-hydatogenetic metasomatic iron deposits in the intrusive body. This kind of deposits is ascribed to the group of iron ore deposits of different genetic types distributed around the intrusive body of diorite or porphyrite. But there also exist gas-liquid inclusions in minerals of contact replacement deposits and hydrothermal deposits. According to the results we can suggest that this group of iron deposits genetically associated with diorite or porphyrite intrusive bodies were generated also with the beginning of the residual magma and developed at the stage of hydatogenesis. Therefore it proves that porphyrite iron deposits involve two genetic series, i.e. the magmatic iron ore and residual magmatic deposits.

Based on the temperature measurement, the temperature for the formation of volcanic iron deposits can be evaluated as follows:

The temperature for the formation of supergene ore-magma iron deposits (Meishan) is in the range of 1075-120°C, in which the magnetite is in the range of 840-450°C. That temperature for hematite in ore-magma iron deposits near the surface is in the range of 1040-350°C (Gushan), higher than that for supergene deposits. The temperature of formation of extrusive rock is higher than that for intrusive rock. As we know the widely developed hematization occurs in the range of 400-350°C, and the siderite and pyrite are formed under the hydrothermal temperatures of 280-260°C.

There are melt inclusions in pre-existing apatite and diopside from deuteric pneumato-hydrothermal metasomatic deposits (Taocun). The temperature for the decrepitation of magnetite impregnations is about 800°C, showing its deuteric genesis, while the temperature for the crystallization of magnetite in large amounts is in the range of 460-360°C, belonging to a pneumato-hydatogenic stage of high temperature.

The temperature for the formation of magnetite in contact metasomatic deposits (Baixiangshan, Xiang yang) is about 630-500°C in the skarn stage and about 480-320°C in the hydrothermal stage, in which most of magnetite formed.

The inclusion gas in minerals from some iron deposits contains H_2O, CO_2, CO, CH_4 and H_2, but no N_2 or O_2. Sulphurous gas has not been analyzed. (Modified from the authors' abstract, see also preceding item. E.R.)

LI, Zhaolin, WU, Qizhi, JIAN, Haosheng, ZHAO, Meifang, LIN, Wensheng and WANG, Aihun, 1982, The determination of formation temperature of the igneous rocks from some areas: Scientia Geol. Sinica, 1982, no. 1, p. 80-87 (in Chinese; English abstract). First author at Dept. Geol., Nanking Univ.

The thermometric investigation of melt inclusions in minerals is one of the effective methods for evaluating the temperature of rock-formation (Tt). In this work we determine Tt for some main types of igneous rocks. The authors characterized the phase state, refractive index, extinction, morphology of gas phase and the phase change during heating of melt inclusions.

Tt of rocks was determined by the homogenization method or the quenching method. The former has been on the heating stage LGHS-1 which we made, with runs from 2 to 8 hours. The melt inclusions in minerals of the different rocks melt at 680-1100°C, and homogenize at 980-1140°C for acidic rocks (granite, adamellite), 980-135°C for volcanic rocks (quartz-keratophyre, lava, microclastic tuff lava), 1040-1120°C for alkali rocks (nepheline syenite), and 1120-1450°C for basalts. (Mofified from the authors' abstract. E.R.)

LIANG, Xiangji and QU, Guolin, 1982, A preliminary experimental estimate of the temperature and pressure of formation of the Makeng iron deposit, Fujian [China]: Zhongguo Dizhi Kexueyuan Yuanboa [Ser. 1], 1982, no. 4, p. 83-94 (in Chinese). Authors at Inst. Miner. Deposits, Chin. Acad. Geol. Sci., Peop. Rep. China.

Diabase and marble from nonmineralized zones of the Makeng skarn magnetite deposit were allowed to equilibrate in acid, neutral, and basic hydrothermal systems at 300-650° and 300-650 atm. This pressure-temp. range and neutral acidity are consistent with ests. of ore-forming conditions obtained on the basis of (1) fluid inclusion Th, the (2) $\delta^{34}S$ values in galena-sphalerite pairs, (3) pH-dependent mineral stability data, and (4) the augite → hornblende transition obsd. in altered diorites of the ore zones. (CA 98: 146801g)

LIDIN, G.D., MATVIENKO, N.G., ZIMAKOV, B.M., GAGAUS, F.G., VARDOIANI, E.Iu. and PEREVERZOV, V.V., 1982, New data on the emission of hydrogenous natural gases from ultrabasic rocks: Dokl. Akad. Nauk SSSR, v. 264, no. 5, p. 1224-1228 (in Russian).

Includes 10 analyses for CO_2, O_2, H_2, He, CH_4 and (N_2+Ar). H_2 is $\geqslant$66.5% in all. (E.R.)

LILLEY, M.D., DE ANGELIS, M.A. and GORDON, L.I., 1982, CH_4, H_2, CO and N_2O in submarine hydrothermal vent waters: Nature, v. 300, no. 4, p. 48-50. Authors at Sch. Oceanography, Oregon State Univ., Corvallis, OR 97331, USA.

Hydrothermal circulation systems of mid-ocean ridges profoundly influence the chemistry of the oceans and the oceanic crust. This has been demonstrated for several major and minor constituents of seawater and trace metals. In addition, several volatile compounds including helium as well as methane and hydrogen are introduced to the sea floor in concentrations greatly exceeding that of ambient bottom water. We present here our measurements of concentrations of methane, hydrogen, carbon monoxide and nitrous oxide in the hydrothermal vent waters from the Galapagos Spreading Centre. The relationships of these constituents to silicon were unique for each vent field, with nitrous oxide at East of Eden being the only instance of negative correlation. These gases could serve as important energy sources, in addition to hydrogen sulphide, for the chemosynthetic bacteria which support the extensive and diverse animal population living in these environments. (Authors' abstract)

LIN, Leslie, 1982, Ancient fluids in crystals: The Research News, v. 33, no. 3/4 (The Univ. of Michigan), p. 3-11.

A popular account of the inclusion research activities of W.C. Kelly at the Univ. of Michigan. (E.R.)

LIN, Shan, 1982a, A contribution to ignimbrites in Shixiahe, Gansu Province: Geochimica, 1982, no. 2, p. 205-212 (in Chinese; English abstract).

Shixiahe ignimbrites in Gansu Province were formed as a result of the fracture eruption during Mesozoic time. They are typical welded rocks, the cooling elements of which are still seen clearly, with well developed columnar joints, plastic fragments and fluidal structure. The unit weight of the rocks was found lying between those of lavas and tuffs. Crystallinoclastic plagioclases of both abyssal and volcanic types were recognized. In crystallinoclastic quartz fluid and glass inclusions were identified with the inclusion temperature ranging from 500 to 600°C. In accordance with the petrochemical characteristics these ignimbrites are thought to be rhyotaxitic aluminium-supersaturated calc-alkali rocks of Pacific type. Studies on the indices σ and τ figured out by A. Rittmann and V. Gottini show that this type of rocks should be assigned to igneous rocks occurring in the orogenic zones and island-arc areas. (Author's abstract; sic.)

LIN, Shan, 1982b, Some special decrepitation phenomena of pneumato-hydatogenetic inclusions of minerals: Mineral Deposits, v. 1, no. 2, p. 92-96 (in Chinese; English abstract). Author at Huadong Geol. College.

In the process of measuring the temperature of a great number of pneumato-hydatogenetic inclusions the author has found that some of them change abnormally both in gaseous and aqueous phases. The facts are enumerated as follows:

1. The blebs will increase in volume and decrepitate before the homogenization takes place when some fluid inclusions are heated.
2. The blebs will decrease in volume and decrepitate before the homogenization takes place when some inclusions are heated.
3. The blebs will expand first, then contract when some fluid inclusions are heated.
4. Some fluid inclusions will be homogenized twice when heated.
5. For saline minerals, the inclusions of pure hydatogenetic phase will produce blebs when heated, and the blebs will increase in volume with the rise of temperature till decrepitation happens.

The author therefore makes the suggestion that a clear distinction should be made between normal and abnormal phenomena in measuring the temperature of pneumato-hydatogenic inclusions, otherwise the ore-forming temperature cannot be determined with confidence(sic). (Author's abstract)

LINDBLOM, Sten, 1982, Fluid inclusion studies of the Laisvall sandstone lead-zinc deposit, Sweden: Medd. Stockholm Univ. Geol. Inst. No. 252 and doctoral thesis, Univ. Stockholm, 171 pp.

The ore forming environment at Laisvall was characterized by a total salt content of 24 eq. wt% NaCl with as much as 9 wt% $CaCl_2$. Its temperature fluctuated between 180°C and 120°C but generally decreased with time. The cementing mineral assemblage was deposited in the general sequence calcite, barite, fluorite, galena, sphalerite. This sequence was partially repeated several times.

The Laisvall ore mineral assemblage was deposited by mixing two solutions. One solution was an almost saturated metalliferous Na-Ca-Cl brine initially at 180°C that moved into the area from the west. The other was a less saline in situ groundwater solution of lower temperature. The brine solution entered the area in at least three major pulses. The different minerals, sulfides, calcite, barite and fluorite were deposited by different mechanisms as the environment changed in temperature and composition. Sulfide deposition was accompanied by calcite dissolution. This relationship was reversible indicating equilibrium conditions during mineral precipitation. Reduced sulfur may have been produced by reaction of sulfate and organic matter in the groundwater solution.

The host rock before mineralization was an uncemented sandstone with 25-30 vol.% porosity. The still remnant "microvugs" clearly show that the ore mineral assemblage was deposited in open space growth.

Postmineralization metamorphism has been restricted to a minimum as revealed by microfracture analyses and general lack of deformational textures in the ore minerals. Further evidence for the lack of significant metamorphism is provided by the sphalerite which displays three types of zoning changing with time and rate of growth. The zoning is related to color change and fluid inclusion temperature variation. (Author's abstract)

LIPMAN, P.W. and MULLINEAUX, D.R., eds., The 1980 eruptions of Mount St. Helens, Washington: U.S. Geol. Survey Professional Paper 1250.

Includes numerous articles on gas emissions and fumarole incrustations and their chemistry, of pertinence to inclusion studies in volcanic processes. (E.R.)

LIU, Bin, 1982, Studies of solid and fluid inclusions in the copper deposits in Baiyinchang: Acta Geol. Sinica, v. 56, no. 2, p. 165-173 (in Chinese; English abstract). Author at Xian Inst. Geol. & Min. Resources, Chinese Acad. Geol. Sci.

The copper orebodies are located in quartz keratophyre and quartz keratophyre tuff. In quartz phenocrysts and quartz crystaloclastics of these rocks, two types of glass inclusions are recognized: devitrified glass inclusions, and glass inclusions with gas bubbles. Temperatures for the formation of the glass inclusions are found to be 860°-910°C.

In the quartz crystals collected from altered volcanic rocks, five types of gas-fluid inclusions were found highly saline polyphase inclusions; liquid phase inclusions; monophase liquid inclusions; gas phase inclusions; fluid inclusions with CO_2. Remarkable changes in Th, salinity, grain size, and number of fluid inclusions are observed from the center of mineralization to the periphery.

In the late magmatic stage a hydrothermal solution with higher salinity and containing abundant Cl, Na, K, Fe, Cu, and Ag, etc. existed, and is considered to be the source of mineralization. This fluid moved up along weak zones, intruded into the quartz keratophyre and quartz keratophyre tuff, and mixed with the sea water infiltrating into the rocks. The metals in the fluid precipitated to form the deposits as the temperature and pressure declined. (Author's abstract)

LIU, Yingjun, LI, Zhaolin, XIE, Shaoqing, ZHAO, Meifang, JIANG, Haoshan and WU, Qizhi, 1982, Preliminary experimental study on the geochemistry of tungsten in southeastern China: Tungsten Geology Symposium, Jiangxi, China, sponsored by ESCAP/RMRDC and Ministry of Geology, PRC, 12-22 Oct., 1981: Pub. by ESCAP/RMRDC, Bandung, Indonesia, p. 359-374 (in English).

LOBATO, L.M., FORMAN, J.M.A., FUZIKAWA, K., FYFE, W.S. and KERRICH, R., 1982, Uranium enrichment in Archean basement: Lagoa Real, Brazil: Revista Brasileira de Geosciencias, v. 12, no. 1-3, p. 484-486 (in Portuguese; English abstract).

In the Lagoa Real region of the Sao Francisco craton altered basement, amphibolite-granulite facies felsic gneisses host significant uranium deposits. Retrograde alteration under epidote-amphibolite facies conditions as revealed by mass balance calculations is dominatd by sodium addition, oxidation, silica leaching and uranium enrichment. Oxygen isotope data indicate that uranium was precipitated from isotopically light fluids at temperatures near 500°C. Fluid inclusion data indicate similar temperatures at variable salinities. It is proposed that the geochemical observations are in accord with a model where the basement has been thrust over Proterozoic sediments and processes are controlled by an inverted thermal gradient. (Authors' abstract)

LOMAN, J.M., LEVY, P.W. and SWYLER, K.J., 1982, Radiation induced sodium metal colloid formation in natural rock salt from different geological localities, in S.V. Topp, ed., The Scientific Basis for Nuclear Waste Management, Elsevier Sci. Pub. Co., Inc., v. 4, p. 433-440.

LONDON, David, 1982a Fluid-solid inclusions in spodumene from the Tanco pegmatite, Bernic Lake, Manitoba (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 549. Author at The Geophys. Lab., 2801 Upton St., NW, Washington, DC 20008.

Spodumene (α-$LiAlSi_2O_6$) from the Tanco pegmatite, Manitoba, contains large (30-300 μm) primary and pseudosecondary inclusions. At 25°C, ~95% of the inclusions contain H_2O-rich liquid and vapor, and a complex assemblage of crystalline phases. Temperatures for initial melting of H_2O-ice (+?) range from -49°C to -45°C, and final disappearance of ice occurs at

-4.9(1.9)°C; H_2O-rich liquid + vapor homogenize to liquid at 260(15)°C. These values appear to be independent of the presence or absence of included solid phases. On the basis of energy dispersive analyses by EDAX, the entrapped crystalline phases consist principally of albite, Cs-analcime, pollucite, quartz, and (Li- or Be- ?) aluminosilicate, and a trigonal (?) phase that consists entirely of elements lighter than Na (e.g., a Li- or Be-carbonate or borate). The included crystalline phases melt to a quenchable glass between 375°C (initial melting) and 440°C (complete melting). On the basis of the heating - freezing measurements, the H_2O-rich fluid can be modelled as a low-salinity (2-3 equivalent wt% NaCl) aqueous solution that was entrapped at some P and T along an isochore that originates at 260(15)°C on the liquid-vapor curve for H_2O (+ 2-3 wt% NaCl) and has a slope of ~12 bars/°C. The assemblage of included crystalline phases may have been trapped as a silicate melt whose composition can be approximated by the system $LiAlSiO_4$-$CsAlSi_2O_6$-$NaAlSi_3O_8$-SiO_2-H_2O plus the unidentified carbonate or borate. If the assumed isochore is valid, and if the contents of the inclusions were trapped as a single H_2O-silicate fluid or as H_2O-fluid + immiscible silicate melt, then the minimum T (entrapment) ≅ 440°C, and the minimum P (entrapment) ≅ 2300 bars. This approximate P and T for the growth of spodumene at Tanco lies within the experimentally determined stability field of spodumene + quartz. (Author's abstract)

LONDON, D., 1982b, Stability of spodumene in acidic and saline fluorine-rich environments: Carnegie Inst. of Washington Year Book, v. 81, p. 331-334.

LONDON, David and BURT, D.M., 1982a Chemical models for lithium aluminosilicate stabilities in pegmatites and granites: Am. Min., v. 67, p. 494-509. First author at Geoph. Lab., 2801 Upton St., NW, Washington, DC 20008.

The primary lithium aluminosilicates in pegmatites are spodumene (α-$LiAlSi_2O_6$) and petalite ($LiAlSi_4O_{10}$). These minerals are frequently replaced by fine-grained assemblages of eucryptite (α-$LiAlSiO_4$), albite, micas, and clay minerals as a result of subsolidus cation exchange reactions with residual pegmatitic fluids.

All three of the lithium aluminosilicates may be converted to albite in quartz-saturated, Na-rich environments, but in quartz-undersaturated environments (as within large single crystals of spodumene), the replacement assemblage eucryptite + albite is stable to high values of the exchange potential $\mu(NaLi_{-1})$. The stability of the primary pegmatite assemblage quartz + albite + spodumene (or petalite) + amblygonite-montebrasite + lithiophilite means that lithiophilite or amblygonite-montebrasite cannot be altered to natrophilite ($NaMnPO_4$) or lacroixite ($NaAlPO_4F$), respectively, until Na-Li exchange has locally converted all of the lithium aluminosilicates to albite. Of the three lithium aluminosilicates, eucryptite is the most susceptible to replacement by muscovite, but spodumene also may be converted directly to mica ("killinite"). In acidic fluids with a high capacity to hydrolyze solid phases and leach alkali cations, the lithium aluminosilicates may be altered to (or become unstable relative to) kaolinite, cookeite, muscovite, lepidolite, and topaz. The common late-stage assemblage topaz + lepidolite + quartz forms in KF- and HF-rich environments outside of the lithium aluminosilicate stability region. All of the lithium aluminosilicates are unstable relative to amblygonite (or montebrasite) + quartz in P- and F-rich environments, but spodumene is stable to higher activities of these acidic volatiles than are eucryptite and petalite. (Authors' abstract)

LONDON, David and BURT, D.M.,b 1982, Lithium aluminosilicate occurrences in pegmatites and the lithium aluminosilicate phase diagram: Am. Min., v. 67, p. 483-493.

LONDON, D., SPOONER, E.T.C. and ROEDDER, E., 1982, Fluid-solid inclusions in spodumene from the Tanco pegmatite, Manitoba: Carnegie Inst. of Washington Year Book, v. 81, p. 334-339.
See London, 1982a, above. (E.R.)

LONG, D.T. and ANGINO, E.E., 1982, The mobilization of selected trace metals from shales by aqueous solutions: effects of temperature and ionic strength. Econ. Geol., v. 77, p. 646-652. First author at Dept. Geol., Michigan State Univ., East Lansing, MI 48824.

Removal of trace metals from shales by subsurface brines is often suggested as an origin of base metals in low-temperature, strata-bound ore deposits. This investigation studied the hypothesis that brine leaching of shales can increase metal content of subsurface brines sufficiently that the brines could potentially serve as ore-forming fluids. Two aspects were studied: the effect on mobilization of changes in the brine temperature (25°, 50°, and 90°C) and of changes in the ionic strength (0, 0.7, 2.0, and 4.0). The results of this study support the hypothesis. The following observations were made: (1) Increasing either the temperature or ionic strength of the brine increased the amount of leaching, but the trends were neither simple nor linear; a brine with an ionic strength of 10 at 120°C might not be any more effective in leaching trace metals than a brine with an ionic strength of 5 at 90°C. (2) Changing the salt composition of the brine changed the amount and type of mobilization. Calcium, for example, was found to be effective in leaching Pb and Zn, while K was found to be effective in mobilizing Cu. (Authors' abstract)

LOUCKS, R.R., 1982a Metal distribution zoning in fissure veins, Topia, Durango, Mexico (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 550. Author at Dept. Geol., Florida State Univ., Tallahassee, FL 32306. (See also Geol. Assoc. Can./Min. Assoc. Can. Program, v. 7, p. 63)

Tetrahedrite-freibergite, polybasite, sphalerite, Ag-rich galena, and electrum co-precipitated over virtually the entire paragenetic sequence in crustification-banded fissure veins in early Tertiary andesites at Topia. Permeability variation along fractures was not redistributed by significant structural dislocations during mineralization. Distribution patterns of Ag, Au, Pb, and Zn, determined in five veins employing channel sample assay data from 6000 localities, a new graphical method of trend analysis, and contouring of arrays of metal ratio and concentration data on longitudinal vein sections, reveal that along each vein rich ore is confined to a sub-horizontal, sinusoidally contorted ore "ribbon" of small (25-100 m) width having an amplitude of 150-250 m and a strike length of several km. Spatial variations in average homogenization temperatures of primary fluid inclusions in a 2 mm-wide sphalerite color-composition band correlated through a 100 x 350 m vein interval indicate temperature gradients as steep as 25°C/100 m in the inferred flow direction and imply major temperature control in producing telescoped precipitation across the narrow ore horizon. Ore grade drops sharply above and below the ore band due to silica dilution. Fissures pinch to ramified shear zones at shallow depth. Sinusoidal inflections of metal ratio contours on vein sections closely resemble sinusoidal inflections of isotherms in experimental long Hele-Shaw cells in which a series of laterally abutting convection cells yield upward-directed isotherm lobes in zones of upwelling flow. Detailed metal zoning patterns and fluid inclusion and isotope data suggest the existence of a system of subsidiary convection eddies with half-widths 50-100 m in the upper few hundred meters of a broad, deep meteoric water hydrothermal system. The zoning study has provided guides to specific locations of undeveloped ore, to improved estimation of ore reserves, and broad-scale guides to district exploration. (Author's abstract)

LU, H.-Z., 1982, Geological and fluid inclusion studies of Fankou lead-zinc ore deposit, China (abst.): EOS, Trans. Am. Geophys. Union, v. 63, p. 468. Author at Dept. Geol., Univ. Pennsylvania, Philadelphia, PA 19104.

The Fankou lead-zinc ore deposit occurs in Devonian and Carboniferous carbonate rocks. This deposit was thought to be a hydrothermal ore deposit related to a granite, but the present research suggests it is stratabound and a stratiform mineral deposit.

As a result of geological studies, primary sedimentary and later replacement features were found. Part of some ore bodies are concordant with the host rocks, but most are discordant lenses and veins in carbonate rocks. Thus there are two types of ores, primary sedimentary and later replacement. The replacement type is very common. Isotopic studies indicate that most of the Pb and S are of sedimentary origin, but part of the Pb is radiogenic in origin, possibly introduced during later replacement. A regional geochemical survey indicates that the Pb and Zn contents of the Fankou region are respectively 1.5 and 3 times higher than the world average. Only a few one-phase liquid inclusions were found in the primary sedimentary type. Gas-liquid fluid inclusions were found in the replacement type ore but not in the primary sedimentary type. The fluid which replaced the primary sedimentary rocks had a temperature of 100-200°C, a salinity of 3-6 wt% NaCl equiv. and a low pressure. Under the action of such fluid, the original sedimentary rocks were replaced to form the present ore deposit. (Author's abstract)

LU, Huanzhang, JIANG, Bangjie and SUN, Xinyi, 1982, Application of a new inorganic gas-chromatograph to fluid inclusion research: Geochem., v. 1, no. 3, p. 321-327. Authors at Inst. Geochem., Acad. Sinica.

See Lu et al., 1980, Fluid Inclusion Research--Proceedings of COFFI, v. 13, p. 148, 1980. (E.R.)

LU, Huanzhang, SHI, Jixi, YU, Cimei and XU, Shengjiao, 1982, Geologic and fluid inclusion studies of ten types of tungsten ore deposits in South China: Geochem., v. 1, no. 2, p. 200-217. Authors at Inst. Geochem., Acad. Sinica.

See Lu, 1981, Fluid Inclusion Research--Proceedings of COFFI, v. 14, p. 129, 1981. (E.R.)

LUCIDO, Giuseppe, 1982, The significant role of the van der Waals forces in the origin of primary magmatic water: Miner. Petrogr. Acta, v. 26, p. 109-119 (in English). Author at Istituto di Min., Petro., & Geoch. della Univ. di Palermo.

Although terrestrial water is generally assumed to be from magmatic gases (Rubey's theory), the author thinks that the "major part" of the present waters on the Earth's surface has been produced in a different way.

The nature of the van der Waals interactions and the effects of the partial electrical charges in the water molecules are reviewed with particular attention given to the fundamental facts involved in the origin of primary magmatic water. It is concluded that the physics and chemistry of water support the hypothesis that H_2O escapes from magmas in different physical states in different physical environments.

In the author's opinion, during the geologic past, the van der Waals forces played a very important role(sic). (Author's abstract)

L'VOV, S.N. and ZAREMBO, V.I., 1982, The limiting partial volumes of dissolved electrolytes at high state parameters: Geokhimiya, no. 4, p. 565-575.

Measurements on the $NaCl-H_2O$ system have given the limiting partial molar volumes of the dissolved salt in the range 323-573 K at pressures from 10 to 80 MPa. A model for ionic hydration is proposed that has been used in deriving the limiting partial molar volumes for 16 1-1 and 2-1 electrolytes in water over the range 498-623 K at the saturation vapor pressure of the pure solvent. (Authors' abstract)

L'VOV, S.N., ZAREMBO, V.I. and GILYAROV, V.N., 1981, Precision investigations of the volume properties of aqueous solutions of sodium chloride at high parameters of state: Geokhimiya, no. 4, p. 505-516 (in Russian; translated in Geochem. Int'l., v. 18, no. 2, p. 118-129, 1982).

Abstract in Fluid Inclusion Research--Proceedings of COFFI, v. 14, p. 131. (E.R.)

LYAKHOV, Yu.V., 1982, Thermobarogeochemical studies of temperature-facies zoning and their significance for prospecting and evaluation of hydrothermal ore deposits, in Use of methods of thermobarogeochemistry during prospecting and studies of ore deposits, N.P. Laverov, ed.: Moscow, "Nedra" Publ. House, p. 213-220 (in Russian).

The principles and methods are proposed for construction and interpretation (with use of computer) of the space-substance models that make possible the determination of nature and various details of paleotemperature zoning of ore objects and solution of many problems of theoretical and practical geology. Especially, the decrease of paleotemperature gradient values found on passing from near-surface conditions (50-20°C/100 m) to deep ones (20-5°C/100 m) proves the better thermostatic conditions of hydrothermal systems and makes possible the evaluation of the depth of the deposit formation and vertical extent of ore mineralization. (Author's abstract translated by A.K.)

LYAKHOV, Y.V., PIZNYUR, A.V., POPIVNYAK, I.V., POZDEEV, K.M., EKHIVANOV, V.A., MUSIKHIN, V.P. and OKHRIMENKO, V.G., 1982, Some aspects of thermobarogeochemical evaluation and prediction of gold and polymetallic mineralization (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 206-207. Authors at L'vov State Univ., L'vov, USSR.

The paper gives generalized results of a thermobarogeochemical study of Au, pyrite-polymetallic and Pb-Zn deposits. An important role of carbon-dioxide-aqueous solutions has been found in the formation of the mineralization; the mineral-forming process being most active during the deposition of the "productive" mineral complexes. (From the authors' abstract)

LYASHCHENKO, A.K. and CHURAGULOV, B.R., 1981, Pressure influence on temperature coefficients of solubility of electrolytes in water: Zhurn.

Neorg. Khimii, v. 26, no. 5, p. 1190-1197 (in Russian). Authors at Inst. General and Inorganic Chem. of Acad. Sci. USSR.

Pressure influence on T dependence of solubility of electrolytes in water solutions is discussed. T coefficients of solubility of electrolytes are calculated for a wide T and P range. Change of T coefficients of solubility is determined by alteration of ion hydration and solvent structure with P increment. (Authors' abstract translated by A.K.)

MACDONALD, A.J. and SPOONER, E.T.C., 1982, Carbonate complexing of molybdenum in hydrothermal solutions: evidence from Boss Mountain, British Columbia (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 552. Authors at Dept. Geol., Univ. Toronto, Toronto, Ontario, M5S 1A1, Canada.

Microthermometric analysis of fluid inclusions in main stage breccia and sheeted vein quartz-molybdenite mineralization at the Boss Mountain mine indicates that the bulk of the ore was deposited between temperatures of 350°C and 250°C. Mineralization was accompanied by carbon dioxide effervescence throughout the deposit, with the exception of the lowest level in the mine (4440), below which molybdenite grade declines rapidly. Although fluid inclusions were examined throughout approximately 3 cubic kilometers, no thermal gradient was detected.

The coexistence of H_2O liquid-rich and CO_2 vapor-rich inclusions above the 4440 level indicates that the hydrothermal fluid underwent phase separation after passing this elevation; i.e., the solvus in the H_2O-CO_2-NaCl system was intersected. The fluid inclusions from the 4440 level (i.e. those that have not undergone phase separation) homogenize around 350°C and contain approximately 2 mole % equivalent NaCl and 4 mole % CO_2. A fluid at this temperature and of this composition undergoes phase separation on the solvus at a pressure of approximately 350 bars (= a lithostatic load of 1.3 km).

Both thermodynamic and experimental investigations of the solubility of molybdenum in hydrothermal fluids indicate that halides (Cl and F) and sulphur are not important complexing agents. It has been proposed that molybdenum is transported as molybdate, bimolybdate and hydroxy-oxide species.

The Boss Mountain data indicate a direct association between effervescence of CO_2 from the hydrothermal fluid and precipitation of MoS_2. It is suggested, therefore, that effervescence destabilized a Mo carbonate complex, allowing the metal to combine with dissolved sulphur to form the insoluble sulphide. (Authors' abstract)

MAGID, M.Sh., 1982, Problem of the possible effective pressure acting on the deep-seated crystalline rocks: Geologiya i Geofizika, no. 7, p. 95-100 (in Russian; English abstract). Author at VSEGEI, Leningrad, USSR.

Analysis of geologic and petrophysical data indicates that crystalline and sedimentary rocks were subjected to effective fluid pressures determined by the difference of external lithostatic and intrapore pressures. (From the author's conclusions, translated by A.K.)

MAHTAB, M.A., 1982, Geochemical aspects of gas outbursts in Louisiana salt mines: Bull. Assoc. Engrg. Geol., v. 19, no. 4, p. 389-400. Author at Henry Krumb Sch. Mines, Columbia Univ., New York, NY 10027.

Gas outbursts in Louisiana salt mines are sudden eruptions of salt and gas from the face or roof of a mine heading that result in a generally semi-ellipsoidal cavity with axial length of up to 50 m or more. The potential risks from gas outbursts include loss of life or even the mine. Several characteristics of gas outbursts in Louisiana salt mines and suggested methods for their prevention are common to both coal mines and other salt mines.

The objectives of this paper are to synthesize the available knowledge of the geomechanical aspects of gas outbursts, suggest a plausible mechanism for gas outbursts in Louisiana salt mines, recommend procedures for prediction and prevention of the outbursts, and outline the needs for further study in this important area of geomechanics.

In Louisiana salt mines, a gas outburst occurs at a certain depth when a heading face approaches a pressure pocket (impure or altered salt with entrapped, high-pressure gas). It is proposed that a gas outburst is initiated by disking in biaxial compression and propagates by spalling of the cavity walls and further disking. The outburst is terminated by a combination of dilatancy hardening, increase in stress along the cavity axis, and enlargement of the cavity to the boundaries of the pressure pocket.

Identification of burst-prone areas will require research into in situ measurement of material characteristics and further understanding of the mechanism of gas outbursts. Shock blasting in advance of mining appears to be a promising technique for controlling gas outbursts. (Author's abstract)

MAISONNEUVE, Jacques, 1982, The composition of the Precambrian ocean waters: Sedimentary Geol., v. 31, p. 1-11.

MAISONNEUVE, J. and PERICHAUD, J.J., 1982, Radioactive heat and post-magmatic low temperature mineralizations: Bull. BRGM, sec. II, v. 2, no. 4, p. 393-399 (in French). First author at Dept. géol. & min., 5 rue Kessler, 63038 Clermont-Ferrand Cedex, France.

Hydrothermal mineralizations can be much younger than the intrusions to which they appear related. Since the cooling of a granite batholith takes less than 1 M.y. the question arises of the origin of the heat of hydrothermal events occurring tens or hundreds millions of years after the intrusion.

The hypothesis proposed is that the energy originating from the decay of U, Th and K in granites can, under suitable conditions, lead to a sufficient build-up of temperatures to account for late hydrothermalism. (From the authors' abstract)

MANANKOV, A.V. and SHARAPOV, V.N., 1982, Kinetics of crystallization of basalt melts of various alkalinity and iron content: Akad. Nauk SSSR Doklady, v. 267, no. 4, p. 916-920 (in Russian). First author at Tomsk State Univ., USSR.

The paper presents the kinetics of crystallization of titanomagnetite, clinopyroxene and labradorite from high-alumina leucobasalt and alkaline basalt melts at T 1400-1000°C in air and helium atmospheres. Pertinent to degree of crystallinity of melt inclusions. (A.K.)

MANNING, D.A.C., 1982a The behavior of fluorine at the late-magmatic and early post-magmatic stages in the development of the Cornish granites: the application of experimental studies (abst.): J. Geol. Soc. London, v. 139, part 1, p. 97.

Experimental studies of the system Qz-Ab-Or at PH_2O=1kb have shown that fluorine partitions predominantly into the melt rather than the vapor phase, and that F-rich melts may exist down to 550°C or less. In Cornish F-rich granites, a proportion of the fluorine content of the magma has been fixed prior to complete consolidation in primary topaz and lithium-mica. Alteration of these F-rich aluminosilicate phases ($F/(F+OH)\approx0.8$) leads to F-poor muscovite ($F/(F+OH)\approx0.05$) and fluorite of hydrothermal origin. The hydrothermal fluid is thus enriched in fluorine by post-magmatic reactions with F-rich aluminosilicate phases. Experimental and petrographic data suggest that whereas fluorine may aid concentration of metals such as Sn and W by magmatic processes, the affinity of magmatic fluorine for aluminosilicate phases does not favor the formation of residual F-rich ore-forming fluids. Such fluids may be produced by post-magmatic reaction between aqueous solutions of many possible origins and F-rich granitic rocks, independent of their crystallization. (Author's abstract)

MANNING, D.A.C., 1982b-Partitioning of tungsten between granitic melts and a coexisting aqueous phase: Bull. Minéral., suppl., v. 105, p. 53 (in French).

The partition coefficient of tungsten between "minimum melts" in the system Qz-Ab-Or and aqueous phase have been determined at 800°C and 1 kb for pure H_2O and fluoride and chloride solutions. The coefficients are strongly dependent on concentration for experiments with pure H_2O and NaCl solutions. With an NaCl solution, tungsten is partitioned strongly in favor of the aqueous phase and has a solubility maximum in the melt of 0.5 wt. %. With pure H_2O, the solubility maximum in the melt is between 1 and 2 wt. %; for lower concentrations, tungsten is partitioned in favor of the melt. In the presence of fluorine, tungsten is apparently partitioned in favor of the melt. However, for certain melt compositions, a crystalline phase (possibly WO_3) precipitates, which complicates the interpretation. Preliminary experiments suggest that tungsten is partitioned almost equally between the melt and carbon-bearing [CO_2?] fluid.

The different behavior of tungsten in the presence of F or Cl probably reflects the behavior of these elements in granitic systems. F is partitioned strongly in favor of the aluminosilicate melt with depolymerization and partial destruction of the melt structure, which favors the incorporation of tungsten complexes. On the other hand, Cl has little effect on the aluminosilicate melt structure if one considers its [W] low solubility in these melts. Tungsten complexes cannot be easily incorporated [in the melt structure] which explains the partitioning of tungsten towards the aqueous phase. These experimental data can be applied directly to certain occurrences of tungsten associated with the fluorine-rich granites of Cornwall (England). (Abstract translated courtesy R. Bodnar)

MARAKUSHEV, A.A., 1981, The fluid regime in the formation of diamond-containing rock: Geol. Rudnykh Mestorozh., no. 4, p. 3-17 (in Russian; translated in Internat. Geol. Review, v. 24, no. 11, p. 1241-1252, 1982). Author at Lomonosov Moscow Univ.

Diamond forms in the mantle during crystallization of peridotite and eclogite magmas, by the reactions: $2CO + CH_4 \rightarrow 3C + 2H_2O$ and $CO_2 + CH_4 \rightarrow 2C + H_2O$. Diamond-bearing peridotite and eclogite magmas were introduced into disjunctive structures of platforms; in the process, the high-pressure mineralization was best preserved in the volcanic environment of the upper parts of pipes. The composition of kimberlites is determined by the compositions of peridotites and eclogites which are replaced by the kimberlite magmas and inherit their high-pressure mineralizations. (Author's abstract)

MARIGNAC, Christian, 1982, Geologic, fluid inclusions, and stable isotope studies of the tin-tungsten deposits of Panasqueira, Portugal - a discussion: Econ. Geol., v. 77, p. 1263-1266. Author at Lab. Metal., Ecole Nationale Superieure de Géol. Appliqué, P.O. 452, 54001 Nancy Cedex, France.

A criticism of Kelly and Rye 1979 (Fluid Inclusion Research--Proc. of COFFI, v. 12, 1979, p. 84-86) concerning aspects of the mechanism and timing of vein opening at Panasqueira, Portugal. (E.R.)

MARSHALL, J.D., 1982, Isotopic composition of displacive fibrous calcite veins: reversals in pore-water composition trends during burial diagenesis: J. Sedimentary Petr., v. 52, no. 2, p. 0615-0630. Author at Dept. Geol., Leicester Univ., Leicester, UK.

Stable isotope and petrographic analyses of diagenetic calcite ("cone-in-cone" and "beef") veins from British Jurassic and Lower Cretaceous shales have been used to determine the environment of precipitation of fibrous calcites. Successive growth took place by antitaxial displacive addition at the vein margins, away from primary sedimentary laminations or early diagenetic concretions. Carbon and oxygen isotopic ratios ($\delta^{13}C$ ±0 and $\delta^{18}O$ -4 to -11‰) indicate a relatively late diagenetic origin for the veins after tens or probably hundreds of meters of burial, and after cessation of bacterial activity and considerable modification of the oxygen isotopic composition of the pore water. Vein growth was discontinuous and took place in waters of changing isotopic and trace-element composition. Changes are not unidirectional and are unlikely to result from the simple evolution of a single connate pore water; reversals in isotopic trends indicate that precipitation took place during periods of renewed (lateral?) groundwater flow, trapping different sources of bicarbonate-bearing solution. (Author's abstract)

MARTIGNOLE, J. and NANTEL, S., 1982, Geothermobarometry of cordierite-bearing metapelites near the Morin anorthosite complex, Grenville, province, Quebec: Can. Min., v. 20, p. 307-318. First author at Dept. géol., Univ. Montreal, Case postale 6128, Succursale "A," Montreal, Quebec H3C 3J7.

Involves some discussion of the volatile content of cordierites vs. the composition and pressure of a volatile phase. (E.R.)

MARTIN, R., MULLIS, J., NUNGAESSER, W. and GALETTI, G., 1982, The whewellite of the "terres noires" of la Drome (France): Schweiz. Mineral. Petrogr. Mitt., v. 62, p. 1-13 (in French). First author at 4 chemin du Léman, CH-1260 Nyon, Switzerland.

The whewellite deposit of Condorcet in the Drome is the second discovered in France. It is located in the Oxfordian marls. The x-ray values correspond well to those of the synthetic whewellite. The results of chemical analysis are very near to the theoretical values. The morphology of the crystals of whewellite and the mineral paragenesis in the septarian seem to have been conditioned by the physicochemical variations of the growth-environment. (Authors' abstract)

The whewellite contains methane inclusions with Th of -70°C, indicating that the methane is not pure (more than 1 mol.% heavier hydrocarbons). (H.A. Stalder)

MARTIN, S., 1981, Episyenitization and mineralization in the Hyverneresse (North Millevaches Plateau-French Massif Central) leucogranite; petrography, mineralogy, geochemistry, fluid inclusions: Doctoral dissertation, Univ. Clermont-Ferrand, France, 228 pp. (in French).

Indexed under fluid inclusions. (E.R.)

MASTERSON, W.D., IV, 1981, Epithermal gold mineralization in the Velvet district, Pershing County, Nevada: M.A. thesis, The Univ. Texas at Austin, Austin, TX.

Gold mineralization in the Velvet District occurs in an eastward dipping sequence of Miocene tuffs, flows, and tuffaceous sediments on the west flank of the Trinity Range in Pershing County, Nevada. Numerous north-northeast trending normal faults extend through the district. These faults served as conduits for ascending hydrothermal fluids which deposited gold and silver along poorly defined zones of brecciation, argillic alteration, and quartz veining. Concentration of gold does not exceed a few parts per million and is highest in zones of intersecting fractures.

The hydrothermal solutions which deposited the gold were the near-surface expression of a larger geothermal system. Meteoric water leached gold, silver, arsenic, antimony, and other metals from the surrounding rock as it percolated downward towards a deep heat source. The hot fluids escaped upward along fracture zones and precipitated precious metals in veins near the surface. Fluid inclusion studies indicate that the quartz veins were deposited in the temperature range 218-264°C from fluids which had salinities equivalent to 0.2-0.8 weight percent NaCl. $\delta^{18}O$ of quartz veins varies from -2.5 to +6.7‰, and the low values appear to define a zone of concentrated fluid flow and potential subsurface mineralization in the southeast part of the district. The lowest value, -2.5‰, indicates that the ore fluid must have been Tertiary meteoric water with $\delta^{18}O$ equal to -13‰.

Reaction of hydrothermal fluids with wall rock produced an alteration assemblage of illite-kaolinite-quartz which underlies most of the shafts, adits, and prospect pits in the district. The illite-kaolinite-quartz assemblage is laterally gradational into a kaolinite (or dickite)-smectite-alunite-quartz assemblage which is indicative of lower temperatures. Pyrite and other sulfides are rare, but limonite and jarosite are widespread in surface outcrops. Alteration of tuffs released abundant silica which precipitated as quartz veins and discharged in hot springs at the bottom of lakes, where thick deposits of diatomaceous earth accumulated. (Author's abstract)

MATHEZ, E.A., DIETRICH, V.J. and IRVING, A.J., 1982, Abundances of carbon in mantle xenoliths from alkalic basalts: Terra Cognita, v. 2, p. 199-200. First author at Dept. Geol. Sci., Univ. Washington, Seattle, WA 98195, USA.

In mantle xenoliths from volcanic rocks, C exists as CO_2 in fluid inclusions and as an elemental form in microcracks and on inclusion walls. Carbonate is usually present as well and is generally believed to have been introduced after eruption. Both absolute amounts of C and relative abundances of its various forms were determined in a suite of representative xenoliths. Interior portions of samples were crushed to coarse (<1.4 mm) fragments, washed in cold 1N HCl, and fused with a flux. Fusion in an oxidizing atmosphere liberated all elemental C and vapor of CO_2, which was then determined by titration. In constrast, only vapor was liberated from samples fused in a reducing atmosphere. A similar procedure was followed for unwashed samples.

A significant proportion of the C in nearly all samples is removed by acid-washing. The soluble fraction must reside on grain boundaries and is presumed to be carbonate. In samples collected from environments in which caliche is present, carbonate contamination from meteoric sources is suspected. In others, carbonate probably also originated by post-eruptive redistribution of C from host lavas.

Most acid-washed Cr-diopside spinel lherzolites contain 10-40 ppm (by wt.) total C. These concentrations are considerably lower than those determined from previous analyses. The range in C contents of four Al-augite pyroxenites is 40-80 ppm, and one of the amphibole-phlogopite-apatite-spinel lherzolites from Nunivak Is., Alaska contains 85 ppm C.

The average C:CO_2 ratio for all samples is 0.06. Assuming that elemental C results from the reaction 2CO → C + CO_2, then the vapor from which C precipitated consisted of ~30 mole % CO. (Authors' abstract)

MATHIESON, G.A., 1982, The Cantung E-zone scheelite skarn orebody, Tungsten, N.W.T., Canada; a revised genetic model: MS thesis, Queen's Univ., Kingston, Ontario, Canada, 156 pp.

Indexed under Fluid Inclusions. (E.R.)

MATHIESON, G.A. and CLARK, A.H., 1982, The Cantung E-Zone scheelite skarn orebody, tungsten, N.W.T., Canada: a revised genetic model (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 558. Authors at Dept. Geol. Sci., Queen's Univ., Kingston, Ontario, K7L 3N6, Canada.

Models proposed for this large exoskarn deposit by Zaw and Clark (1977; 1978) and Dick (unpubl. Ph.D. thesis, 1980) differ regarding: (i) the relations between contact metamorphism and skarn formation and (ii) the temporal relations of "anhydrous" (gt-cpx-sch-po-cpy) and "hydrous" (amph and/or bi-sch-po) skarns.

Textures in foliated contact hornfelses demonstrate that metamorphism, of hornblende hornfels facies, was essentially complete prior to skarn development. New fluid inclusion data show that, whereas considerable hydrous skarn formed simultaneously with the anhydrous facies, a progressive increase in the relative volume of hydrous skarn occurred as temperatures decreased from ca. 505°C to 270°C (Th corrected for 1 kbar; after Zaw and Clark). This transition was not paralleled by changes in fluid salinity, which remained in the range 4-14 wt.% NaCl equivalent. Th values vary widely on a small scale, but there is no evidence of fluid boiling. The hydrous skarns are not strictly retrograde, and scheelite was probably not redistributed during skarn evolution.

A high proportion of scheelite (and apatite) grains contain inclusions with $0°C<Tm<10°C$, suggesting the presence of CO_2, and indicating local fluid immiscibility. Thus, temporary blockage of fluid channelways may have caused increases in fluid XCO_2 and, critically, calcium activity, which favored scheelite precipitation.

Comparison of the P-T conditions delimited for the unusually rich E-Zone orebody reveals that it formed at shallower depths and lower temperatures than the majority of Cordilleran tungsten skarns (cf. Newberry & Einaudi, 1981). (Authors' abstract)

MATKOVSKII, O.I., BARTOSHINSKII, V.Z., GRITSIK, V.V. and SHKLYANKA, V.M., 1982, Mineralogy of barite from the Beregovo deposit: Mineral. Zh., v. 4, no. 6, p. 62-72 (in Russian). Authors at L'vov State Univ., L'vov, USSR.

Barite in the Beregovo deposit of the Ukrainian Carpathians accompanies alunite, Au-polymetallic, and kaolinite mineralization. Five crystallomorphic types of barite crystals were distinguished, based on measurements by goniometer. Study of the fluid inclusions in the different morphol. types showed that the highest temp. (295-200°) barite (2 types) was related to the main (polymetallic) stage of mineralization. Two other types formed at 120-100° during the culmination of argillization accompanying the sulfide stage. The lowest temp. barite sepd. together with chalcedony in siliceous metasomatites. (Modified from CA 98: 129383e)

MATUZENKO, M.Yu., L'VOV, S.N. and ZAREMBO, V.I., 1982, Model calculations on the standard thermodynamic functions for the formation of polyatomic ions in aqueous solution at 298-623K: Geokhimiya, no. 5, p. 720-725 (in Russian).

MATUZENKO, M.Yu., YEGOROV, V.Ya., ZAREMBO, V.I. and PUCHKOV, L.V., 1982, Thermodynamic parameters of aqueous solutions of alkali carbonates at 298-573 K: Geokhimiya, no. 3, p. 381-386 (in Russian).

MAYER, Erwin and BRUGGELER, Peter, 1982, Vitrification of pure liquid water by high pressure jet freezing: Nature, v. 298, p. 715-718. Authors at Inst. Anorganische und Analy. Chemie, Univ. Innsbruck, A 6020 Innsbruck, Austria.

The vitrification of pure liquid water by projecting a thin jet of liquid water at high speed into a liquid cryomedium is reported. The influence of the experimental parameters on the cooling rate and the devitrification of the jet-frozen vitrified material have been investigated. A structural difference between vitrified liquid water and amorphous solid water prepared from the vapor phase is inferred from a comparison of the X-ray diffraction patterns. (Authors' abstract)

MAZOR, E. and THOMPSON, J.M., 1982, Evolution of geothermal fluids deduced from chemistry plots: Yellowstone National Park (U.S.A.): J. Volcanol. Geotherm. Res., v. 12, p. 351-360. First author at Geo-Isotope Group, Isotope Dept., Weizmann Inst. Sci., Rehovot, Israel.

Large amounts of chemical data, obtained in geothermal fields, may readily be sorted-out by the aid of a simple set of graphs that provide a clear over-all picture and facilitate the understanding of geochemical processes taking place. As a case study, data from several hundred samples of the thermal springs at the well-known Yellowstone National Park are discussed.

The pattern obtained seems to indicate: (1) geochemical similarity between the spring groups of Heart Lake, Shoshone, Upper, Midway, Lower and Norris Geyser Basins, i.e., a geochemical uniformity of major spring groups located over 40 km apart; (2) these groups may be described as originating from a common fluid, most resembling the composition of Norris waters, accompanied by CO_2 and other volatiles, that react with igneous rocks, forming local variations; (3) the secondary reactions occur at (medium) depth, before the ascent to the surface; (4) extensive concentration--dilution processes occur during the ascent to the surface.

The water of the Mammoth group may be described as originating from the same Norris-like fluid that has been diluted (low Na and Cl contents) and intensively reacted with carbonaceous rocks, thus gaining in Ca, Mg, SO_4 and HCO_3. (Authors' abstract)

MAZOR, Yu.V., MEL'NIKOV, F.P., SEREGIN, A.M. and SOKOLOV, B.A., 1982, Use of thermobarogeochemical methods in oil-gas and coal geology, in N.P. Ermakov, ed., Thermobarogeochemistry in Geology - Materials of the Sixth All-Union Symposium on Thermobarogeochemistry: Vladivostok, Far East Sci. Center, Acad. Sci. USSR Pub. House, p. 121-124 (in Russian).

The possibilities are considered, connected with use of fluid inclusion study methods in petroleum-gas geology, especially inclusion investigations in low-T minerals: gypsum, anhydrite, calcite and salts, which provide new information about parameters of oil formation and ways of hydrocarbon migration. (Authors' abstract, translated by A.K.; note - abstract of this paper was not published in the Abstract Volumes of the Vladivostok Symposium, A.K.)

MEGRELISHVILI, Zh.Sh., 1982, Conditions of formation and location of metasomatites at the Bektakar china stone deposit (Georgia): Izvestiya Vyssh. Uchebn. Zaved.-Geologiya i Razvedka, no. 9, p. 153-154 (in Russian). Author at Moscow Geol.-Prosp. Inst., USSR.

The deposit consists of quartz, quartz-sericite (Th 180-240°C), quartz-hydromica-kaolinite (Th 460-520°C), quartz-adularia-albite-sericite (Th 280-420°C) and quartz-adularia-epidote-chlorite metasomatites. (A.K.)

MEL'NIKOV, F.P., 1982a Perspectives of development of cryometric studies of inclusions of mineral-forming solutions, *in* Use of methods of thermobarogeochemistry during prospecting and studies of ore deposits, N.P. Laverov, ed.: Moscow, "Nedra" Publ. House, p. 31-37 (in Russian).

The author discusses various principles of freezing stage construction and concludes that L nitrogen freezing stages are the best devices. There are listed data on mineral-forming fluids obtainable by freezing method. Cryometric studies may be divided into four groups: 1. Cryometry of low-concentration solutions; 2. Cryometry of high-concentration solutions; 3. Cryometry of gases; 4. Cryometry of hydrocarbons in inclusions. Habit of crystallohydrates is described, but without quoting the typical features of various compounds. Also cryometry of CO_2 and hydrocarbons is presented briefly. (Abstract by A.K.)

MEL'NIKOV, F.P., 1982b Thermobarogeochemical studies of hydrocarbons in inclusions, *in* Use of methods of thermobarogeochemistry during prospecting and studies of ore deposits, N.P. Laverov, ed.: Moscow, "Nedra" Publ. House, p. 184-189 (in Russian).

Data on hydrocarbon occurrences in various ore deposits of various genetic types are quoted. The problems of paragenetic and genetic connection of endogene mineral formation with oil origin are discussed, as well as scientific and practical importance of studies of hydrocarbon inclusions in endogeneous minerals. (Author's abstract translated by A.K.)

MEL'NIKOV, F.P., DEMIN, Yu.I. and POLYANSKIY, Ye.V., 1982, Temperature regime and dynamics of thermal fields of granite intrusives in the Born-Gorkhon ore field, *in* N.P. Ermakov, ed., Thermobarogeochemistry in Geology - Materials of the Sixth All-Union Symposium on Thermobarogeochemistry: Vladivostok, Far East Sci. Center, Acad. Sci. USSR Pub. House, p. 59-62 (in Russian).

Computer calculations of thermal field; abstract of this paper was not published in the Abstract Volumes of the Vladivostok Symposium.(A.K.)

MELNIKOV, F.P., KULIKOV, I.V. and GROMOV, A.V., 1979, Multiphase inclusions in fluorite of Tryny-Auz deposit: Deposited in V.I.N.I.G.I., no. 3965-79, Moscow, 1979.

As quoted in Kulikov et al., 1982, this volume. (E.R.)

MELNIKOV, F.P., KULIKOV, I.V. and GROMOV, A.V., 1982, Physico-chemical conditions of fluorite ore formation of Tyrny-Auz (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 207-208. First author at Moscow State Univ., Moscow, USSR.

The Mo-W skarns at Tyrny-Auz (largest deposit of this type in the North Caucasus) were followed by high-temperature fluorite ores, originated in special and paragenetic connection with rhyolite bodies and explosive breccias. Fluorite, andradite, sulphides, calcite, scheelite, and quartz are main minerals of these ores. Being saturated with large multiphase inclusions of highly concentrated mineralizing solutions these minerals, and fluorite in particular, are extremely interesting for thermobarogeochemical studies.

The Tyrny-Auz fluorite forms colorless transparent crystals mostly of an octahedral habit, containing numerous multiphase highly concentrated inclusions. The mode of their distribution in the crystals and the equilibrium form of the vacuoles as negative crystals relate these inclusions to the primary ones. The inclusions are distributed remarkably irregularly: there are sites with inclusions occupying about 5% of the host mineral volume, and, at the same time, sites completely devoid of any. The sizes of some inclusions are striking, reaching 15-20 mm and more in diameter, while their average size is 0.1-1.0 mm. The described inclusions contain both gaseous and liquid phases and from 3-4 to 10-20 daughter minerals per vacuole. Inclusions with maximum amount of solid phases are mainly encountered in the fluorite of the lower levels, their number as well as their volume decreasing gradually towards the upper layers. The number and composition of the solid phases - are quite often drastically different in the neighboring inclusions within one zone of the host-crystal. Traces of boiling of the solutions are observable. Thus, it can be readily concluded that these large oversaturated inclusions form under transient conditions, when an accelerated growth of minerals out of heterogeneous solutions leads to the formation of large cavities. The transient conditions of crystallization are also evidenced by a higher amount of defects in the fluorite structure.

X-ray examination of the highly concentrated inclusions have revealed these solid phases: magnetite, pyrite, pyrrhotite, chalcopyrite, sphalerite, quartz, calcite, halite, sylvine, graphite and others. They dissolve when heated in a wide range of temperatures 200-700°C. The ore minerals are the last ones to disappear (the temperature of dissolution is 700-820°C). Above 800°C the inclusions seem to be homogenized into the liquid phase, although we failed to see that moment due to the gradual "depressurization" of the vacuoles occurring at these temperatures and sometimes accompanied by a remarkable dissolution of their walls. Such observations on fluid inclusions in fluorite have been attempted for the first time , as well as the X-ray identification of a wide range of the daughter ore minerals.

The concentration of the dissolved chlorides NaCl + KCl in the inclusions was found to be 60-70%. The pressure at the lower levels of the deposit was found by Lemmlein's method to be about 1200 bar.

It is thus concluded that the fluorite of the Tyrny-Auz deposit was crystallized out of concentrated high-temperature brines under transient conditions of tectonic activity. (Authors' abstract)

MEL'NIKOV, F.P. and MITIN, S.N., 1982, Studies of gas-liquid inclusions in halite from Upper Jurassic evaporite formations of the East Kuban' and Chernoles depressions, in N.P. Ermakov, ed., Thermobarogeochemistry in Geology - Materials of the Sixth All-Union Symposium on Thermobarogeochemistry: Vladivostok, Far East Sci. Center, Acad. Sci. USSR Pub. House, p. 117-121 (in Russian).

For abstract, see Fluid Inclusion Research--Proceedings of COFFI, vol. 12, 1979, p. 117. (A.K.)

MELTON, C.E. and GIARDINI, A.A., 1982, The evolution of the Earth's atmosphere and oceans: Geophys. Res. Lett., v. 9, p. 579-582. Authors at Dept. Chem., Univ. Georgia, Athens, GA 30602

A model describing the evolution of the present atmosphere and hydrosphere has been developed, based in large part on the analyses made by these authors of the gases evolved on crushing or graphitizing diamonds.

See Giardini and Melton, 1981, Fluid Inclusion Research--Proceedings of COFFI, v. 14, p. 69; Melton and Giardini, 1981, Fluid Inclusion Research--Proceedings of COFFI, v. 14, p. 138, and v. 13, p. 161-162. (E.R.)

MERCOLLI, Ivan, 1982, The fluid inclusions in the nodules of quartz of the dolomitic marbles from the region of Campolungo (Ticino): Schweiz. mineral. petrogr. Mitt., v. 62, p. 245-312 (in Italian; English abstract). Author at Istituto di cristal. & petro. del Politecnico Fed. di Zurigo, ETH-Zentrum, 8092 Zurigo.

A layer in the Triassic dolomitic marbles of the Campolungo area contains nodules of quartz, calcite, tremolite and talc. The fluid inclusions in the quartz nuclei of these nodules are the main argument of this work.

From the mineralogical and structural analysis it could be deduced that the quartz nuclei (partial with fluorite) of the nodules are anterior to the alpine metamorphism. Presumably they are either the product of an older hydrothermal activity or sedimentogenic material. They show a boudinage parallel to S_0 and S_1 (respectively the sedimentary layering and the alpine foliation originated by the isoclinal fold of the dolomitic marbles) or a remobilization in lenses parallel to S_2 (second alpine foliation generated by the local folding of the isoclinal folds) and discordant to S_0 and S_1.

The reaction rim separating the quartz core from the dolomitic marble is a chaotic undeformed (postkinematic) fabric of tremolite and calcite. Important is the difference between the tremolite in the marble (prismatic, parallel to S_1, rich in Al and poor in F) and the tremolite in the nodules (big radiate aggregates of acicular crystals poor in Al and rich in F).

The fluid inclusions, all secondary, could be classified as follows:

- CO_2 rich inclusions a) with more than 85% of CO_2; b) with less than 85% of CO_2; and c) with impure CO_2;
- aqueous inclusions (about 5% NaCl solution),
- multiphase inclusions with 40-50% solution of NaCl (at room temperature they contain a NaCl crystal), a gas bubble and an unknown birefringent solid phase (the last is not always present).

The multiphase inclusions coexist always in the same fractures with the very CO_2-rich (a) inclusions. These two types of inclusions must therefore be cogenetic. The consequence is that the fluid at this time must have been unmixed in two phases (CO_2 and NaCl solution).

Relative age relationship show that the aqueous inclusions represent the last fluid stage.

The evolution of the nodules and the associated fluid phases could be summarized as follows:

- formation of the quartz nuclei in the dolomitic sediment;
- boudinge or remobilization of the quartz during the predominantly kinematic phase of the alpine metamorphism and synkinematic crystallization of prismatic tremolite in the siliceous layers of the dolomitic marble during the thermal phase;
- formation of a reaction rim around the quartz nodules; to this stage corresponds an unmixed fluid phase with CO_2 and a highly concentrated NaCl solution;
- talc is formed after tremolite and the fluid phase is represented by inclusions with less than 85% CO_2;
- crystallization of a later talc generation together with the contamination of the CO_2;
- end of the diaphthoretic phase related with the aqueous inclusions.

For the building of the reaction rim, the thermo-barometric data indicated by the fluid inclusions agree with a temperature of about 500°C obtained by the calcite thermometer. The pressures instead are low for all inclusion types (ca. 2 kbar). This could be explained with a drastic lowering of the pressure after the climax of the metamorphism (in this area 4-7 kbar); at the same time the cooling was very slow. Such a development was postulated for the Leventina valley by Werner et al. (1976) and fits well the data obtained from the inclusions. (Author's abstract)

MEYER, H.O.A., 1982, Mineral inclusions in natural diamond, in International Gemological Symposium Proc., 1982, D.M. Eash, ed., Gemological Inst. Am., Santa Monica, CA, p. 445-456.

MICHELS, D.E., 1982, A simple formula for saturation temperature/pressure of NaCl solutions: Trans. Geothermal Resources Council, v. 6, p. 95-97. Author at Republic Geothermal, Inc., 11823 E. Slauson Ave., Santa Fe Springs, CA 90670.

The saturation temperatures and pressures of NaCl solutions throughout the geothermally interesting range can be calculated by: psia = $\exp[6.7028 - 10^{-7}(\text{ppm Cl}) - 3712/(°\text{F}+460)]$.

Results of this equation agree with tabular data generally to within ±2.5 percent of psia for NaCl concentrations up to 15 weight percent and 300°C. At higher NaCl concentrations different sets of tabular data are themselves out of conformance while the equation yields intermediate values.

This equation can be adapted to mixed-salt brines and to dynamically flashing systems by including modifiers for just the second term in the brackets. (Author's abstract)

MIKHAYLOVA, N.G. and APLONOV, V.S., 1982, Method of preparation of water leachates from minerals, in Use of methods of thermobarogeochemistry during prospecting and studies of ore deposits, N.P. Laverov, ed.: Moscow, "Nedra" Publ. House, p. 111-115 (in Russian).

Grinding of minerals and then leaching has two imperfections: sorption of ions on ground mineral surface and opening to the leaching water of all solid inclusions in mineral, including relatively soluble ones. The alternative is inclusion opening by decrepitation, although during decrepitation not all inclusions are opened. In experiments quartz from a pegmatite vein from Karelra was used. It was crushed by hand in a metal mortar to a grain size of 0.5-1.0 mm, washed in weak solution of HCl and then cleaned by distilled water to negative reaction for Cl. The cleaned quartz was divided into three parts: one part was ground; the second one calcined at 500°C for one hour (Td 420-450°C) and then ground; the third one ground and then calcined at 500°C for one hour. The determinations of NH_4, K, Na, Ca, Mg, F, Cl, SO_4 and HCO_3 showed that the totals of anions and cations are characterized by 10% error; samples that were decrepitated and then ground yielded lower ion contents than those ground and then decrepitated, but decrepitated and then ground samples are very close to those only ground. Thus, grinding rather than decrepitation should be recommended. (Abstract by A.K.)

MILLER, Christine and RICHTER, Wolfram, 1982, Solid and fluid phases in lherzolite and pyroxenite inclusions from the Hoggar, central Sahara: Geoch. J., v. 16, p. 263-277. First author at Inst. für Min. & Petr., Univ. 4, A-6020 Innsbruck.

Major and trace elements have been determined in spinel lherzolite, spinel pyroxenite and garnet websterite xenoliths from the Hoggar and in their host basanites and nephelinites. Transition metal and REE abundances do not support a genetic link between these ultramafic rocks and the lavas erupted at the surface. Mineral chemistry and textures suggest a complex evolution and subsolidus reequilibration in the range 800-1,000°C. High-density CO_2 fluid-inclusions define minimum pressures of 10-12 kb. Thus the ultramafic xenoliths came from a relatively low pressure regime within an inhomogeneous lithospheric mantle segment characterized by a disturbed geotherm. (Authors' abstract)

MILLER, M.B., 1982, A petrographic and fluid inclusion study of some scheelite-bearing quartz veins, Cabarrus County, North Carolina: MS thesis, Univ. North Carolina, Chapel Hill, North Carolina, 85 pp.
Indexed under Fluid Inclusions. (E.R.)

MILLERO, F.J., MUCCI, Alfonso, ZULLIG, James and CHETIRKIN, Peter, 1982, The density of Red Sea brines: Marine Chem., v. 11, p. 463-475. Authors at Rosenstiel Sch. Marine & Atmosph. Sci., Univ. Miami, Miami, FL 33149.

The densities of artificial and real Red Sea brines have been measured at 25°C with a vibrating tube densimeter. Measurements were also made on mixtures of Red Sea brines with seawater and pure water. The results have been used to characterize the density - composition relations of waters across the interface of brine and average Red Sea waters. The results for the real and artificial brines are in reasonable agreement.

The composition of the brines and mixtures with seawater have been characterized by conductivity measurements of weight diluted samples. The conductivity salinities were found to be conservative to within ±0.07% for the mixtures.

The densities of brines and mixtures of brines and seawater were estimated from apparent molal volume data using Young's rule. The calculated densities for all of the solutions were found to be in good agreement with the measured values, demonstrating the applicability of Young's rule to concentrated natural waters. (Authors' abstract)

MILLERO, F.J., RICCO, J. and SCHREIBER, D.R., 1982, PVT properties of concentrated aqueous electrolytes. II. Compressibilities and apparent molar compressibilities of aqueous NaCl, Na_2SO_4, $MgCl_2$, and $MgSO_4$ from dilute solution to saturation and from 0 to 50°C: J. Solution Chem., v. 11, no. 10, p. 671-686. Authors at Rosenstiel Sch. Marine & Atmospheric Sci., Univ. Miami, Miami, FL 33149.

The relative sound velocities (U-U°) of aqueous NaCl, Na_2SO_4, $MgCl_2$, and $MgSO_4$ solutions were measured from 0.05m to saturation and from 0 to 45°C. The sound speeds were combined with our earlier work and fitted to a function of molality and temperature to standard deviations within 0.3 $m\text{-}sec^{-1}$. The adiabatic compressibilities, β_s, were determined from the sound speeds and used to calculate adiabatic apparent molar compressibilities, $K_{\phi,s}$, isothermal compressibilities, β, and apparent molar compressibilities, K_ϕ, were determined from the adiabatic values using literature data for expansibilities and heat capacities. The values of K_ϕ have been extrapolated to infinite dilution using an extended limiting law. The resulting K° at various temperatures are in reasonable agreement with literature values. The results of this study have been combined with our earlier results to derive a secant bulk modulus equation of state for NaCl, Na_2SO_4, $MgCl_2$, and $MgSO_4$ solutions valid from 0 to 50°C and 0 to 1000 bar. (Authors' abstract)

MIRONOVA, O.F., 1982, Present state of methods of analysis of bulk composition of inclusion gas phase, in Use of methods of thermobarogeochemistry during prospecting and studies of ore deposits, N.P. Laverov, ed.: Moscow, "Nedra" Publ. House, p. 58-64 (in Russian).

Gas analysis should be preceded by microscopic and decrepitation studies for finding optimum conditions of analysis of gases. Letnikov's recommendation that any sample should be heated to 700-800°C for gas release, may lead to changes of gas composition. Any method of inclusion opening causes change of its equilibrium due to sharp P decrease. Mechanical crushing needs special materials for mills or mortars; contamination by H_2 is particularly dangerous, as well as gas sorption on ground mineral. Thermal method of inclusion opening is used more commonly and is better for data for thermodynamic calculations. Also it may be used for complete release of water. High-T fractions are enriched in CO_2 and/or CH_4, synthetized on heating from various carbon compounds dispersed in rocks or minerals. The greatest doubts are caused by gas analysis of rocks, because gases of various origin are then mixed. No single method of gas release can be recommended for universal use, but the individual methods should be considered for a given study.

The volumetric method of analysis may be used for individual inclusions but for bulk analyses other methods should be used like mass spectrometry (difficulties in H_2O determinations and distinguishing CO vs N_2) and gas chromatography (use of appropriate detector). (Abstract by A.K.)

MIRONOVA, O.F., SALAZKIN, A.N., SAVEL'YEVA, N.I. and KOPNEVA, L.A., 1982, Methods and devices for geochemical mapping of endogeneous processes, in N.P. Ermakov, ed., Thermobarogeochemistry in Geology - Materials of the Sixth All-Union Symposium on Thermobarogeochemistry: Vladivostok, Far East Sci. Center, Acad. Sci. USSR Pub. House, p. 131-135 (in Russian).

For abstract, see Fluid Inclusion Research--Proceedings of COFFI, vol. 11, 1978, p. 140-141. (A.K.)

MISHRA, Biswajit and MUKHERJEE, Asoke, 1982, Preliminary studies on fluid inclusion geothermometry of quartz-sulfide veins from Zawar area, Rajasthan, using a heating stage with kanthol strips (abst.): [Proceedings & Abstracts], National Workshop on Fluid Inclusion Studies, 22-23 March, 1982, Indian Inst. Tech., Bombay, p. 30-31 (unpaginated). Authors at Dept. Geol. & Geophy., I.I.T., Kharagpur - 721 302.

A newly fabricated heating stage, using kanthal strips, has been devised for study of fluid inclusion homogenization temperature ≈ 500°C. Primary inclusions in sphalerite, quartz and carbonate (dolomite) present in quartz-sulfide veins from Zawar area, were subjected to heating runs. Inclusions in the host minerals are characterized by (i) a wide variation in gas:liquid ratio, (ii) all homogenizing in liquid state and (iii) occasional presence of cubic daughter crystals. Inclusions in light honey-yellow colored sphalerite show relatively lower temperature of homogenization (280-298°C) than that of the dark reddish-brown colored ones (310-338°C). Inclusions in quartz show a wide range of homogenization temperature (191-362°C) which includes the thermal range exhibited in sphalerite and recrystallized carbonate (277-344°C). Cubic daughter crystals in inclusions in quartz become completely soluble with the trapped liquid at somewhat higher temperature (345-352°C).

Assuming that the uncorrected filling temperatures register the temperatures of crystallization, the following tentative inferences seem justified: (i) crystallization of quartz was protracted in time preceeding and succeeding those of sphalerite and recrystallized dolomite, (ii) constitutents of quartz-sulfide veins indicate [a] thermal condition beyond the thermal regime of diagenesis but within that of greenschist facies of metamorphism, (iii) quartz-sulfide veins (and recrystallized dolomite) may therefore signify metahydrothermal fluid activity, (iv) as such, the assumption that such veins are cogenetic with the main ore lodes is not tenable and the thermal condition of vein materials may not reflect that of the ore lodes. (Author's abstract)

MOHAN, P.C. and JAIRETH, S., 1982, A new model of microscope heating and freezing stage (abst.): [Proceedings & Abstracts], National Workshop on Fluid Inclusion Studies, 22-23 March, 1982, Indian Inst. Tech., Bombay, p. 50 (unpaginated). Authors at Dept. Earth Sci., Univ. Roorkee, Roorkee.

A simple, inexpensive, but accurate microscope heating stage giving acceptable results has been developed. The stainless steel heating stage uses a thin semicircular ring of high alumina tube with a kanthal wire (22 S.W.G.) winding as a heating element. The heating element is enclosed in circular transparent fused quartz discs and the sample rests on the upper disc. A stainless steel ring containing another transparent fused quartz disc separates the heating chamber from the objective. A chromel-alumel thermocouple is introduced close to the sample. Two holes in the stainless steel chamber open just above the upper disc. These holes can be used for introducing chilled air for freezing studies. The stage has been designed for all objectives up to magnification of 12.5 x. For higher magnifications, i.e. 20 or 32 x, objectives with working distance of at least 6 mm are necessary.

Trial runs show that heating stage can be used easily to 600°C, which can be attained within half an hour. By using liquid nitrogen, the stage can cool the sample to temperatures below -100°C. (From the authors' abstract)

MOISEENKO, V.G., MIRONJUK, A.F. and ZAIKIN, I.D., 1982, Evolution of ore forming fluids (according to thermobarogeochemical data) (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 208-209. Authors at Amur Complex Res. Inst., Blagoveshchensk, USSR.

The thermobarogeochemical investigations of Sn deposits of the cassiterite-silicate and cassiterite-sulphide formations, Au deposits of the poor- and low-graded sulphide formation and W deposits of the skarn-greisen formation [give] evidence the alkaline-alkaline earth-bicarbonate-chloride composition of the ore-forming solutions.

The composition of fluid inclusions in cassiterite, scheelite and gold (minerals of main ore stages), was studied in order to estimate the specific features of the hydrothermal solutions which form deposits of various kinds of mineral resources. In the inclusions of cassiterites Na significantly prevails over K, relatively high contents of NH_4, HCO_3, Cl and CO_2 are determined. The salt content of the inclusions in cassiterite is defined by the following generalized ranges of ions (in the order of decreasing concentation): $Na^+ - NH_4^+ - (Ca^{2+}, Mg^{2+}) - K^+$; $(HCO_3^-, Cl^-) - (\Sigma S, F^-)$. CO_2 (predominant phase), CO, CH_4, N_2, H_2, H_2S are present in the gaseous component of the fluid. The hydrotherms of main ore stages of gold and tungsten deposits are defined by anion concentration ranges similar to those of the tin-ore deposits, although they differ in a reduced role of Na and an increased relative concentration of Ca for the tungsten deposits and of Ca and Mg for gold deposits.

The hydrothermal solution compositions vary along the lateral during transition from the oceanic to the continental crust. For example, the gold deposits of marginal and intercontinental volcanic belts are formed by fluids of an alkaline-bicarbonate nature, while the marginal zone are characterized by increased role of Na in the solutions, and decreased ratio of the reduced forms of carbon to the oxidized ones. Spacial and temporal changes of ore-forming fluid composition have also been determined. (From the authors' abstract)

MOISEENKO, V.G., MIRONYUK, A.F. and ZAYKIN, I.D., 1982, Regularities of composition of gas-liquid inclusions in cassiterites of tin ore deposits of the [Soviet] Far East on the basis of thermobarogeochemical data, in N.P. Ermakov, ed., Thermobarogeochemistry in Geology - Materials of the Sixth All-Union Symposium on Thermobarogeochemistry: Vladivostok, Far East Sci. Center, Acad. Sci. USSR Pub. House, p. 24-32 (in Russian).

The composition of gas-liquid inclusions was studied by water-leachate and gas-chromatography methods in cassiterites of the tin-ore deposits belonging to the cassiterite-silicate and cassiterite-sulfide formations (the deposits Silin, Arsen'yevshoe, Yantarnoe, Dubrovskoe, Solnechnoe, Festival'noe, Val'kumey, Khinganskoe and Goluboe). The inclusion fluids in cassiterites are alkaline-alkaline earth-Cl-HCO_3 plus sometimes with S, frequently with Na>>K. Fluids of the main ore stage, when cassiterite precipitated, had near-neutral, weakly alkaline reaction and low redox potential. Salt and gas composition of fluids changed from deep to upper levels of the ore bodies. (Authors' abstract, translated by A.K.; note: abstract of this paper was not published in the Abstract Volumes of the Vladivostok Symposium, A.K.)

MOISEENKO, V.G. and SAKHNO, V.G., 1982, Deep fluids, volcanism and ore formation of the Pacific belt: "Nauka," Moscow, 192 pp., 1000 copies printed, price 2 rbls 80 kopecks (in Russian). Authors at Amur Complex Sci.-Research Inst., Blagoveshchensk-on-Amur, USSR.

The authors discuss the peculiarities of volcanism of some structures of Pacific, transitional zone and continent margin on the basis of studies of samples from islands, island arcs of W part of Pacific, marginal seas and volcanic zones of Asian continent. Analysis is made with use of petrologic method. The book presents new data on the content of gas components and salt composition in inclusions in minerals of volcanic rocks. Peculiarities of gas composition and their evolution is shown against the background of general theory of volcanism in the transitional zone from ocean to continent. In the same scale are presented the features of ore mineralizations connected with various types of volcanic activity. The data on gas and salt composition in rocks presented in the book were obtained by use of advanced analytical methods. (Author's abstract, translated by A.K.)

MOLDOVANYI, E.P. and LOHMANN, K.C., 1982, Isotopic identification of diagenetic environments, Sligo Formation, southwest Texas (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 568. Authors at Dept. Geol. Sci., The Univ. Michigan, Ann Arbor, MI 48109.

Isotopic analyses of individual calcite cements within the reefal facies of the Lower Cretaceous Sligo Formation, southwest Texas, indicate multiple phases of cementation at relatively shallow burial depth. Moreover, variations in composition of individual generations of cement indicate that diagenetic conditions varied along the Sligo shelf and shelf margin.

Fibrous isopachous cements consisting of inclusion-rich radiaxial calcite have an average isotopic composition of -2.0‰ $\delta^{18}O$ and +3.2‰ $\delta^{13}C$ (PDB). These values are indicative of a marine precursor and approximate the composition of the original marine carbonate components. The earliest generation of equant spar which has an average $\delta^{18}O$ composition of -3.5‰ and a range in $\delta^{13}C$ from +3.0‰ to -3.0‰ (PDB) defines a trend characteristic of cementation in a shallow phreatic environment with evidence of localized vadose recharge. This generation is followed by a cloudy spar having an average $\delta^{18}O$ composition of -5.8‰ and a range in $\delta^{13}C$ from +2.5 to -7.0‰ (PDB). Two-phased fluid inclusions and extremely light carbon composition suggest cementation at increased burial temperatures prior to and in conjunction with hydrocarbon migration. A final generation of equant spar which fills fractures and late stage voids has a composition of -7.8‰ $\delta^{18}O$ and +2.5‰ $\delta^{13}C$ (PDB) and must represent cementation in an even deeper, and higher temperature, phreatic environment.

Integration of isotopic and petrographic data has enabled us to discriminate among multiple phases of cementation to determine the exact timing and environment of hydrocarbon migration. In the case of the Sligo Formation, hydrocarbon migration occurred subsequent to the earliest generation of spar and prior to late stage fracture formation. (Authors' abstract)

MOOKERJEE, Dipica, 1982, Determination of temperature of uranium mineralization from fluid inclusion studies in Dhabi uranium deposit, Madhya Pradesh (abst.): [Proceedings & Abstracts], National Workshop on Fluid Inclusion Studies, 22-23 March, 1982, Indian Inst. Tech., Bombay, p. 36 (unpaginated). Author at Atomic Mineral Div., Hyderabad.

From the fluid inclusion and mineral paragenesis studies of Dhabi hydrothermal vein type uranium deposit in granite in Sarguja district of Madhya Pradesh, it is found that microclinization and sericitization has taken place around 500°C, secondary quartz crystallization around 200°C, uranium mineralization around 150°C, pyrite deposition at less than 150°C and finally the carbonate gangue deposition.

Absence of inclusions in the minerals like fluorite, calcite etc. as also the rarity and fineness of fluid inclusions indicate that the processes of mineralization operated over a long period of time(sic). (Author's abstract)

MOON, S.M., 1982, Fluid inclusion studies on amethyst deposits around Eonyang district in Gyeongsangnam-Do: Master's thesis, Dept. Geol., Graduate Sch., Busan National Univ. (in Korean; English abstract).

The Eonyang amethyst deposits are amethyst and quartz crystal-bearing hydrothermal veins which filled vugs in Cretaceous granites.

Th of polyphase inclusions in quartz were measured with a Leitz microscope heating stage (Model 350).

Most of the fluid inclusions are primary and mainly composed of liquid plus a minor gas phase.

The observed filling temperatures are 260°C to 360°C or higher in crystalline quartzes and 230°C to 360°C or higher in vein quartzes.

The salinity deduced from Tm NaCl are 32 to 44 wt.% in crystalline quartzes and 34 to 38 wt% in vein quartzes.

Data from geological, mineralogical and fluid inclusion studies reveal that the amethyst mineralization in the Eonyang district proceeded at high temperature with high salinity. Hence the amethyst deposits of Eonyang district are considered to be of high temperature hydrothermal origin. (From the author's abstract)

MOORE, B.J., 1982, Analyses of natural gases, 1917-80: Bureau of Mines Information Circular 8870, 1055 pp. Author at Section of Helium Resources Eval., Br. of Helium Resources, Helium Field Opns., Bureau of Mines, Amarillo, TX.

This publication contains 12,554 analyses of gas samples from oil and gas wells and natural gas pipelines in 39 States and 24 foreign countries. These gas samples were collected in the period 1917-80 as part of the Bureau of Mines survey for helium occurrences. The gas analyses contained herein were made by several methods over the period covered. Analytical work on samples collected early in the period was done on the Orsat apparatus. The one-cut apparatus and four-cut fractional distillation equipment were added later. In 1949, a mass spectrometer was acquired and used for all gas analyses made after than time. Helium analyses throughout the period coverd were made on special helium analytical equipment designed and built by the Bureau of Mines' Helium Operations Laboratory. (Author's abstract)

MOORE, E.L., ULMER, G.C. and GRANDSTAFF, D.E., 1982, Interaction of basalt and continental ground water at 200 and 300°C (abst.): EOS, Trans. Am. Geophys. Union, v. 63, p. 450. Authors at Dept. Geol., Temple Univ., Philadelphia, PA 19122.

Samples of Columibia River basalt were reacted with a basaltic-type simulated ground water at 200 and 300°C, 300 bars, and water:rock mass ratios of 5, 10, and 20 in a Dickson rocking autoclave. Results were somewhat different from equivalent experiments conducted with sea water. (Mottl and Holland, GCA, 1978) A major decrease in solution pH, such as that found with sea water, was not observed. Calculated steady-state solution conditions at 300°C, and a mass ratio of 10 are: pH $\simeq$ 7.7 (neutral pH $\simeq$ 5.5), log $fO_2 \simeq -31$, log $fS_2 \simeq -11$, and Eh $\simeq$ -0.74. Reaction products identified include: potassium feldspar, quartz, illite, and smectite. Calculations indicate that the solution also became slightly supersaturated with calcite, although none was identified in reaction products. Fe, Mn, Cu, and Pb concentrations were low, in constrast to sea water experiments. Concentrations of Mg, Na, and ΣCO_2 in solution decrease; K, Si, and H_2S increase and Ca and SO_4 remain fairly constant. Calculated steady-state conditions of the 200°C solution are: pH $\simeq$ 7.7 (neutral pH $\simeq$ 5.5), log $fO_2 > -39$, log $fS_2 < -17$, and Eh>-0.68. The solution was slightly supersaturated with quartz and calcite. Again a major decrease in pH was not observed, similar to that at 300°C. Concentrations of Mn, Cu, and Pb were low, and high concentrations of Fe occurred in colloidal suspension. Concentrations of Ca in solution decrease and Mg, K, Si, Fe, and SO_4 increase. (Authors' abstract)

MORASSE, Suzanne, 1982, Preliminary study of the petrography and petrology of the fluid phase present in the quartz-chalcopyrite veins of Scott Canton, Chibougamau, Quebec: Unpublished B.Sc.A. diss., Univ. Quebec à Chicoutimi, Quebec, Canada, 52 pp.

A quartz vein containing chalcopyrite was the subject of the present investigation due to the fact that it is located very close to a large pluton of tonalitic composition, within the Abitibi greenstone belt of the Canadian Shield. The principal aim of this dissertation was to identify the fluid phases present in the quartz. The tectonic effects suffered by the quartz necessitated a careful petrographic study to decipher the deformation and recrystallization features and their relation to the generation of inclusions. The preliminary microthermometric data helped in identifying three distinct generations of fluid inclusions in the most preponderant quartz type which is "heterogranular granoblastic" in nature. This discrimination was possible through their homogenization temperatures, volumetric ratios (V/T), the salinity and the presence of 3-phase inclusions (CO_2 L+V and H_2O L). Possible signs of boiling and a generation of high temperature inclusions ≫ + 400°C have also been noted indicating a probable connection with the Chibougamau Pluton. This work clearly underlined the necessity of further work to determine the interrelations between the three generations of inclusions and the magmatic and metamorphic history of the area. (Author's abstract)

MOROZOV, A.I. and SOLOVKINA, O.A., 1982, Studies of complex formation in the system $KCl-AlCl_3$ by IR spectroscopy: Zhurn. Neorg. Khimii, v. 27, no. 2, p. 326-330 (in Russian). Authors at Inst. of General and Inorg. Chem. of Acad. Sci. USSR, Moscow.

The paper discusses IR absorption spectra of compounds $KAlCl_4$ and KAl_2Cl_7 that possibly may be found as dms in inclusions of salt-rich fluids. (A.K.)

MOROZOV, A.I., SOLOVKINA, O.A. and EVDOKIMOV, V.I., 1982, Compound KAl_2Cl_7 and its thermal stability: Zhurn. Neorg. Khimii, v. 27, no. 8, p. 2075-2079 (in Russian). Authors at Inst. of General and Inorg. Chemistry of Acad. Sci. USSR, Moscow.

See previous entry. (A.K.)

MORRISON, G., 1982, Geology of the La Negra Mine vicinity, State of Queretaro, Mexico: MS thesis, Colorado Sch. of Mines, Golden, Colorado, 118 pp.

Indexed under Fluid Inclusions. (E.R.)

MOSKOVSKII, G.A., GOLOVIN, B.A. and GARYAINOV, V.A., 1982, Study of inclusions in salt minerals from drill-core and sludge samples (areas of the near-edge zone and the central part of the Caspian syneclise), in Nov. Dannye Geol., Geokhim., Podzemn. Vodam Polezn. Iskop. Solenosnykh Basseinov, [Vses. Solevoe Soveshch. "Solenosnye Form. Prakt. Znach. Ikh Izuch."], 2nd 1979, (Pub. 1982), A.L. Yanshin and M.A. Zharkov, eds.,: Izd. Nauka, Sib. Otd., Novosibirsk, USSR, p. 115-119 (in Russian).

A study was made of the inclusions in halite from petroleum-exploration borehole samples and the role of secondary inclusions in minerals, in hydrocarbon (hc) migration through salt strata. The K^+, Mg^{2+}, and SO_4^{2-} concentrations in liquid inclusions in halite provided a means of estg. the composition of the subsurface salt formations, except where the salts were strongly deformed. Examination of the morphol. of hc accumulations in salts showed the existence of 4 main types: (1) drops and films of liquid petroleum in intercrystal voids, (2) gas-liquid hc inclusions in interstices, (3) gas hc inclusions largely held within mineral crystals, and (4) solid hydrocarbons (oxidized petroleum). The sequence sepd. in chromatog. detn. of the gas phase of a salt core was CH_4; C_2H_6; C_2H_4; C_3H_8; C_3H_6; iso-C_4H_{10}; C_4H_8; C_4H_{10}; neo-C_5H_{12}; iso-C_5H_{12}; amylene; C_5H_{12}; 2,2-Me butane; 2,3-Me butane; 3-Me pentane; and $Me_2(CH_2)_4$. Similarity to the hc indexes for rocks underlying the salt strata indicates a vertical migration path of hydrocarbons through the salt beds. (CA 98: 201734q)

MOTYKA, R.J., MOORMAN, M.A. and POREDA, Robert, 1982a Fluid geochemistry of Hot Springs Bay Valley, Akutan Island, Alaska: Trans. Geothermal Resources Council, v. 6, p. 103-106. First author at Alaska Div. Geol. & Geoph. Surveys, Box 80007, College, AK 99708.

Several thermal springs and a fumarole field occur in Hot Springs Bay Valley on Akutan Island. The thermal springs are low in Mg, SiO_2-rich, and moderately concentrated in Na-Cl, a chemistry typically associated with hot-water hydrothermal systems. B/Cl ratios indicate the several sets of springs are derived from a common parent hot-water reservoir. Application of silica, cation, and sulfate-water oxygen-isotope geothermometry gives a range of 160-190°C for the parent reservoir. Recent geophysical investigations performed in cooperation with the Geophysical Institute, U of Alaska, identified a broad zone of apparent low resistivity underlying the lower part of the valley in the vicinity of the thermal springs. Relatively high CH_4 content and low H_2/CH_4 ratios occur in gases from both the thermal springs and from the fumarole field located at the head of the valley about 4 km southeast of the hot springs. The similarity in H_2/CH_4 suggests underlying reservoirs are similar in both areas. Both sites have a ratio of $^3He/^4He$ WRT atmospheric levels of about 7.0. (Authors' abstract)

MOTYKA, R.J., MOORMAN, M.A. and POREDA, Robert, 1982b, Fluid geochemistry of the Makushin geothermal area, Unalaska Island, Alaska: Geother. Resources Council, Transactions, v. 6, p. 107-110. First author at Alaska Div. Geol. & Geoph. Surveys, Box 80007, College, AK 99708.

Several fumarole fields and numerous thermal springs occur on the eastern flanks of Makushin volcano. The thermal springs at Makushin are typically near-neutral in pH, have very low chloride levels (10 ppm), and are comparatively rich in Mg, Ca, SO_4, HCO_3 and SiO_2. Similarities in cation and isotopic compositions of Makushin thermal springs and local surface streams indicate the thermal waters are locally derived meteoric waters. These surface waters infiltrate to relatively shallow depths where they are heated by steam and gases rising from a vapor-dominated zone. Predominate fumarolic gases are CO_2, N_2, and sulfur gases. All samples showed a significant level of H_2 and a high H_2/CH_4 ratio. The ratio of $^3He/^4He$ WRT atmospheric levels range from 4.5 to 6.0. Fumaroles and hot springs in the upper parts of Glacier and Makushin Valleys form a roughly linear trend, suggesting their distribution may be structually controlled. (Authors' abstract)

MU, Zhiguo, HUANG, Fusheng, CHEN, Chengye, ZHENG, Shuhui, FEN, Sulan, LIU, Daren and MEI, Yongwen, 1982, Oxygen, hydrogen and carbon isotope studies of Piaotang and Xihuashan quartz vein-type tungsten deposits, Jiangxi Province: Tungsten Geology Symposium, Jiangxi, China, sponsored by ESCAP/RMRDC and Ministry of Geology, PRC, 12-22 Oct., 1981: Pub. by ESCAP/RMRDC, Bandung, Indonesia, p. 385-401 (in English). First author at Dept. Geol., Peking Univ.

Oxygen, hydrogen and carbon isotope compositions of rocks minerals and their fluid inclusions are measured for Piaotang and Xihuashan wolframite-quartz vein tungsten deposits occurring in endo-contact and exo-contact zones of the granitic intrusive. Comparative studies of both mines are made. The isotope data are presented relative to PDB and SMOW. Routine analytical precision is maintained for all analytical procedures. The $\delta^{18}O$ values of vein quartz for both mines are 13.01 (38) ± 0.95 and 12.50 (33) ± 0.67 respectively. The δ^{18} values of wolframite are 5.35 (22) ± 0.90 and 5.86 (19) ± 0.52. The depositional temperatures of both mines calculated from the $\delta^{18}O$ quartz and wolframite are 332 (24) ± 30°C and 368 (20) ± 30°C. The range of $\delta^{13}C$ values of the vein carbonates are -3 to -9. The isotope composition of the water of the primary fluid inclusions in two mines are: $\delta D = -63.5$ (64) ± 11.6 and -63.5 (40) ± 20.6, $\delta^{18}O =$ 6.65 (24) ± 0.87 and 7.23 (29) ± 0.51 respectively. Isotopic compositions of the modern meteoric water in this region are -38.7 (14) ± 10.2 for δD and -6.13 (14) ± 0.97 for $\delta^{18}O$. The isotope values of the magmatic water extracted from the primary fluid inclusions of the quartz in the igneous rock are: $\delta D = -64.2$ (8) ± 6.3, $\delta^{18}O = 9.8$ (8) ± 1.04. The main conclusion of the isotope studies may be summarized as follows: the tungsten mineralization is of hydrothermal origin related to granite. The ore-bearing fluids were mainly derived from magmatic waters. The mineralization exhibits pulsatory features. The granite is of S-type formed by crystal remelting of Precambrian submarine volcano-sediments in which certain horizons are relatively rich in tungsten. (Authors' abstract)

MU, Zhiguo, ZHENG, Shuhui and CAO, Zhengmin, 1982, Hydrogen, oxygen and carbon isotope studies of the minerals and their fluid inclusions in the Shangbao pyrite deposit, Laiyan County, Hunan Province: Geol. Review, v. 28, no. 4, p. 367-370 (in Chinese with English abst.). Authors at Geol. Dept., Beijing Univ.

The mineralization in the deposit occurs in the outer part of the contact zone between a small granite body and the Hutian Limestone. The principal paragenetic minerals include pyrite, fluorite, quartz and carbonate minerals.

The isotopic analytic techniques used in the paper are: the BrF_5 method, to extract oxygen in the minerals and water; the uranium furnace method, used to extract hydrogen in the water; the H_3PO_4 method, used to extract carbon in the carbonates; and the vacuum decrepitation and crushing techniques, used to extract water in fluid inclusions of the minerals.

Stable isotope studies of fluid inclusion water of the minerals indicate that the δDH_2O values of ore-forming fluids range from -33.3 to -98.9 per mil (SMOW), δDH_2O of present-day meteoric waters from -21.41 to -36.78 per mil (SMOW), $\delta^{13}C$ of carbonates from -1.18 to -4.74 per mil (PDB), and $\delta^{18}O$ of the minerals from +2.29 to +16.15 per mil (SMOW). All the above mentioned data imply that the deposit is an hydrothermal deposit of magmatic origin, and it is possible that the surface water was involved in the mineralization at a late stage. (Authors' abstract)

MUDRINIČ, C., 1982, Ore matter sources and geochemical characteristics of antimony deposits in Serbia and Macedonia (Yugoslavia) (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 34-35. Author at Belgrade Univ., Belgrade, Yugoslavia.

The antimony deposits can be divided according to their mineralogical and chemical compositions as follows: (1) polymetallic Sb-As + Pb-Zn; (2) bimetallic Sb-As or As-Sb; and (3) monometallic Sb and rarely As.

Ore metals may have been transferred mainly as complex ions of the $Sb_2S_3^{3-}$, As^{3-} types in alcal solutions however, the role of chlorides, fluorides and sulphates should not be ignored, either. Th of fluid inclusions in cleiophane, quartz and calcite range from 330 to 160°C for the polymetallic deposit type. Crystallization temperatures in the monometallic and bimetallic deposits were 200°-90°C. This affects the mineral compositions, with a great variety of minerals emerging in the polymetallic deposits. Subsequent differentiation of ore components (even in a case of telescopy) brings their mineral composition actually to 3-2 minerals. (From the author's abstract)

MUENOW, D.W., RAI, C.S., SHARMA, S.K., MATSON, D.W. and BYERS, C.D., 1982, Temperature dependence of CO_2 solubility in high-pressure quenched glasses of diopside composition: a combined high-temperature mass spectrometric and Raman spectroscopic investigation (abst.): EOS, Trans. Am. Geophys. Union, v. 63, p. 451. Authors at Hawaii Inst. Geophy., Univ. Hawaii, Honolulu, HI 96822.

Carbon dioxide solubilities in CO_2-saturated high-pressure quenched glasses of diopside composition (formed by quenching CO_2-saturated diopside melt under 20 kbar pressure from 1580 to 1730°C in a solid-media high-pressure apparatus, using both talc and boron nitride furnace assemblies) have been investigated. A combination of thermogravimetric/mass spectroscopy and Raman spectroscopy were used. Mass pyrograms of these glasses show, in addition to CO_2 gas, small amounts of CO, CH_4 and H_2O. The amounts of CO, CH_4 and H_2O vary from sample to sample, but in the glasses quenched from the <u>same</u> temperatures at a constant pressure (20 kbar) the total carbon content of the samples is constant within the experimental errors, and is independent of the amount of H_2O observed. The CO_2-solubility shows a linear and negative temperature dependence. We do not observe any maximum in the solubility curve as reported previously by others.* The solubility of carbon-containing species in the Di melt at 20 kbar and in the temperature range 1580-1730°C is $(-2.4 \pm 0.67)\ 10^{-3}$ wt% carbon per °C.

The Raman spectra of CO_2-charged Di glasses show that the CO_2 in these glasses exists as CO_3^{2-}. The intensities of the $\nu_1(A_1')$ band of CO_3^{2-} also show a negative temperature dependence. The observed large (~90 cm^{-1}) splitting of the $\nu_3(E')$ mode of CO_3^{2-} ions in the spectra indicates that CO_3^{2-} ions are present in at least two distinct sites in these glasses. This interpretation is consistent with the observed bimodal release pattern for CO_2 in the mass programs.

It is concluded that the differences between the present data and those reported previously* using β-track radioautography technique are most likely due to isotopic inhomogeneities between ^{14}C and ^{12}C in the samples. [*Amer. Min. (1980) <u>65</u>, 885-899.] (Authors' abstract)

MUFFLER, L.J.P., NEHRING, N.L., TRUESDELL, A.H., JANIK, C.J. CLYNNE, M.A. and THOMPSON, J.M., 1982, The Lassen geothermal system: Proc. Pacific Geothermal Conf. 1982 Part 1, Univ. Auckland Geothermal Inst., Auckland, NZ, p. 349-356.

MULLIS, J., 1982, Stern-quartz: Schweizer Strahler, v. 6, no. 4, p. 125-140 (in German and French).

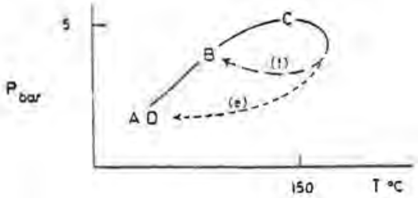
The name Stern comes from the starlike aggregation of small quartz crystals. Star-quartz out of cavities in non-metamorphic sediments and in a volcanic rock are described. All the star-quartzes have grown on cryptocrystalline quartz (chalcedony), that induces the crystallographic direction of the star-quartzes. On the basis of microthermometric investigations chalcedony and star-quartz have crystallized at low temperature (below 200°C and 1200 bar). (Abstract by H.A. Stalder)

MULLIS, J. and SIGL, F., 1982, The genesis of opal, chalcedony and quartz from Gran Canaria (volcanic island W of Maroc): Schweizer Strahler, v. 6, no. 4, p. 155-176 (in German and French).

In the foreground are investigations on quartz crystrals from different habits (stemlike, scepter, cuplike...) out of cavities from a volcanic rock. These quartzes (C) have normally grown on opal and chalcedony (A,B) and are covered by a second generation of opal (D). The following table compiles all the effected investigations:

In the discussion the model given in the figure for the genesis is proposed. Several questions are still open, and it is planned to continue these investigations. (Abstract by H.A. Stalder) Continued next page.

SiO_2-succession	A	B	C	D
Name	opal with low-cristobalite (lussatite)	chalcedony	quartz, low quartz with mimetic lamella	like A
Optic invest. Elongation 2V	 +	 -	 + >5°	 +
n	1.44-1.45	1.532-1.540	1.544-1.553	1.443-1.450
X-ray analysis	low-cristobalite	quartz	quartz	low-cristobalite
Etching			brasilian twins	
Cathodoluminescent	?	dark and bright growth-bands	dark and bright growth-lamella	dark brown, unstructured
Microthermometry			I-inclusions =water vapor II-inclusions =water and water vapor Th 120°-180°C	
Raman spectroscopy			I = H_2O only	
γ-Irradiation			no coloring	



Approximate P-T-conditions for the SiO_2-species A, B, C, D. The cycle e can be repeated several times; only cycle f is realized.

MUNOZ, J.L. and GUNOW, A.J., 1982, Fluorine index: a simple guide to high fluorine enviornments (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 573. Authors at Dept. Geol. Sci., Univ. Colorado, Boulder, CO 80309.

Although the association of high-fluorine mica with porphyry molybdenum deposits is well-documented, the definition of just how much F must be present to recognize an anomalously high-fluorine mica is a more difficult question. This results from the fact that the distribution of F between mica and fluid is a complex function of temperature, mica composition, and fluid composition. We have used our thermodynamic data on F-OH exchange in micas to construct graphs for both biotite and muscovite/phengite in which weight % F is plotted vs. weight % MgO; both graphs are contoured with lines we call fluorine index (FI). FI may range from 0 to 15, and increases with HF activity in magma or fluid. A difference of one FI unit corresponds exactly to a difference of 0.25 in log fugacity ratio (fH_2O/fHF) in fluid which equilibrated with the mica, assuming comparable equilibration temperatures.

Sericite and biotite from the Henderson molybdenite deposit have FI's ranging from 9 to 11.5; in contrast, comparble mica from porphyry copper deposits at Santa Rita and Bingham range from 4 to 7.5; the latter values overlap significantly at the lower range with micas from unmineralized granitic rocks. In spite of the method's simplicity, relative FI's from Henderson micas correlate remarkably well with relative log (fH_2O/fHF) values for the same micas which were rigorously calculated from structural formulae and thermodynamic data.

Advantages for using FI values include (1) simplicity; only weight %

F and MgO are required, (2) FI values are directly proportional to relative HF activities, (3) the method is easily applicable to exploration. (Authors' abstract)

MURAMATSU, Yoichi and NAMBU, Matsuo, 1982a, Fluid inclusion studies of pyrometasomatic iron-copper ore deposits and igneous rocks at the Kamaishi mining district, Iwate prefecture, Japan (I) Fluid inclusions in igneous rocks: J. Japanese Assoc. Mineral., Petrol., & Econ. Geol., v. 77, no. 5, p. 7-17 (in Japanese; English abstract). Authors at Res. Inst. Miner. Dress. Metall., Tohoku Univ., Sendai, Japan 980.

Fluid inclusions in quartz from several igneous rocks as well as from barren quartz veins were studied as a part of investigation into the origin of ore-forming fluids and mineralization of the pyrometasomatic iron-copper ore deposits in the Kamaishi mining district, Iwate prefecture, Japan. Igneous rocks are mainly composed of diorite-diorite porphyrite intruded before the mineralization, Ganidake granodiorite related to skarnization and mineralization, and Kurihashi granodiorite intruded after the mineralization.

Polyphase, liquid and gaseous inclusions are observed in quartz of those igneous rocks. It is found that polyphase inclusions, which mainly contain halite, are abundant in quartz of the diorite-diorite porphyrite and Ganidake granodiorite, but remarkably poor in that of the Kurihashi granodiorite. This tendency is in good agreement with those of both chlorine and copper contents in the igneous rocks.

Th of fluid inclusions in quartz from the Ganidake granodiorite ranges from 247 to over 380°C. On the basis of the data on Tm NaCl in polyphase inclusions, it is deduced that the salinity of fluid would have been in a range between 30 to 50 wt.% NaCl equiv.

From these results of investigation, it is inferred that the original ore-forming fluid was high in both temperature and salinity, and that highly saline fluid played an important role on the transportation of metal elements. It is also deduced from the distribution of polyphase inclusions in the rocks that highly saline fluid would have originated in some deeper parts of the Ganidake granodiorite, along which the ore deposits are distributed. But the relation between the intrusion of the diorite-diorite porphyrite and mineralization has been left unsolved. (Authors' abstract)

MURAMATSU, Yoichi and NAMBU, Matsuo, 1982b, Fluid inclusion studies of pyrometasomatic iron-copper ore deposits and igneous rocks at the Kamaishi mining district, Iwate prefecture, Japan (II) Fluid inclusions in the Shinyama pyrometasomatic ore deposit: J. Japanese Assoc. Mineral., Petrol., & Econ. Geol., v. 77, no. 5, p. 181-190 (in Japanese; English abstract). Authors at Res. Inst. Miner. Dress. Metall., Tohoku Univ., Sendai, Japan 980.

Th and salinities of fluid inclusions in quartz and calcite collected from the Shinyama pyrometasomatic iron and copper ore deposit of the Kamaishi mine, Iwate prefecture, Japan, were measured by means of the heating- and freezing-stage microscope.

Fluid inclusions are generally several microns in size. Most inclusions are liquid inclusions, but some of them are gaseous inclusions. Polyphase inclusions are not recognized.

Most Th of liquid inclusions in quartz and calcite which are considered to have been formed at the main stage of sulfide mineralization, range from 290 to 334°C. The Th has a tendency to increase from the upper level to the lower, but no tendency is recognized laterally, that is, from the igneous rock side to the limestone side. Salinities of liquid inclusions in quartz range from 4.2 to 15.0 wt.% NaCl equiv. No relationship is recognized between the Th and salinity.

On the other hand, most of the Th and salinities of liquid inclusions in vein quartz range from 284 to 310°C, and from 5.5 to 7.9 wt.%, respectively.

From the result of the present inclusion study, it is inferred that the ore-forming fluids had relatively high salinities, and that the densities of fluids varied remarkably from the main stage of sulfide mineralization to the post-ore vein quartz. (Authors' abstract)

MURAMATSU, Yoichi and NAMBU, Matsuo, 1982~~,~~c Fluid inclusion study on the contact metamorphic tungsten ore deposits of the Yaguki mine, Fukushima prefecture, Japan: Mining Geol., v. 32, no. 2, p. 107-116 (in Japanese; English abstract). Authors at Res. Inst. Miner. Dress. Metall., Tohoku Univ., Sendai, Japan 980.

The filling temperature and the salinity of fluid inclusions in minerals from the pyrometasomatic copper-iron and tungsten ore deposits of the Yaguki mine were measured by means of a microscope with heating and freezing stages. The present works aim at the clarification of mineralization relationships between the two kinds of deposits. The results could be summarized as follows:

(1) The ranges of Th of fluid inclusions in quartz, scheelite, and epidote from the tungsten deposits are 200°-340°C (265°C), 220°-330°C (270°C), and 230°-330°C (290°C), respectively (parentheses indicate arithmetical mean values). And the ranges of the salinity of the former two minerals mentioned above are 1.0-2.9 and 2.9-10.5% in NaCl equiv. concentration, respectively.

(2) The range of Th of fluid inclusions in quartz and calcite from copper-iron deposits is 200°-360°C (291°C), which is almost the same as that of the Akagane mine, Iwate Prefecture. The salinity could not be measured because of a minute inclusion size.

(3) The results of the fluid inclusion study indicate that the mineralization stage of tungsten is later than that of copper-iron. This process of mineralization is supported by the mineral succession and mineral assemblages obtained from the field evidence and the microscopic observation.

(4) The Th of inclusions from copper-iron ore deposits decreases distinctly toward the upper level, whereas those of inclusions from tungsten ore deposits are confined to a narrow range in spite of the depth.

(5) There is a linear relationship between Th and the salinity of fluid inclusions in quartz from the tungsten deposits, while scheelite occupies a very narrow area in the diagram of Th vs. salinity of inclusions. From these facts it is inferred that scheelite crystallized under the condition of narrow ranges of both temperature and salinity. (Authors' abstract)

MURTHY, V.R., 1982, Isotopic and trace element evidence for mantle metasomatism (abst.): EOS, Trans. Am. Geophys. Union, v. 63, p. 612. Author at Dept. Geol. & Geophy., Univ. Minnesota, Minneapolis, MN 55455.

A primary prerequisite for any postulated mantle source of basalts is that it be capable of yielding, upon melting, liquids with appropriate trace element content as well as the trace element ratios observed in natural basalts. This constraint, when examined in the light of data of diagnostic lithophile trace elements such as K, Rb, Sr, etc., rules out anhydrous lherzolitic mantle from both the suboceanic and subcontinental region as an adequate source material for basalt generation. The trace element data, coupled with scant Nd and Sr iosotopic data clearly emphasize the role of hydrous minerals such as amphibole and mica and other trace element rich accessory minerals, in creating appropriate local mantle environment from which basaltic melts can be derived. This "enrichment" process is attributed to mantle metasomatism, for which abundant petrologic and chemical evidence is now available. It is suggested that such a metasomatism is a necessary precursor for alkaline magmatism in both the continental and oceanic mantles, and possibly for tholeiitic magmatism as well. Data from xenoliths and nodules show evidence for migration in and out and consequent gain and loss of fluids extremely enriched in compatible trace elements and volatiles. Isotopic data indicate that such metasomatic processes in the mantle can both be ancient and recent, suggesting that the chemical heterogeneity of the mantle represents a continuum of processes of melt and residua formation and the refertilization and subsequent melting of earlier formed residua. The metasomatic fluids may be derived from the deeper fertile mantle or may be connected to the tectonic process of lithosphere subduction and recirculation in the mantle. (Author's abstract)

MYSEN, B.O., 1982, Experimental results relevant to fluid-melt and fluid-mineral element partitioning in the upper mantle (abst.): EOS, Trans. Am. Geophys. Union, v. 63, p. 449. Author at Geophys. Lab., Carnegie Inst. Washington, 2801 Upton St., NW, Washington, DC 20008.

Experimental fluid-mineral and fluid-melt element partitioning data at upper mantle pressures and temperatures are available for elements Na, K, Ce, Sm, and Tm and for components in the systems $CaO-MgO-SiO_2-H_2O-CO_2$ and $Na_2O-Al_2O_3-SiO_2-H_2O-CO_2-HF$. The solubility of these components in aqueous fluids increases by at least an order of magnitude between 10 and 30 kbar, and may increase by 300-500 %/100 °C temperature decrease. For rare earth elements (REE) in the upper mantle, C(fluid)>C(melt)>C(mineral) for all major peridotite minerals and typical silicate melts and for all $CO_2/(CO_2+H_2O)$. Their solubilities in CO_2 and H_2O-fluids differ by a factor of $\sim$4 as compared with diopside components, for example, where the difference is greater than an order of magnitude.

Alkali- and alkaline-earth solubilities in aqueous fluids may exceed 10 wt%, but decrease rapidly with increasing H_2O/CO_2. Recent data on HF/H_2O indicate that HF enhances alkali and alumina solubilities.

Low K/Rb and Sr/Rb of andesitic magmas compared with abyssal tholeiite may be due to an H_2O-rich flux through the source region of andesite melt in the upper mantle. Their REE patterns often also reflect such a process. The strong light REE and alkali enrichments in alkali basalt may also be explained with the aid of a CO_2-rich fluid precursor to the partial melting process. Irregularities in radiogenic isotope ratio relations (e.g., $^{87}Sr/^{86}Sr$ versus $^{144}Nd/^{143}Nd$) may also be understood if metasomatic fluids fluxed the magma source regions. (Author's abstract)

NABELEK, P.I., LABOTKA, T.C., O'NEIL, J.R. and PAPIKE, J.J., 1982, Fluid-rock interaction during contact metamorphism of argillites and limestones evidenced from stable isotopes (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 574.

NAHNYBIDA, Cynthia, HUTCHEON, Ian and KIRKER, Jill, 1982, Diagenesis of the Nisku Formation and the origin of late-stage cements: Can. Min., v. 20, p. 129-140. Authors at Dept. Geol. & Geoph., Univ. Calgary, Calgary, Alberta T2N 1N4, Canada.

Late-stage calcite, dolomite and anhydrite cements, which occur in

Upper Devonian dolostones of the Nisku Formation, west-central Alberta, have been examined using thin-section petrography, fluid inclusion microthermometry, stable-isotope data and electron-probe microanalysis. The entire diagenetic sequence is interpreted to be: selective dissolution of fossils, dolomitization, extensive stylolitization, precipitation of calcite cements before, during and after stylolitization, and late-stage anhydrite emplacement. Fluid inclusion data indicate that the late calcite cements were deposited at temperatures of between 140 and 155°C from solutions approximately 2.4-3.7 m NaCl (equivalent). At the present depth of burial of 2.5 km and H_2O activities estimated from NaCl-equivalent contents of the aqueous phase in fluid inclusions, the minimum temperature of dehydration of gypsum to anhydrite would range from 75°C (fluid pressure) to 135°C (lithostatic pressure). The temperature range determined in this study, though moderately high, is not inconsistent with published bore-hole temperatures and vitrinite-reflectance data. Gypsum was not observed; these temperatures would represent a minimum range at the 2.5 km burial depth. Isotopic data for sulfur and oxygen in both "early" and "late" anhydrites show a distinct separation and may indicate that sulfate, introduced into solution by dissolution of "early" anhydrite, was being reduced during the precipitation of "late" anhydrite. (Authors' abstract)

NAKAMURA, Takeshi and KIM, M.Y., 1982, Macrostructures of vein filling in ore veins, with special reference to those of plutonic tungsten-tin-copper veins at the Otani mine, Kyoto Prefecture, Japan: Min. Geol., v. 32, no. 2, p. 85-94 (in Japanese; English abstract). First author at Fac. Sci., Osaka City Univ., Japan.

Concepts on hypogene mineral zoning, mineral association, mineral paragenesis, and mineralization stage relating to macrostructures of vein filling in ore veins are briefly discussed.

As an example of plutonic ore vein, macrostructures of vein filling of plutonic tungsten-tin-copper vein at the Otani mine, Kyoto Prefecture, Japan, one of representatives of plutonic tungsten-tin veins related genetically to granitoid of Late Cretaceous in the Inner zone of Southwest Japan, are examined. Based on macrostructures of vein filling on the order of ore body, three major mineralization stages, called stage I, stage II, and stage III from earliest to latest, are distinguished by major tectonic breaks. Sequence of mineralization, characteristic features of each mineralization stage, and variations of Th and salinity ranges of fluid inclusions in minerals from stage I to stage III are summarized. (Authors' abstract)

NALDRETT, A.J., INNES, D.G., SOWA, J. and GORTON, M.P., 1982, Compositional variations within and between five Sudbury ore deposits: Econ. Geol., v. 77, p. 1519-1534. First author at Dept. Geol., Univ. Toronto, Toronto, Ontario M5S 1A1, Canada.

Relevant phase equilibria data indicate that Cu, Ni, Zn, Pt, and Pd are likely to become enriched in the residual liquid of a fractionating sulfide melt whereas Co, Rh, and Ru will concentrate in the early crystallizing monosulfide solid solution. The correspondence between the experimental data and natural observations is strong evidence that the zoning is the consequence of the fractionation of a sulfide melt, with the residual liquid being expelled progressively into the footwall. (From the authors' abstract)

NAPOLES, E.M., 1982, Fluid inclusion study of core samples from the Malitbog thermal area, Tongonan geothermal field, Philippines (abst.):

Proc. Pacific Geothermal Conf. 1982 Part 1, Univ. Auckland Geothermal Inst., Auckland, NZ, p. 413-414.

Fluid inclusion studies of cores from Wells MB1 to 5, 208A and MN1 demonstrate strong meteoric water dilution as the geothermal fluid coming from beneath the Mahiao sector migrates to the southeast towards Sambaloran, Malitbog and Mamban. Extensive silicification in the area, probably induced by percolating ground water to the east of Malitbog, must have caused the present hot fluid boundary to migrate deeper, sloping quite steeply towards Mamban.

Reports on the hydrothermal alteration minerals in the area suggest the existence of a "fossil system" (Wood, 1978) but latter vein minerals reflect the present fluid characteristics.

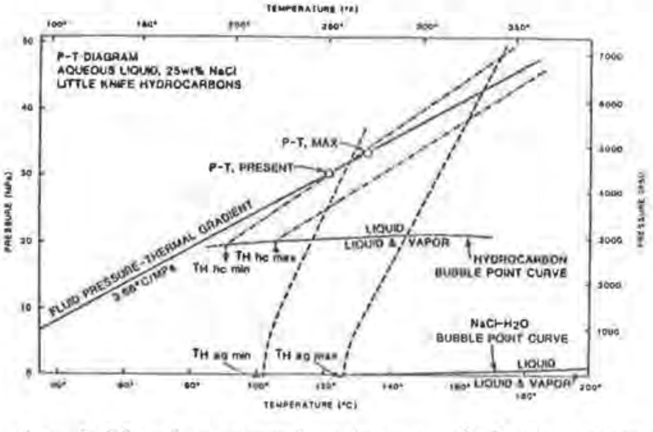
Homogenization measurements give strikingly similar temperature results with chemical geothermometers and show parallel trends with the boiling-point-with-depth profiles that are extrapolated to the water level for each well.

Salinity measurements reveal a complex pattern of meteoric water dilution. In some samples, however, contamination with highly saline fluid seems to have occurred. (Author's abstract)

NARR, Wayne and BURRUSS, R.C., 1982, Origin of reservoir fractures in Little Knife field, North Dakota (abst.): AAPG Bull., v. 66, no. 5, p. 612. Authors at Gulf Sc. & Tech. Co., Pittsburgh, PA.

Thin, vertical, planar fractures in the Mission Canyon Formation of the Little Knife field, in west-central North Dakota, appear to be naturally occurring extension fractures. The fractures are restricted to carbonate units, but are not lithology dependent within the carbonate rocks. Fracture density averages 1 ft (0.3 m) of fracture per 2.3 ft (0.7 m) of core. The predominant east-west trend of the fractures, measured in oriented core from six wells, parallels the estimated maximum horizontal compressive stress in the Williston basin.

Formation and mineralization of these fractures were the most recent diagenetic events in the Little Knife carbonates. Heating- and cooling-stage observations of fluid inclusions in crystals bridging the fractures yield homogenization temperature ranges of 90 to 106°C and 102 to 126°C for hydrocarbon and aqueous inclusions, respectively. Correlation of these observations with the PVT properties of Little Knife reservoir fluids leads to the following conclusions: (1) the fractures formed after the strata were buried to at least their present depth of 9,800 ft (3,000 m), which indicates their age is post-Mesozoic; (2) the pore-fluid pressure gradient was normal hydrostatic immediately after, if not during, fracture system development; (3) formation-water salinity has remained fairly constant since fracture initiation; (4) migration of



hydrocarbons into the reservoir probably preceded or accompanied fracture genesis; and (5) methane concentration may have decreased since fracture initiation.

The geologic mechanism specifically responsible for creating the fractures remains unknown. The potential for using fluid inclusions to document changing methane concentration within a reservoir could be significant to studies of hydrocarbon migration. (Authors' abstract)

NARR, Wayne and CURRIE, J.B., 1982, Origin of fracture porosity - example from Altamont field, Utah: Am. Assoc. Petr. Geol. Bull, v. 66, no. 9, p. 1231-1247. First author at Gulf Res. & Dev. Co., P.O. Drawer 2038, Pittsburgh, PA 15230.

The occurrence of natural fracture systems in subsurface rock can be predicted if careful evaluation is made of the geologic processes that affect sedimentary strata during their cycle of burial, diagenesis, uplift, and erosional unloading. Variations in the state of stress within rock arise, for example, from changes in temperature, pore pressure, weight of overburden, or tectonic loading. Hence geologic processes acting on a sedimentary unit should be analyzed for their several contributions to the state of stress, and this information used to compute a stress history. From this stress history, predictions may be made as to when in the burial cycle to expect fracture (joint) formation, what type of fractures (extension or shear) may occur, and which geologic factors are most favorable to development of fractures.

A stress history is computed for strata of the naturally fractured Altamont oil field in Utah's Uinta basin. Calculations suggest that fractures formed in extension, that the well-cemented rocks are those most likely to be fractured, that fractures began to develop only after strata were buried to great depth, and that the fracture system continued to develop as strata were uplifted and denuded of overburden. Geologic evidence on fracture genesis and development is in accord with the stress history prediction.

Stress history can be useful in evaluating a sedimentary basin for naturally fractured reservoir exploration plays. (Authors' abstract)

Fluid inclusion evidence is used in several ways to reconstruct the fracture system history. (E.R.)

NASEDKIN, V.V. and BOYARSKAYA, R.V., 1980, Minerals in volcanic-glass pores: AN SSSR Izvestiya, Ser. Geol., no. 11, p. 90-97 (in Russian; translated in Int'l. Geol. Review, v. 24, no. 9, p. 1101-1108, 1982). Authors at Inst. Geol. Ore Deposits, Petrog., Mineral. & Geochem., USSR Acad. Sci., Moscow, USSR.

Two samples of obsidian from the Arteni deposit (Armenian SSR) were chosen for study. They were investigated with an S4 scanning electron microscope equipped with a microprobe. Mineral inclusions whose composition led to a tentative identification as oldhamite (CaS), metallic iron, manganese spinel and zinc spinel, magnetite, amphibole and silica gel were found in the pores. The surface of the glass around the pore was rich in the volatiles Cl and S. Two stages of mineral formation, high-temperature and low-temperature, are distinguished. Oldhamite, spinel and ores [magnetite probably meant--IGR editor] formed during the high-temperature stage and the silica gel and amphibole in the low-temperature stage. It is demonstrated that the scanning electron microscope can be used to study mineral inclusions and mineral-forming fluids. (Authors' abstract)

NAUMENKO, V.V., 1981, Endogene ore mineralization in the epochs of tectonic-magmatic activization in Europe: "Naukova Dumka," 216 pp., 500 copies printed, price 2 rbls. (in Russian). Author at Inst. Geochem. and Physics of Minerals, Kiev, Ukraine.

The book quotes a number of Th data for various ore deposits, essentially from the Russian literature. (A.K.)

NAUMKIN, P.A., EFIMOVA, M.I., SOLYANIK, V.A., PORECHIN, A.A. and YAKOVETS, V.A., 1982, Petrochemical and temperature parameters of Upper Cretaceous granitoids from Askol'd Island, in N.P. Ermakov, ed., Thermobarogeochemistry in Geology - Materials of the Sixth All-Union Symposium on Thermobarogeochemistry: Vladivostok, Far East Sci. Center, Acad. Sci. USSR Pub. House, p. 55-59 (in Russian).

For abstract, see entry Efimova, Naumkin, Mikhaylova and Ovcharek in Fluid Inclusion Research--Proceedings of COFFI, vol. 11, 1978, p. 58. (A.K.)

NAUMKO, I.M., MAMCHUR, G.P. and YARYNICH, O.A., 1982, Peculiarities of minerogenesis in the Volynian cavity pegmatites revealed from carbon isotopic composition of carbonates: Dopovidi Akad. Nauk Ukr. RSR, Ser. B. Geol., Khim., Biol., no. 7, 1982, p. 14-16 (in Ukrainian; English and Russian abstract)

NAUMOV, G.B., SALAZKIN, A.N., NIKITIN, A.A., MIRONOVA, O.F. and SAVEL'YEVA, N.I., 1982, Results of studies of fluid haloes in ore fields of Eastern Transbaikalia, in Use of methods of thermobarogeochemistry during prospecting and studies of ore deposits, N.P. Laverov, ed.: Moscow, "Nedra" Publ. House, p. 225-231 (in Russian).

Wide haloes of hydrothermal alteration were found in the granite wallrocks of ore deposits. Different saturation by volatiles was established for granites of ore-bearing and barren areas and differences in mineral-forming solution compositions were determined for various stages of mineral formation. The above data may be used for determination of relative degree of "opening" of geological structures, their influence on the distribution of ore bodies, depth of ore mineral formation and mechanism of processes of ore formation. (Authors' abstract translated by A.K.)

NAUMOV, V.B., 1982, Possibilities of determination of pressure and density of mineral-forming media on the basis of inclusions in minerals, in Use of methods of thermobarogeochemistry during prospecting and studies of ore deposits, N.P. Laverov, ed.: Moscow, "Nedra" Publ. House, p. 85-94 (in Russian).

The author reviews the methods of P determination based on the CO_2-H_2O system, the Th-Td Naumov and Malinin methods and the so-called "Lemmlein-Klevtsov method" with use of the chloride dms [but without quotation of the critical remarks given by Roedder and Bodnar, Fluid Inclusion Research-Proceedings of COFFI, vol. 13, 1980, p. 210-211]. He presents moreover a newly calculated table of dP/dT values for NaCl solutions up to Th 500°C. Also four typical examples of calculation of fluid density from fluid inclusions are shown: 1) one-phase inclusions, 2) two-phase inclusions, 3) $LH_2O + LCO_2 + GCO_2$ inclusions, 4) $LH_2O + G +$ dms. (A.K.)

NAUMOV, V.B. and IVANOVA, G.F., 1982, Genetic relations of rare-metallic mineralization with acid magmatism with reference to the study of microinclusions and indicator microcomponents (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 82-83. Authors at Inst. Geochem. & Chem., Moscow, USSR.

The deposits are defined by the following specific features: high temperatures (500°-200°C, mostly 400°-250°C) and pressures (2.6-0.1 kbar, mostly, 1.5-0.5 kbar) of ore mineralization that are significantly higher than temperatures and pressures at the most probable depth of occurrences of deposits (1-3 km) with the gradient 50°C/km and lithostatic load of rocks 270 bar/km.

Recent 5 years' investigation results of melt microinclusions have provided estimation of the acid magma crystallization parameters: the temperature varies from 1200° to 550°C, water pressure from less than 0.1 to 6.1 kbar, water concentration in the melt from less than 0.1 to 13.9 weight %. The process of formation of some hypabyssal granite massifs involved a remarkable rise of water pressure and concentration. Melts with minimal water concentration (0.1-0.5 weight %) are characterized by maximal temperatures, while low-temperature melts are characterized by a high water pressure (3-5 kbar) and a high water concentration (3-8 weight %). The region of coexistence of silicate melts and hydrothermal solutions has been found within 950-550°C. Evolution of physicochemical parameters in the "melt-solution" system has been observed. (From the authors' abstract)

NAUMOV, V.B. and KHODAKOVSKIY, I.L., 1982, Hydrothermal mineral formation from thermobarometric and thermodynamic data, in N.P. Ermakov, ed., Thermobarogeochemistry in Geology - Materials of the Sixth All-Union Symposium on Thermobarogeochemistry: Vladivostok, Far East Sci. Center, Acad. Sci. USSR Pub. House, p. 80-86 (in Russian).

For abstract, see Fluid Inclusion Research--Proceedings of COFFI, vol. 11, 1978, p. 149. (A.K.)

NAUMOV, V.B., KOVALENKO, V.I. and KOSUKHIN, O.N., 1982, Parameters of crystallization of ongonite magmas from studies of melt inclusions: Akad. Nauk SSSR Doklady, v. 267, no. 2, p. 435-437 (in Russian). First author at Inst. Geochem. and Anal. Chem. of Acad. Sci. USSR, Moscow.

The authors studied all facies of Li-F acid rocks: volcanic, subvolcanic dikes and stocks, hypabyssal massifs and chamber pegmatites. Melt inclusions in minerals of ongonite-type rocks yielded the following Th: ongorhyolites, Durben-Dort-Ula (Mongolia), apatite 1200-1170°C, quartz 1180-760°C; ongonite dike, Dadal-somon (Mongolia), quartz 1050-830°C, topaz 730-680°C; subvolcanic ongonite stock, Ary-Bulak massif, Transbaikalia (USSR), topaz 930-580°C, quartz 110-620°C; ongonite dike, Ongon-Khayrkhan (Mongolia), topaz 1020-920°C, quartz 550-540°C; Li-F granites, Baga-Gazryn (Mongolia), quartz 860-790°C; amazonite pegmatites, same location, topaz 720-640°C; granites, Khingilay-Shily, E. Transbaikalia (USSR), topaz >650°C; Li-F granites, Yugodzyr massif (Mongolia), topaz 650-600°C; chamber pegmatites, Volyn (USSR), topaz 760-600°C. Water content in inclusion melt ranges from 0.2 to 10 wt. %, PH_2O 90-4200 bars. Ongonite melts have low viscosity and due to this fact inclusions need rapid quenching (>350°C/min), otherwise melt "boils" with segregation of large number of G bubbles. Water concentrates in melts during evolution of melt on T decrease. (Abstract by A.K.)

NAUMOV, V.B. and SAMOYLOVICH, L.A., 1982, Practical peculiarities of use of homogenization method, in Use of methods of thermobarogeochemistry during prospecting and studies of ore deposits, N.P. Laverov, ed.: Moscow, "Nedra" Publ. House, p. 141-145 (in Russian).

Three essential problems are discussed that have to be solved correctly for successful use of fluid inclusion homogenization method in practical prospecting and studies of raw material deposits: 1) most correct selection of material for homogenization, 2) most correct and exact experiments with homogenization, 3) most correct use of results of homogenization of inclusions. (Authors' abstract translated by A.K.)

NÉGRONI, J.M., 1982, F-Ba-Pb-Zn mineralizations in the structural and metallogenetic evolution of the lead-zinc Pontgibaud mining district (France): Bull. BRGM, Sec. II, v. 2, no. 3, p. 237-242 (in French, English abstract). Author at IMGM, Dépt. gisements miniers, Ecole des mines d'Alès, 6, avenue de Clavières, 30107 Alès Cedex, France.

Generally integrated in the Pontgibaud mining district, the fluorite-barite mineralizations are extensively present in the Saint-Jacques d'Ambur vein deposits, NW of the main Pb-Zn vein axis. The distribution and geometry of the structures show a different kind of formation compared to that of the Pb-Zn veins with quartz gangue. The filling texture are typical of open fractures (banded structures, geodes).

Three mineralization types can be distinguished:

- hypersilicified tectonic breccias (BTH),
- quartz-barite-fluorite veins with some sulfides,
- quartz-fluorite veins.

Diversification and predominance of gangue minerals are related to an improverishment of sulfide minerals corresponding to a change in the composition of the fluids and in the conditions of crystallization. The fluorite biphase fluid inclusions show a strong salinity. The homogenization temperatures are near to 130°C.

Chronologically, the F-Ba-Pb-Zn mineralizations represent a late stage and probably the ultimate stage in the evolution of the Pontgibaud district, corresponding to a distinct metallogenic period recognized elsewhere in the French Massif Central. (Author's abstract)

NEHRING, N.L., DES MARAIS, D.J. and TRUESDELL, A.H., 1982, Thermal decomposition of hydrocarbons in the Cerro Prieto, Mexico, geothermal reservoir: Geother. Resources Council, Transactions, v. 6, p. 305-307. First author at U.S. Geol. Survey, Menlo Park, CA 94025.

The distribution of low-molecular-weight hydrocarbons (C1-7) in geothermal systems depends on hydrocarbon source and temperature/time regime. In the Cerro Prieto, Mexico, geothermal reservoir, thermal decomposition of coal to form methane is extensive at temperatures near 340°C. In high-temperature wells, only methane, ethane, propane, and benzene are present. At temperatures near 290°C, thermal decomposition is extensive, as evidenced by such intermediate products as n-butane, n-pentane, and C4 and C5 branched hydrocarbons. The wide variety of hydrocarbons and low concentrations of methane relative to other hydrocarbons in surface samples indicate only moderate thermal decomposition of the source carbon and intermediate hydrocarbons. (Authors' abstract)

NEKRASOV, I.J. and KONIASHOK, A.A., 1982, The system Au-Fe-Sb-S under hydrothermal conditions at 300-600°C: Akad. Nauk SSSR, Dokl., v. 265, no. 1, p. 180-185 (in Russian).

NERONSKIY, G.I., LEVITSKIY, Yu.T., OSTAPENKO, N.S. and BELOUSOV, V.I., 1982, Problem of thermovacuum decrepitation of gold, in N.P. Ermakov, ed., Thermobarogeochemistry in Geology - Materials of the Sixth All-Union Symposium on Thermobarogeochemistry: Vladivostok, Far East Sci. Center, Acad. Sci. USSR Pub. House, p. 165-170 (in Russian).

For abstract, see Fluid Inclusion Research--Proceedings of COFFI, vol. 13, 1980, p. 173. (A.K.)

NEWTON, R.C. and HANSEN, E.C., 1982, Nature and origin of fluids in charnockitic metamorphism (abst.): EOS, Trans. Am. Geophys. Union, v. 63, p. 448. Authors at Dept. Geophys. Sci., Univ. Chicago, Chicago, IL 60637.

Whole rock, mineral and fluid inclusion analysis of incipient charnockite formation from lower-grade rocks at Kabbaldurga, South India, and Cone Peak, California, reveal the following characteristics of the metamorphism:

1) Conversion of migmatitic gneisses to charnockites was, in some cases, virtually isochemical in terms of major and minor elements, and must have been effected by a pervasive vapor. H_2O constituted 0.1-0.3 of the total vapor; the major volatile species was CO_2.

2) Locally high activities of F at Kabbaldurga and S at Cone Peak were characteristic.

3) Temperatures were ~750°C and pressures were 5.5 kbar at Kabbaldurga and 8.0 kbar for Cone Peak.

4) Weak retrogression in the waning stages partially destroyed orthopyroxene.

Anatexis was closely associated with charnockitic conversion at both localities but was not causative. Both leucosome and restites were converted to charnockite by increasingly dry solutions along shear veins. Similar relations of anatexis and charnockitization were deduced by B.L. Weaver (Contr. Min. Pet. 71, 271, 1980) at Madras from trace element studies and C.R.L. Friend (Nature 294, 550, 1981) at Kabbaldurga from field relations. Available evidence indicates that continued streaming of CO_2 can lead to dry, depleted and refractory high grade granulites without extraction of a partial melt.

Possible sources of the copious CO_2 necessary for conversion of whole terranes include decarbonation of mantle peridotite in a subcontinental plume, destruction of shelf carbonates or evaporates in the closing phase of a Wilson Cycle, or decarbonation of subducted shelf sediments under a continental foreland. (Authors' abstract)

NIKISHOV, K.N. and SAFRONOV, A.F., 1981, Some aspects of the genesis of chromite and magnesium garnet from inclusions in diamonds and from kimberlitic rocks: Dokl. Akad. Nauk SSSR, 1981, v. 256, no. 5, p. 1215-1217 (in Russian; translated in Dokl. Acad. Sci. USSR, v. 256, p. 139-140, 1982).

The possibilities that such inclusions may have been melt inclusions at one time should be kept in mind. (E.R.)

NIKOLAEVA, O.V., RYZHENKO, B.N. and GERMANOV, A.I., 1982, Reduction of sulfate by hydrocarbons and alcohols in aqueous solutions at 200-300°C: Geokhimiya, no. 5, p. 726-742 (in Russian; translated in Geochem. Int'l., v. 19, no. 3, p. 88-104).

NIKOL'SKIY, N.S., 1981, Metastable crystallization of natural diamonds from the fluid phase: Dokl. Akad. Nauk SSSR, 1981, v. 256, no. 4, p. 954-958 (in Russian; translated in Dokl. Acad. Sci. USSR, v. 256, p. 126-129, 1982).

NISHIWAKI, Chikao, 1982, Tectonic stress and metallogenesis; primarily with reference to porphyry copper genesis: Mining Geol., v. 32, no. 4,

p. 291-304 (in Japanese; English abst.).

In earlier papers the author has reported that porphyry copper deposits in the southwest Pacific island arcs strongly favor a compressional stress environment, such as plate collision zones, while kuroko and related volcanogenic massive sulphide deposits favor extensional horizontal stress environment. In this paper he attempts to show how the physical and chemical effects of tectonic stress are implicated to metallogenesis. How this would control the metallogenesis particularly in the case of porphyry copper was investigated and described in the latter half of the paper.

From the results of many in-situ stress measurements two areas, one for extensional and the other for compressional stress regions, are selected, and the stress values in terms of depth are illustrated in Figure 1. Two sets of in-situ measurements at the present plate collision sites are superimposed on Figure 1-B and found to be in harmony with that of the compressional region. Average stress gradients by depth are also shown in Figure 1 and their value at the selected depth and their average P are tabulated in Table 1. Figure 4 schematically contrasts the porphyry intrusions under extensional and compressional environments, and their cooling processes were traced by the P-T diagram shown in Figure 6. Numerical values of the points of interests are given in Table 2 and 3. In the case of the "compressional" B-series in Fig. 4 the second boiling begins at lower temperature, 900° or lower, and at a lesser depth, when about 50% of the magma body is already made up of crystals. The boiling will generate very saline fluid, composed of approximately 50% of alkali chlorides, which again dissolves more chalcophile metals than dilute fluid. The higher confining pressure also inhibits the large volume increase which would have been caused by the second boiling under lower pressure. The increase is about 10-20% (Fig. 7), of which 5-10% could be absorbed by ductile deformation of the host rock. But when further boiling causes the inner pressure to become still higher, final brittle failure takes place resulting myriads of minute cracks in the solid rock mass around the magma body (Fig. 4, B-b). The metalliferous saline hydrothermal solution will rapidly permeate outward through these minute cracks. Opening and extension of the cracks will continue outward and upward. Due to the contact with wall rock, encounter with circulating meteoric underground water and continuous upward migration, temperature and salinity will be lowered rapidly, by 700°C to 200°C and 50 wt% to less than 10 wt% respectively. Together with intense chemical reaction with wall rock metal solubility will be reduced rapidly. More than 90% of metal content in the starting solution will be precipitated before it reaches to the surface. This is an ideal case for porphyry-type disseminated copper deposition.

By contrast, in the case of the lower confining pressure of the "extensional" A-series of Figure 4, magma may initiate a second boiling earlier, thus at higher temperature, at a deeper level, but with lower confining pressure, and with a far lower crystal ratio, say about 10% solid. The salinity of the separated fluid is lower but the volume increase of the total magma mass is far larger being 50% or more (Fig. 4, Fig. 6, Fig. 7 and Table 3). This large increase in volume may cause extrusion of the magma, often accompanied by explosion. Deep fractures caused by extensional deviatoric stress, coupled with high inner pressure, may lead a system of wider hydrothermal veins, instead of numerous minute cracks. Deposition of metal sulphides may occur at shallower depth in the case of wider veins than of porphyry copper type dissemination in myraids of minute cracks in and around intrusive stocks. The overflow of magma or of metalliferous solution to the surface through vein fracture will cause greater loss of metal from it's original containment in the mother magma. Shallower ore deposits have more chance to be washed off by later erosion. There may be sporadic network of copper sulphide dissemination but it's size is limited. If this overflow of magma, accompanied by metalliferous solution, from magma or leached from surrounding rock mass, occurs under the sea especially in an ocean basin, the most of exhaled metal can be trapped by deep sea water, and concentrated as volcanogenic massive sulphide deposits, often associated with small metal dissemination at their roots. (From the author's abstract)

NORMAN, D.I. and NGUENE, F.R., 1982, Genesis of Sn-granites and Sn deposits in light of Rb-Sr isotope, fluid inclusion, and petrographic studies (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 210-211. Authors at New Mexico Inst. Mining & Tech., Socorro, NM, USA.

Tin-granites and -deposits at Mayo Darle, Cameroon and Franklin Mts., Texas (U.S.A.) were studied. Both are composite biotite-granites which intruded volcanics. Sn mineralization occurs near the upper contacts of the granites. The granites have hematitic alteration and alteration of biotite to chlorite and muscovite which increases in intensity near Sn mineralization. Thin section study indicates that some K and SiO_2 was introduced to the granite during alteration.

Fluid inclusion studies at Mayo Darle indicate Sn mineralization by boiling 500 ± 20° fluids of 55 eq.wt% NaCl. Similar fluids are observed in quartz grains in the granite. Rb-Sr isotopic study of fluid inclusion waters indicate the fluids from quartz grains fall on the isochron, i.e., were trapped at near the time of granite crystallization. Fluids in cassiterite and quartz gangue are plot way off the granite isochron and have high amounts of radiogenic Sr. The ore depositing fluids were not directly derived from the granite magma.

We postulate that saline fluids passing through the granite altered biotite thereby releasing K, Rb, radiogenic Sr and Sn. Alteration of Fe-Ti oxides resulted in hematite and mobilization of Sn. As the fluids ascended they reacted with the granite resulting in an altered rock high in K, Rb with Sn mineralization and altered Rb-Sr systematics. (From the authors' abstract)

NORMAN, D.I. and TRANGCOTCHASAN, Yongyut, 1982, Mineralization and fluid inclusion study of the Yod Nam tin mine, southern Thailand, in Metallization Associated with Acid Magmatism, A.M. Evans, ed.: New York, J. Wiley, p. 261-272. First author at Dept. Geosci., New Mexico Inst. Mining and Tech., Socorro, NM 87801.

The Yod Nam tin mine is a primary tin deposit which occurs in a two-mica granite of late Cretaceous to early Tertiary age in southern Thailand. Mineralization occurs in a fracture between two intrusive phases of the granite and took place in three stages. An early cassiterite-hematite-quartz-wolframite stage was followed by deposition of sulphides, chlorite, fluorite, cassiterite, wolframite and quartz. K-feldspar and magnetite were the last to be deposited. The alteration assemblage is chlorite-pyrite-quartz-muscovite which extends no more than 50 cm into the granite.

Fluid inclusion studies on cassiterite, quartz and fluorite indicate deposition from 500-250°C fluids of variable salinity, 0-8 eq.wt.% NaCl and at a pressure of 1 kbar. CO_2-rich inclusions were observed, but only in quartz. These data are similar to results of fluid inclusion studies on primary tin deposits throughout the world.

Two models for tin mineralization at Yod Nam are proposed: one involves meteoric-connate waters and the second, post-magmatic fluids.

High mineralization temperatures and high CO_2 content of some depositing fluids lead us to favor ore deposition by fluids derived from a crystallizing magma. (Authors' abstract)

NORMARK, W.R., DELANEY, J.R., MORTON, J.L., KOSKI, R., BARNES, I., STEVENSON, A., HAYBA, D., BARGAR, K., JOHNSON, M.P. and CLAGUE, D., 1982, Hydrothermal vents and sulfide deposits on the southern Juan de Fuca Ridge (abst.): EOS, Trans. Am. Geophys. Union, v. 63, p. 913. First author at U.S. Geol. Survey, 345 Middlefield Road, Menlo Park, CA 94025.

We made acoustic-transponder-positioned dredging and photogeologic studies on a recent U.S. Geological Survey cruise to locate a series of hydrothermal vents within the axial valley of the Juan de Fuca Ridge. The 1-km wide axial-valley floor is remarkably flat for at least 20 km along strike. Detailed study of a 12-km segment of the ridge axis showed that sheet flows and lava lakes constitute about 90% of the valley floor. Fine-scale bathymetric relief, indicated by deep-tow pinger records from the University of Washington camera sled, reveals a shallow (~10 m) apparently continuous axial depression in the northern 5 km of the study area. The presence of vent communities, photographed on nearly all crossings of the axial depression, implies that the associated vents may be continuous along strike. In contrast to the vent systems along the Galapagos Rift and the East Pacific Rise at latitude 21°N, these hydrothermally supported benthic communities are associated with lava-lake collapse features. The fauna appear to differ significantly from those reported at other submarine-vent localities. Sphalerite and pyrite also were recovered from one of the photographed vent areas. (Authors' abstract)

NORMARK, W.R., LUPTON, J.E., MURRAY, J.W., DELANEY, J.R., JOHNSON, H.P., KOSKI, R.A., CLAGUE, D.A. and MORTON, J.L., 1982, Polymetallic sulfide deposits and water-column of active hydrothermal vents on the southern Juan de Fuca Ridge: Marine Tech. Soc. J., v. 16, no. 3, p. 46-53. First author at U.S. Geol. Survey, Menlo Park, CA.

Includes a discussion of the mineralogy and geochemistry of the vent deposits, the ^{3}He plume, etc. (E.R.)

NORTON, D.L., 1982, Fluid and heat transport phenomena typical of copper-bearing pluton environments: southeastern Arizona, in S.R. Titley, ed., Advances in Geology of the Porphyry Copper Deposits, Southeastern North America, p. 59-72.

NORTON, Denis, 1982, The redistribution of aqueous silica in hydrothermal systems: the formation of quartz veins (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 578. Author at Dept. Geosci., Univ. Arizona, Tucson, AZ 85721.

Quartz veins--their form, distribution and content--record a detailed chronology of the structural, chemical and thermal events that form hydrothermal ore deposits. Quantitative models of the transient processes that form quartz veins have been derived from the mathematical theory of magma-hydrothermal systems, transport properties of fluids in the H_2O system, and standard state thermodynamic data for $SiO_2(qtz) \rightleftharpoons SiO_2(aq)$. Calculated gains and losses of quartz in model systems are useful exploration guides to ore deposits in the lithocap region of porphyry copper plutons.

Aqueous silica, advected from source regions into the lithocap, plugs flow channels with quartz because of local equilibruim and irreversible rates of change in aqueous silica concentration. Synchronous dispersion of thermal energy from the pluton into this region reopens flow channels as fractures propagate in response to large increases in pore fluid pressures. Temperatures at which quartz is deposited in these zones of upward-flowing fluids are ≤ the maximum in log K(qtz) at pressures <1 kb. There is a close correlation between temperatures at which quartz veins form in the model system and homogenization temperatures reported for fluid inclusions in quartz from many types of ore deposits. (Author's abstract)

NOSIK, L.P. and PASHKOV, Yu.N., 1982, Methods of studies of isotope composition of inclusion content and problems of interpretation of the results obtained, in Use of methods of thermobarogeochemistry during prospecting and studies of ore deposits, N.P. Laverov, ed.: Moscow, "Nedra" Publ. House, p. 64-73 (in Russian).

Thermal opening of inclusions theoretically may cause isotope fractionation, but experiments did not comfirm this supposition. Presently the isotope composition of He, Ar, O, H, C and S in inclusions is determined; CO_2, CH_4, CO, H_2, SO_2, H_2S and noble gases are the components of G mixture in inclusions, O_2 presence, although occasionally reported, is doubtful. The SO_2-H_2S equilibrium is discussed, as well as decomposition of organic matter. During mechanical opening of inclusions, a part of filling may be fixed in precipitates on the walls of inclusions. For isotope studies the authors recommend thermal method of inclusion opening on the basis of their investigations. The possibility is shown of use of partitioning of isotope of elements in compounds in inclusions and in the crystal lattice of the host mineral for evaluation of physico-chemical conditions of mineral formation. (Abstract by A.K.)

NOVIKOV, N.P., BOGDANOV, A.A., ZUEV, B.K., KUNIN, L.L., MIKHAYLOVA, G.V. and NOVIKOVA, N.N., 1982, Gas formation in silicate glasses under action of high intensity radiation: Akad. Nauk SSSR Doklady, v. 262, no. 2, p. 335-338 (in Russian). Authors at Inst. Geochem. & Anal. Chem. of Acad. Sci. USSR, Moscow.

The measurements proved that in the fracture space formed under action of high-intensity radiation, gaseous oxygen occurs in amount sufficient for wedging of silicate glass. Thermodestruction is the possible cause of gas formation. Processes accompanying oxygen formation were studied. (A.K.)

NOZETTE, S. and WILKENING, L.L., 1982, Evidence for aqueous alteration in a carbonaceous xenolith from the Plainview (H5) chondrite: Geochim. Cosmochim. Acta, v. 46, p. 557-563.

OHMOTO, Hiroshi and LASAGA, A.C., 1982, Kinetics of reactions between aqueous sulfates and sulfides in hydrothermal systems: Geochimica Cosmo. Acta, v. 46, p. 1727-1745. Authors at Dept. Geosci., The Pennsylvania State Univ., University Park, PA 16802.

The rates of chemical reactions between aqueous sulfates and sulfides are essentially identical to sulfur isotopic exchange rates between them, because both the chemical and isotopic reactions involve simultaneous oxidation of sulfide-sulfur atoms and reduction of sulfate-sulfur.

The rate constants obtained in this study were used to compute the changes in the isotopic fractionation factors between aqueous sulfates and sulfides during cooling of fluids. Comparisons with data of coexisting sulfate-sulfide minerals in hydrothermal deposits, suggest that simple cooling was not a likely mechanism for coprecipitation of sulfate and sulfide minerals at temperatures below 350°C. Mixing of sulfide-rich solutions with sulfate-rich solutions at or near the depositional sites is a more reasonable process for explaining the observed fractionation.

The degree of attainment of chemical equilibrium between aqueous sulfates and sulfides in a hydrothermal system, and the applicability of aO_2-pH type diagrams to mineral deposits, depends on the ΣS content and the thermal history of the fluid, which in turn is controlled by the flow rate and the thermal gradient in the system.

The rates of sulfate reduction by non-bacterial processes involving a variety of reductants are also dependent on T, pH, $[\Sigma SO_4^{2-}]$, and $[\Sigma S^{2-}]$, and appear to be fast enough to become geochemically important at temperatures above about 200°C. (From the authors' abstract)

OKRUGIN, V.M. and OKRUGINA, A.M., 1982, Mineralogical and genetic peculiarities of subsurface volcanogenic ore formation in Kamchatka (abst): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 211-212. Authors at Inst. Volcanology, Petropavlovsk-Kamchatsky, USSR.

[A wide variety of ore deposit types formed from] colloidal hydrothermal chloride-carbonate-sodic solutions at 430-150°C. Their formation was accompanied by a local boiling which provided elements of an independent structure-forming role of the mineralizing medium. The ore bodies are surrounded by distinct aureoles of heating and by anomalous K and Hg content. (From the authors' abstract)

ONTOEV, D.O., 1982, Mineral parageneses and their typomorphic peculiarities in the formations of multistage endogenous deposits (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 186-187. Author at Inst. Geol. of Ore Deposits, Petrography, Mineral. & Geochem., Moscow, USSR.

The following Th values for stages of mineralization with typical parageneses of basic minerals have been determined for the deposits of the molybdenite-sulphide-wolframite groups related with high-alkaline granites (Zabaikaljie, Central Kazakhstan, Peru, etc.): pre-ore feldspathic stage 500-400°C; microcline-molybdenite stage 400-340°C; quartz-sulphobismuthite-wolframite stage 360-250°C; quartz-polysulphide-hübernite stage 300-180°C; fluorite-quartz-carbonate stage. (From the author's abstract)

ORLYANSKIY, Yu.N. and OKLADNIKOVA, L.A., 1982, The system Na_3AlF_6-Na_2SO_3-H_2O at 50°C: Zhurn. Neorg. Khimii, v. 27, no. 7, p. 1870-1871 (in Russian). Authors address not given.

The solubility isotherm may be pertinent to dm identification in specific fluid inclusions; see also next entry. (A.K.)

ORLYANSKIY, Yu.N., OKLADNIKOVA, L.A. and BOCHAROVA, N.D., 1982, The system Na_3AlF_6-Na_2SO_4-H_2O at 75°C: Zhurn. Neorg. Khimii, v. 27, no. 7, p. 1869-1870 (in Russian). Authors address not given.

The solubility isotherm may be useful for interpretation of dms in inclusions in alkaline pegmatites etc.; see also previous entry. (A.K.)

OSBORNE, L.W., Jr., 1982, Fluid inclusions and geochemistry of selected veins and mantos in the Leadville district, Colorado: MS thesis, Colorado State Univ., Fort Collins, Colorado.

Indexed under Fluid Inclusions. (E.R.)

OSHURKOVA, O.V. and PARILOV, Yu.S., 1982, Use of capillary isotachophoresis during analysis of salt composition of fluid inclusions by water leachate method, in Use of methods of thermobarogeochemistry during prospecting and studies of ore deposits, N.P. Laverov, ed.: Moscow, "Nedra" Publ. House, p. 115- (in Russian).

The method was evaluated, based on the separation of analyzed mixture of electrolytes for pure electrolytes under action of direct current in hydrodynamic stream induced in capillary. The method makes possible the simultaneous determination of anions and cations from very small volumes of solutions. The conditions of simultaneous determination of Na, K, NH_4, Ba, Mg, Li, Al, Ca, Cl, CNS, NO_3, SO_4 and CO_3 are given in the paper. (Authors' abstract translated by A.K.)

OSTROVSKIY, I.A., 1982, Thermodynamics of reactive gases under conditions of the Earth's mantle: Izvestiya Akad. Nauk SSSR - Ser. Geol., no. 5, p. 5-12 (in Russian). Author at IGEM of Acad. Sci. of USSR, Moscow.

The paper presents extrapolation of $\int_1^P V_T dP$, lnf and isobaric potentials of formation ΔG°_T to T 4000 K and P 250 kbar for Cl_2, F_2, HCl, HF, H_2O, H_2S, S_2, SO_2, SO_3, $SiCl_4$, SiF_4 and $SnCl_4$. (A.K.)

OVCHINNIKOV, L.N., 1982, Geochemical model of hydrothermal ore formation (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 36-38.

OVCHINNIKOV, L.N., BANSHCHIKOVA, I.V. and VASIL'YEV, Ye.V., 1982, Inclusions of melts and solutions -, direct proof of ore-generating role of magmas, in N.P. Ermakov, ed., Thermobarogeochemistry in Geology - Materials of the Sixth All-Union Symposium on Thermobarogeochemistry: Vladivostok, Far East Sci. Center, Acad. Sci. USSR Pub. House, p. 33-37 (in Russian).

For the abstract, see Fluid Inclusion Research--Proceedings of COFFI, vol. 11, 1978, p. 158; note the changed title. (A.K.)

OVCHINNIKOV, L.N., KOZLOV, Ye.D. and RAFAL'SKIY, R.P., 1982, The solubility of stibnite in chloride solutions at elevated temperatures: Geokhimiya, no. 9, p. 1290-1297 (in Russian).

PADOVANI, E.R., SHIREY, S.B. and SIMMONS, Gene, 1982, Characteristics of microcracks in amphibolite and granulite facies grade rocks from southeastern Pennsylvania: J. Geoph. Res., v. 87, no. B10, p. 8605-8630. First author at Nat'l. Sci. Foundation, Washington, DC 20550.

Our observations of the microcracks in a small suite of samples of amphibolite and granulite facies rocks of variable composition show that (1) most cracks are partly or completely sealed, (2) the minerals that seal microcracks are unrelated to phase equilibria associated with granulite facies metamorphic conditions, and (3) the present crack porosity is related to bulk composition rather than to metamorphic grade. All observed cracks (open, healed, sealed) appear to have formed in response to tectonic stresses associated with retrograde metamorphism. (Authors' abstract)

PAGEL, M., 1982, Granites and uranium deposits in Portugal: typology, alterations and mineralizations, in Vein-Type and Similar Uranium Deposits in Rocks Younger than Proterozoic, Panel Proc. Series: Vienna, Int'l. Atomic Energy Agency, IAEA-TC-295/20, p. 323-347 (in French; English abstract). Author at Centre de rech. sur la géol. de l'uranium et Centre de rech. pétrographiques et géochimiques, Vandoeuvre, France.

The granites surrounding the three Portuguese uranium deposits studied here (Urgeirica, Bica and Cunha Baixa) are characterized by high and variable uranium tenors, ranging from 4 to 17 ppm at the surface, compared with thorium tenors of 20 to 37 ppm. The minor minerals containing the uranium and thorium are as follows: uraninite with low ThO_2 tenors, xenotime, monazite, zircon and, to a lesser extent, apatite. On the sides of the uranium-bearing veins, intense sericitic alteration is caused by low-salinity aqueous fluids (1.1 to 5.8% eq.wt. NaCl) at variable temperatures rising to 200-250°C. Several generations can be identified from detailed chemical data on the white micas: magmatic muscovite, deuteric muscovite and phengite occurring along the borders of the mineralized veins. There is evidence of a complex evolution of the fluids within the country rock enclosing the uranium-bearing veins, suggesting that the primary uranium mineralizations are of hydrothermal origin. (Author's abstract)

PALIN, J.M. and NORMAN, D.I., L982, Volatiles in phyllosilicates, Copper Flat porphyry deposit, southwest New Mexico - a potential exploration tool (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 223. Authors at Dept. Geosci., New Mexico Inst. Mining & Tech., Socorro, NM 87801.

Whole rock surface and drill core samples, containing phyllosilicate minerals, have been collected from the Copper Flat porphyry deposit before development. The ore deposit is not exposed at the surface, and the host Laramide quartz monzonite stock shows no well defined zoning of alteration about the known orebody. Upon heating, phyllosilicates release H_2O and significant amounts of other volatiles. The volatile contents of biotite, chlorite and sericite have been measured in an attempt to define the Copper Flat orebody.

The most abundant of the thermally evolved volatiles are: CO_2, CO, CH_4, H_2S, SO_2, and H_2. Carbon dioxide, CO, H_2S, and He appear to be spatially distributed about the orebody. Carbon dioxide is enriched by a factor of 3 and H_2S depleted by a factor of 4 in samples over the orebody. Carbon monoxide shows the greatest decreasing gradient outward from the orebody. However, an independent relationship between CO and CO_2 has not been verified.

The data indicate that the volatile contents of phyllosilicates may provide a tool for delineating drilling targets for hydrothermal mineral deposits which have undefined alteration patterns. (Authors' abstract)

PALMA, V.V. and CLARK, A.H., The San Rafael tin-copper lode system, Puno, S.E. Peru: a Cornwall-type deposit in the central Andean tin belt (abst.): Geol. Assoc. Canada/Min. Assoc. Canada Program with Abstracts, v. 7, p. 71. Authors at Dept. Geol. Sci., Queen's Univ., Kingston, Ontario, K7L 3N6, Canada.

The Central Andean tin belt has, as a productive entity, been extended northwestwards for over 250 km through the recent emergence of the San Rafael mine (14°12'00"S.; 70°20'15"W.) as a major source of Sn concentrates (ca. 900 tonnes metal, 1980). The San Rafael "vein," in part of exceptional grade (+ 10% Sn), is a laterally-extensive, structurally-complex, lode, with marginal, chloritic, wall-rock replacement.

Hydrothermal activity was spatially related to an Upper Oligocene (27 Ma), epizonal, stock of cordierite-biotite monzogranite, emplaced into Upper Ordovician metaclastics. The wide occurrence of brine inclusions in quartz phenocrysts reveals that, prior to ore deposition, the intrusion was permeated by high-temperature (T homogenization, 400-510°C), saline (+38 equiv. wt.% NaCl), aqueous fluids. A similar, perhaps contemporaneous, hydrothermal phase generated essentially barren tourmaline-quartz veins and fine-breccia sheets (lode stage I). These controlled the disposition of the mineralized lode structures, which comprise multiple, anastomosing, quartz-chlorite veins and breccias, within which deposition of botryoidal cassiterite ("wood tin:" Stage II) was followed by those of subordinate acicular "needle-tin," and of massive chalcopyrite (Stage III). Both economic lode stages formed at temperatures (Th) in the range 210-415°C, and involved fluids of low-to-moderate salinity (≤20% NaCl). Confining pressures were low (≤165 bars), but boiling was very local and unrelated to either ore grade or brecciation intensity.

Botryoidal cassiterite is concentrated below 4600 m a.s.l., as is the later needle-tin, whereas chalcopyrite was deposited mainly between 4700 and 5000 m a.s.l. The lode thus displays a distinct, Sn *vs.* Cu, polyascendant, zonation, independent of temperature of fluid salinity. Unlike most Sn veins in Bolivia, and, indeed, elsewhere, the San Rafael lode is, in structure and mineralogy, very similar to the major Sn-Cu lodes of Cornubia, U.K. (Authors' abstract)

PAL'MOVA, L.G., 1982, Improvement of prospecting criteria by thermobarogeochemical methods, *in* N.P. Ermakov, ed., Thermobarogeochemistry in Geology - Materials of the Sixth All-Union Symposium on Thermobarogeochemistry: Vladivostok, Far East Sci. Center, Acad. Sci. USSR Pub. House, p. 144-146 (in Russian).

For abstract, see Fluid Inclusion Research--Proceedings of COFFI, vol. 11, 1978, p. 159. (A.K.)

PANCHAPAKESAN, V., 1982, A suggested classification of inclusions in minerals (abst.): [Proceedings & Abstracts], National Workshop on Fluid Inclusion Studies 22-23 March, 1982, Indian Inst. Tech., Bombay p. 51-54 (unpaginated). Author at Indian Inst. Tech., Powai Bombay 400 076.

An elaborate classification, into 47 categories, based mainly on the phase assemblage at room T. (E.R.)

PANOV, B.S., 1981, Genetic peculiarities and prospecting criteria of fluorite mineralization of Donbass and Priazov'ye, *in* Fluorite of Ukraine (criteria of prospecting), p 20-41 (in Russian): "Naukova Dumka" Publ. House, Kiev, 140 pp., price 1 rbl. 10 kopecks.

In the Donets Basin Th in the fluorite deposits are as follows: Pokrovo-Kireevskoe deposit 280-80 (fluorite; P 750-830 atm for Th 280-220°C, pH 6.2-7.0 ± 0.8), 220-190°C (quartz), 150-90°C (carbonates); Dal'niy mine 145-132°C (fluorite), 100-90°C (carbonates), 140-138°C (quartz); mine Vostochno-Dolomitnyi near town Dokuchaevsk 170-140°C (P 136 atm, pH 6.6, total salt conc. 9.3-4.3%, in fluorite), 175-130°C (quartz), 140-135°C (dolomite), 120-80°C (calcite, total salt conc. 2.5%, pH 7.4-8.8); mines Severnyi and Yuzhnyi near town Komsomol'sk 175-117°C (fluorite, P 130-120), 110°C (amethyst), 140-115°C (calcite); in Priazov'ye, Petrovsko-Gnutovskoe deposit 250-105°C (fluorite, 10.5-11.4 wt. % total salt conc., pH 7), 260-220°C (calcite), 250-200°C (parisite). (A.K.)

PARILOV, Yu.S., 1982, Physico-chemical conditions of accumulation of hydrothermal-sedimentary sulfide ores in the deposits of Kazakhstan: Akad. Nauk SSSR Doklady, v. 266, no. 5, p. 1224-1227 (in Russian). Author at Inst. Geol. Sci. of Acad. Sci. of Kazakh SSR, Alma-Ata.

Ores from the pyrite-polymetal deposits: Shakliya, Mirgalimsay, Tekeli, Atasuy, Ridder-Skolovskoe, Orlovskoe, Zhayren, and Nikolaevskoe were investigated by vacuum decrepitation. Td ranges 40-80°C; inclusions are filled by water solution with 3-28% of total salts and 0.5-7% of gases. Ions consist of $(Cl,F)>SO_4>HCO_3$; $(Na,K)>(Ca,Mg)>NH_4>Fe$; gases of H_2S, SO_3, CO_2, N_2 and Ar. (Abstract by A.K.)

PARILOV, Yu.S., MUKANOV, K.M. and MIKHALEVA, V.A., 1982, Temperatures and compositions of ore-forming solutions of lead ore deposits of Alaigyr (central Kazakhstan): Izv. Akad. Nauk Kaz. SSR, Ser. Geol., no. 2, p. 38-44 (in Russian). Authors at Inst. Geol. Nauk im. Satpaeva, Alma-Ata, USSR.

The Alaigyr Pb ore deposit is localized in Givetian-Frasnian volcanogenic rocks (quartz-feldspar porphyries) and limestones. Com. concns. of ores occur in hydrothermally altered porphyries and tuffs. The vein mineralization includes galena, pyrite, sphalerite, etc. Fluid inclusions in ores have a high content of gases (17%), with CO_2, H_2S, CO, NH_3, H_2, N_2, and Ar. Based on the fluid-inclusion studies, the composition of ore-forming solutions., from both the pre-ore and ore stages, is estd. Vacuum decrepitation of the inclusions indicated that the hydrothermal metasomatism began at ~600°; concluding mineral formation in barite veinlets occurred at 310 to 260°. (C.A. 96: 220720g)

PARRY, W.T. and DOWNEY, L.M., 1982, Geochemistry of hydrothermal chlorite replacing igneous biotite: Clays & Clay Min., v. 30, no. 2, p. 81-90. Authors at Dept. Geol. & Geoph., Univ. Utah, Salt Lake City, UT 84112.

Hydrothermal chlorite replaces igneous biotite in the Gold Hill, Utah, quartz monzonite. Chemical compositions of coexisting biotite and chlorite determined by electron microprobe and wet chemical methods were used to evaluate chemical mass transfer during the alteration process. Secondary fluid inclusions in quartz of granite have Th 171-251°C (avg. 216°C). P est = 200-500 bars. (E.R.)

PASCAL, M.-L. and ROUX, Jacques, 1982, Thermodynamic properties of (Na, K)Cl-H_2O solutions between 400 and 800°C, 1-2 kb; a review of exchange equilibria with sodium-potassium silicates: Geochim. et Cosmo. Acta, v. 46, p. 331-337 (in French; English abstract). Authors at CRSCM 1A, rue de la Férollerie, 45045 Orléans Cedex, France.

Several independent determinations of the difference in Gibbs free energy of formation (from the elements at 25°, 1 bar) between $NaCl^0$ and KCl^0 in aqueous solutions (molality >0.5) are derived from equilibrium data between alkali feldspars, feldspathoids (nepheline-kalsilite), micas (muscovite-paragonite) and hydrothermal (Na, C)Cl-H_2O solutions. These results along with other data from the literature are discussed. The relation:

$$\Delta G^0 f,\ KCL^0 - \Delta G^0 f,\ NaCl^0(J) = -16{,}500(\pm 2{,}500) - 18(\pm 4)\ T(K)$$

is proposed from 400 to 800°C and 1 to 2 Kbar. (Authors' abstract)

PASHKOV, Yu.N., 1982, Problems of use of method of decrepitation, in Use of methods of thermobarogeochemistry during prospecting and studies of ore deposits, N.P. Laverov, ed.: Moscow, "Nedra" Publ. House, p. 64-73 (in Russian).

Decrepitation is used for revealing of zones of hydrothermal impregnation, prospecting for hidden ore bodies, determination of G in industrial sands etc. That method is also sometimes used for determination of T of mineral formation, which is incorrect without special interpretation. Until present, the theory of decrepitation is based on only one supposition, that after homogenization P inside inclusion sharply increases causing the breaking of inclusion walls. Attempts at mathematical description of this phenomenon led to the conclusion that Td depends on mechanical resistivity of host mineral, size of inclusions and distance from the grain surface. The author also briefly characterizes various principles of recording of decrepitation effects. (Abstract by A.K.)

PASTERIS, J.D., 1982a Evidence of potassium metasomatism in mantle xenoliths (abst.): EOS, Trans. Am. Geophys. Union, v. 63, p. 462. Author at Dept. Earth & Planet. Sci., Washington U., Box 1169, St. Louis, MO 63130.

Sulfides are among the metasomatic phases in veined peridotites (e.g., Harte & Gurney, 1975). At least 3 mantle xenolith suites contain K-Fe-Ni-sulfides: Frank Smith, South Africa (Clarke, 1979); Bulfontein, South Africa; Malaita, Solomon Is. (Pasteris, unpub. data). The Malaita sulfides occur in Cpx megacrysts with abundant features strongly suggestive of incipient partial melting (Pasteris, 1981). One large (several mm) complex sulfide intergrowth consists predominantly of Po+Pn. It also contains irregular bodies and veinlets of K-Fe-Ni-(Cu)-sulfide, glass patches, crystal inclusions, and crystals in glass; it is surrounded by patches and partial rims of glass. In reflected light, one sees in the Cpx host, minute silicate regions of comparatively lower reflectivity--presumably glass. They have higher Mg, Al, and Fe than the host Cpx, and are substantially enriched in K. Most of the glasses (inhomogeneous) within and rimming the large sulfide bleb have no K, but one large region adjacent to the sulfide has considerable K and compositionally resembles the minute regions of partial melt in the host Cpx. These features suggest introduction of a K-enriched fluid into the megacryst, which 1) caused incipient melting along fractures in the Cpx, 2) produced complete melting in or introduction of melt into areas around the sulfide, and 3) possibly caused K-metasomatism of preexisting sulfides or introduced new K-sulfides into them. Furthermore, small amounts of Cu are detected in the K-sulfide, but not in the enclosing Po-Pn intergrowth, suggesting that Cu also may have been introduced by the K-bearing fluid. Such assemblages are particularly important because of their implications for fluid movement and large-scale introduction of trace elements and because of our concern for the potassium budget in mantle rocks. [Malaita xenoliths from P.H. Nixon: Nixon & Boyd, 1979.] (Author's abstract)

PASTERIS, J.D., 1982b Kimberlites: insight into the mantle (abst.): EOS, Trans. Am. Geophys. Union, v. 63, p. 613.

PATERSON, C.J., 1982, Oxygen isotopic evidence for the origin and evolution of a scheelite ore-forming fluid, Glenorchy, New Zealand: Econ. Geol., v. 77, p. 1672-1687. Author at Geol. Dept., Univ. Otago, Dunedin, New Zealand.

The Glenorchy lode field in the Otago Au-W-Sb metallogenic province of New Zealand is hosted by metasediments of pumpellyite-actinolite facies to lowest greenschist facies. The lodes cut schistosity at a high angle and consist of anastomosing veins of quartz-scheelite-calcite-pyrite-arsenopyrite within zones of crushed and deformed schist up to 6 m wide.

The temperature of metamorphism was estimated by oxygen isotope geothermometry to be between 370° and 445°C, although pumpellyite stability experiments by Schiffman and Liou (1977) suggest that 400°C would be the upper limit. Oxygen isotope geothermometry gave a temperature range of mineralization of 280° to 350°C. Relative temperatures can be more reliably stated-mineralization occurred after metamorphism at a temperature at least 80°C less than that of metamorphism.

The ore-forming fluid $\delta^{18}O$ was in the range 7 to 10 per mil, and on this evidence could have been either metamorphic or magmatic in origin, but because there is no spatial association between Au-W-Sb mineralization and igneous activity in the Otago area, a metamorphic origin is favored. A model for the origin and isotopic evolution of the ore-forming fluid is proposed whereby the fluid was derived from metamorphic dehydration reactions in rocks of at least upper greenschist facies. The fluid was trapped in the rocks until uplift of the schist pile led to hydraulic fracturing and release of the fluid to existing fault zones. The fluid migrated rapidly upward, retaining a constant $\delta^{18}O$ value, and deposited hydrothermal minerals which were ^{18}O enriched relative to those in the country rock. Ore-forming elements (W, Au) were derived deep in the schist pile, probably also from metamorphc reactions.

The oxygen isotope alteration aureole is probably too narrow to be of any practical use in exploration for similar lode deposits, at least in the Glenorchy area. (From the author's abstract)

PATERSON, M.S., 1982, The determination of hydroxyl by infrared absorption in quartz, silicate glasses and similar materials: Bull. Minéral., v. 105, p. 20-29. Author at Res. Sch. of Earth Sci., Australian Nat'l. Univ., Canberra 2600, Australia.

A survey of calibrations available for various substances supports the view that the strength of absorption of hydroxyl in the 3 μm infrared region is frequency dependent. When proper account is taken of the anisotropy factor γ, it appears that a single calibration line for the integral molar absorption coefficient I can be applied, as a first approximation, to a variety of substances, including silicate and other glasses, quartz and the various forms of water. This relation is $I/\gamma = 150(3780\ \bar{\nu})$ where $\bar{\nu}$ is the wave number in cm^{-1} and I is given in cm^{-2} per mol H/l. Its acceptance allows the hydroxyl content associated with the broad-band or gel-type absorption in quartz and similar substances to be estimated to a first approximation and has the implication that the distribution of hydroxyl bond strengths is much more biassed to high wave numbers than is at first suggested by the shape of the spectrum. (Author's abstract)

PATIL, R.R., 1982a Fluid inclusion study, a tool to solve geological problems (abst.): [Proceedings & Abstracts], National Workshop on Fluid Inclusion Studies, 22-23 March, 1982 Indian Inst. Tech., Bombay, p. 43 (unpaginated).

PATIL, R.R., 1982b Fluid inclusion research in Himalaya - a review (abst.) [Proceedings & Abstracts], National Workshop on Fluid Inclusion Studies, 22-23 March, 1982, Indian Inst. Tech., Bombay, p. 37 (unpaginated).

PATRICK, R.A.D., 1982, Mineralizing fluids at Tyndrum, Scotland (abst.): J. Geol. Soc. London, v. 139, part 1, p. 97.

The Tyndrum lead-zinc deposits occur as veins and vein breccias in Moinian quartzites. The veins occupy fractures associated with the Tyndrum-Glen Fyne fault. Fluid inclusion studies revealed the mineralizing fluids carried 18 wt% equivalent NaCl, had a Na/K ratio of 3:1 and entered the veins at c. 300°C. The inclusions also revealed evidence for "boiling," and secondary inclusions containing fresh water and displaying homogenization temperatures of ~125°C may represent trapping of the resulting condensate. Electron microscope studies of the sphalerite revealed that the secondary inclusions developed along deformation twins, zones of intense dislocation, as well as fractures.

The mineralogy of the deposits indicates the temperature of the solutions increased with time. K-feldspar is a wall rock alteration product and its formation was the result of boiling, a high SiO_2 concentration and the low Na/K ratio of the mineralizing solutions. This low Na/K ratio is explained by the fluids reacting with the K-rich metamorphic source rocks. Sulphur isotope studies indicate a different source of sulphur for the baryte and the sulphides. (Author's abstract)

PATTERSON, C.S., SLOCUM, G.H., BUSEY, R.H. and MESMER, R.E., 1982, Carbonate equilibria in hydrothermal systems: first ionization of carbonic acid in NaCl media to 300°C: Geochimica Cosmo. Acta, v. 46, p. 1653-1663. Authors at Chem. Div., Oak Ridge Nat'l. Lab., Oak Ridge, TN 37830.

The ionization quotients of aqueous carbon dioxide (carbonic acid) have been precisely determined in NaCl media to 5 m and 50° to 300°C using potentiometric apparatus previously developed at Oak Ridge National Laboratory. The pressure coefficient was also determined to 250°C in the same media. These results have been combined with selected information in the literature and modeled in two ways to arrive at the best fits and to derive the thermodynamic parameters for the ionization reaction, including the equilibrium constant, activity coefficient quotients, and pressure coefficients. The variation with temperature of the two fundamental quantities $\Delta V°$ and ΔC_p^o were examined along the saturation vapor pressure curve and at constant density. The results demonstrated again that for reactions with minimal electrostriction changes the magnitudes and variations of ΔC_p^o and $\Delta V°$ with temperature are small and, in addition, ΔC_p and ΔV are approximately independent of salt concentration.

The results have also been applied to an examination of the solubility of calcite as a function of pH (in a given NaCl medium) for the neutral to acidic region both for systems with fixed CO_2 pressure and systems where the calcium ion concentration equals the concentration of carbon. The pH of saturated solutions of calcite with $P(CO_2)$ of 12 bars increases from 5.1 to 5.5 between 100° and 300°C. (Authors' abstract)

PAVLOV, A.L., 1982, Possible role of element-organic compounds in formation of quartz-ore deposits: Geologiya i Geofizika, no. 7, p. 37-43 (in Russian). Author at Inst. Geol. Geophys. of Siberian Branch of Acad. Sci. USSR, Novosibirsk.

The author discusses the role of compounds like C_2H_5Cl, $(C_2H_5O)_4Si$, AlC, $(C_2H_5)_4Sn$ etc., hypothetically existing in various stages of postmagmatic processes and possibly producing minerals and gases (CO, CO_2, CH_4) detectable in fluid inclusions. (A.K.)

PAVLUN', N.N., 1982, Crystallogenetic sequence and certain typomorphic features of pyrites from the deposit Akchatau: Mineralog. Sbornik, v. 36, no. 1, p. 31-36 (in Russian; English abstract). Author at L'vov Univ., L'vov, Ukrainian SSR.

Th of inclusions in quartz paragenetic with cubic pyrite are 405-320°C (Td of this pyrite 420-360°C); with pyrite of habit being combination of cube and pentagonal dodecahedron {210} - 350-290°C (Td of pyrite 380-320°C); with pyrite of pyritohedron habit - 350-240°C (Td of pyrite 340-280°C). (Abstract by A.K.)

PAVLUN', N.N. and SIMKIV, Zh.A., 1982, Evolution of chemical composition of mineral-forming solutions of rare-metal ores in the deposit Akchatau (central Kazakhstan): Zapiski Vses. Min. Obshch., v. 111, no. 1, p. 67-74 (in Russian).

The deposit Akchatau (rare metal-W-Mo) consists of greisens and quartz veins. Four horizontal zones were found there from the bottom up: 1) under ore, 2) main ore, 3) above-ore, and 4) "secondary" ore zones. Two stages of mineral formation were distinguished: I pneumatolytic-hydrothermal, including substages molybdenite-quartz, Th* 440-340°C, P 1200-1000 bars, and commercial rare-metal-molybdenite-wolframite-quartz plus pyrite-wolframite-quartz, Th >480-260°C, P 1600-500 bars; II hydrothermal, including galena-sphalerite-quartz, Th 310-150°C, P 550-350 bars, and fluorite quartz plus zeolite-calcite, Th 180-60°C. Early hydrotherms were of F-Cl-K-Na type, total salts up to 65% (NaCl+KCl). Later hydrothermal solutions had Cl-K-Na composition with increasing CO_2 amount, total salts from 41 to 32 wt. %. Special attention was paid to a) rare-metal-molybdenite-wolframite-quartz and b) pyrite-wolframite-quartz substages; 6000 Th measurements in quartz and fluorite and 17 water leachates from quartz were made. Th increases with the depth increment; average paleotemperature vertical gradient is 25°C per 100 m, horizontal - from 8 to 10°C per 100 m, displaying essentially concentric pattern of paleoiosotherms. The ions: Cl (0.61-5.65 here and later in mg/250 ml), $HSiO_2$ (this ionic form accepted conditionally) 2.56-8.06, Na 0.62-3.63, F 0.56-0.61, K 0.20-1.71, Ca 0-0.27, HCO_3 0-0.44, pH of water leachates ranges from 6.4 to 5.3. (Abstract by A.K.)

*All Th without P corrections. (A.K.)

PEARCE J.A. and BALDWIN, J.A., 1982, Geochemical tracers for identifying the pathlines of mineralizing fluids: examples from the El Salvador porphyry copper deposit, Chile (abst.): J. Geol. Soc. London, v. 139, p. 98.

PECHERKIN, A.I., 1982, Saturation of water by calcium sulfate during filtration into riverside gypsum massif: Sovetskaya Geologiya, no. 1, p. 54-47 (in Russian). Author at the Perm State Univ., Perm, USSR.

The paper bears plots of $CaSO_4$ concentration vs time for filtration rates 0-100 cm/sec at 25°C, $CaSO_4$ solubility in water at T 0-100°C and time of gypsum solubility vs velocity of filtration at T 0-50°C during the forced flow; applicable to fluid inclusion studies in sedimentary and diagenetic minerals. (A.K.)

PECK, C.W., 1982, A geochemical and fluid inclusion study of the mineral deposits of the Platoro fault zone, Platoro Caldera, San Juan Mountains, Colorado: MS thesis, Colorado Sch. Mines, Golden, Colorado.

Indexed under Fluid Inclusions. (E.R.)

PECK, J.H., 1982, Fluid inclusion studies for dating fault movement, in O.C. Farquhar, ed., Geotechnology in Massachusetts, Proc. of a Conference in March 1980, Graduate Sch. Univ. Massachusetts, p. 443-446. Author at Stone & Webster Engrg. Corp.

Faulting is pervasive in New England and records tectonic movements which have occurred in the geologic past. No presently active faults are known. Determination of the age of last movement on old faults is difficult but is required when faulting is found on or near nuclear reactor sites or other facilities licensed by the Nuclear Regulatory Commission. Analyses of fluids trapped within minerals which have crystallized from aqueous solutions circulating in fault planes give specific data on the geologic conditions present at the time of crystallization. Fluid inclusions reveal ranges of temperature, pressure, salinity, composition, and oxidation state of the solutions.

The studies of fluid inclusions in quartz, calcite, sphalerite, and other less common transparent crystalline minerals in fault zones provide clues as to depth of overburden, geothermal conditions, and anomalous fluid sources after initial fault movement. The minerals themselves act as sensitive strain indicators for the detection of movement after various stages of mineral crystallization.

Determination of the temperature range of crystal formation, the approximate formation pressure, and the composition of the fluids has enabled the geologist to put limiting values on the depth and other geologic conditions of formation. Assuming reasonable values for hydrostatic and lithostatic pressures and geothermal gradients, one can calculate qualitatively a depth range for crystallization. Minimum age of last fault movement is approximated by assuming conservative denudation rates and calculating the time necessary to exhume the mineralized fault. (Author's abstract)

PENG, Ligui, 1982, The study of mineral inclusions on the pyritic Cu-bearing deposit of Baiyinchang in Gansu Province, China: Bull. of Xi'an Inst. Geol. & Min. Resources, Chinese Acad. Geol. Sci., no. 4, p. 114-123 (in Chinese, English abstract).

Based on the study of the mineral inclusions mineralized rocks and ore minerals in quartz-keratophyre series of this area, some conclusions are drawn as follows:

1. On the basis of the uniform temperature of the solid inclusions in the quartz-keratophyre series (1050°C to 1150°C) and of melting of quartz-keratophyre matrix, and the appearance of a large number of gas bubbles at 1100-1150°C, [we suggest] that various quartz-keratophyres originated from magma at a temperature of 1050-1150°C and that the rocks formed from rapidly cooling magma with a great deal of volatile flux, not far from the volcanic orifice.

2. Two [stages of] gas inclusions [were recognized]. The early period belongs to the uncolored gas-liquid inclusions with a uniform temperature (Th?) of 207-405°C (not corrected for pressure). The later period formed colored gas-liquid inclusions (coexisting with polyphase inclusions containing liquid CO_2 and daughter minerals) with a uniform T of 153-469°C. The metallogenesis is related to the later hydrothermal action.

According to the data obtained, the metal-bearing solutions are characterized by pH>8, salinity = 20.0%±, density = 1.02, and in part containing immiscible hydrothermal [fluids] of high salinity (30-60%), rich in Si, Fe, Na, Cu, S, P, CO_2, and the presence of Mg, Ca, K, Pb, Ti, Ag et al. which are the major source of mineralization. The T of hydrothermal fluid ranged from 153-469°C and the T of metallogenesis is calculated at 200-374°C [indicating a] middle-high temperature hydrothermal deposit.

3. The enriched zone of colored gas-liquid inclusions is a promising area of mineralization, and ore deposits of large scale are apt to be found in a district rich in solid inclusions. (Modified by E.R. from the author's abstract)

PERCHUK, L.L. and LINDSLEY, D.H., 1982, Fluid-magma interaction at high pressure-temperature conditions, in S. Akimoto and M.H. Manghnani, eds., High-Pressure Research in Geophysics: Advances in Earth and Planet. Sci., v. 12, p. 237-250. First author at Inst. Exp. Min., the U.S.S.R. Acad. Sci., 142432, Chernogolovka, Moscow, USSR.

The chemical fluid-magma interaction has been studied involving two kinds of systems: "basalt-fluid" and "peridotite-fluid" at 1 to 4 GPa and 1,200 to 1,500°C. The plagioclase melt has been used as a starting material to investigate the first system. The alkali fluid has been introduced in the capsule to produce the alkali melt and carbonatite from the plagioclase melt: $Ca_{1-x}Na_xAl_{2-x}Si_{2+x}O_8 + (1-x)(Na_nK_{1-n})_2CO_3 + H_2O = Na_x(Na_nK_{1-n})_{1-x}Al_{2-x}Si_{2+x}O_{18}\cdot zH_2O + (1-x)CaCO_3\cdot(1-z)H_2O$.

The K-Na exchange between silica-rich magma and (K, Na)Cl fluid has been also carried out over the wide Na/(Na + K) range at 1,100°C and 6 bars: $0.44NaAlSi_3O_8\cdot 0.56SiO_2 + KCl = NaCl + 0.44KAlSi_3O_8\cdot 0.56SiO_2$.

The reaction $CaMgSi_2O_6\cdot Mg_2SiO_4\cdot Mg_3Al_2Si_3O_{12} + (1 + n)(K_2O\cdot 2H_2O\cdot CO_2) =$

$K_2Mg_6Al_2Si_6O_{22} \cdot 2H_2O + CaCO_3 + n(K_2CO_3 \cdot 2H_2O)$ can explain the origin of carbonate and phlogopite material in kimberlite magma in the depth more than 150 km beneath the platforms in Eastern Siberia and South Africa. (Authors' abstract)

PERRY, E.C., Jr. and MONTGOMERY, C.W., eds., 1982, Isotope studies of hydrologic processes: Northern Illinois Univ. Press, 118 pp.

A selection of 12 papers from a 1980 AGU meeting, covering a variety of subjects of potential interest to fluid inclusion studies: stable isotopes of O and H in water, C in HCO_3^-, S in SO_4^{2-} and S^{2-}, and radioisotopes of U, H, and Ra, as well as various aspects of rock-water interaction in geothermal systems and sediments. (E.R.)

PERSIKOV, E.S. and KALINICHEVA, T.V., 1982, Concentration and temperature dependence of viscosity of magmatic melts (method of calculation and prediction): Akad. Nauk SSSR Doklady, v. 266, no. 6, p. 1467-1471 (in Russian). Authors at Inst. Exper. Mineralogy of Acad. Sci. USSR, Chernogolovka near Moscow, USSR.

The paper bears data on viscosity of the melts: SiO_2, albite and albite-H_2O, binary and pseudobinary systems like granite-H_2O, basalt-H_2O, andesite-H_2O, Na_2O-SiO_2, MgO-SiO_2 etc.; pertinent to formation of melt inclusions. (A.K.)

PESQUERA, A., FORTUNE, J.P., HERRERO, J.M. and VELASCO, F., 1982, Pb-Zn-Ba vein deposits related to the granite of Penas de Haya (western Pyrenees-Spain) (abst.): Bull. BRGM, sec. II, v. 2, no. 3, p. 287. First author at Dept. Cristal. Mineral., Univ. del Pais Vasco, App. 644, Bilbao, Spain.

The Basque Paleozoic massif of Cinco-Villas (Navarre-Guipuzcoa) includes numerous Pb-Zn-F-Ba deposits and rather fewer iron deposits.

All the deposits display roughly the same paragenesis: sphalerite, galena, fluorite, quartz, siderite, pyrite, arsenopyrite, chalcopyrite, pyrrhotite, antimony sulfosalts, silver sulfosalts, cassiterite, etc. The sphalerite-pyrite-pyrrhotite association and measurements on the fluid inclusions in the fluorite indicate an emplacement temperature of between 250°C and 350°C. (From the authors' abstract)

PETROV, P., 1982a, Primary spectorial fluid inclusions in quartz (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 212. Author at Sofia Univ., Sofia, Bulgaria.

Primary sectorial inclusions, the orders of their distribution and relations with other types have been observed in the quartz of lead-zinc lodes of Southern Bulgaria (Madan ore district, Majar Ore field). The sectorial inclusions possess one common peculiarity consisting in their normal orientation towards rhombohedral facets. The vacuoles of the inclusions are rather complex in shape. Simple negative crystals are extremely scarce. As proved by optical examinations, low-temperature conditions enable recrystallization and splitting of some inclusions. This results in anomalous inclusions with different phase filling. Sectorial inclusions impart milky-white color to the aggregates of gangue quartz and to individual crystals in which they are present. Since the degree of saturation with inclusions is rhythmical, quartz acquires zonal structure.

It has been proved that ore minerals occur only in those parts of ore lodes where quartz is only slightly defective and poor in sectorial fluid inclusions. (Author's abstract)

PETROV, P.P., 1982b, Primary sectorial fluid inclusions in milk-white quartz: Comptes rendus de l'Académie bulgare des Sci., v. 35, no. 4, p. 487-490 (in English).

Dense masses of subparallel primary inclusions, elongated in the direction of growth, and arranged in white zones representing growth stages, are described from various Bulgarian ore and non-ore quartz veins. (E.R.)

PETROVSKAYA, N.V. and NOVGORODOVA, M.I., 1982, Changes of acidity-alkalinity of solutions during formation of gold ore deposits, p. 141-154, *in* Acid-basic properties of chemical elements, minerals, rocks and natural solutions: "Nauka," Moscow, 216 pp., 1100 copies printed, price 2 rbls 50 kopecks (in Russian).

Changes of pH of mineral-forming solutions (Th 50-450°C) during origin of gold ore deposits are polycyclic in agreement with the idea of the separation of ore process into stages. Commercial stage of hydrothermal ore process is characterized by alkaline solutions. Important role is displayed by acid and alkaline dissolving of rocks and ores. Under shallow conditions the colloid masses precipitate from solutions, next significantly or completely recrystallized. (Authors' abstract, translated by A.K.)

PETROVSKAYA, S.G., 1982, Geochemical peculiarities of mineral associations and conditions of their formation in the molybdenum deposit (Western Transbaikalia): Geologiya i Geofizika, no. 7, p. 81-87 (in Russian). Author at Inst. Geochem., Irkutsk, USSR.

The Mo deposit Khorzhertuy (Dzhida ore region) formed due to late Paleozoic-early Mesozoic tectonic-magmatic activization, in connection with intrusion of porphyry-like, fine grained leucocratic granites. Two stages of deposit formation are distinguished: greisen and hydrothermal. Greisen minerals bear inclusions homogenizing in G phase at 480-365°C and in L phase at 350-310°C; quartz of the hydrothermal stage yielded Th 510-280°C. Quartz veinlets with coarse-flaky molybdenite are characterized by inclusions with Th 510-460°C in G and 370-300°C in L, the inclusions commonly bear LCO_2, KCl, NaCl and MoO_2(sic, a misprint for MoS_2?-A.K.), indicating heterogeneous fluid during mineral growth. (Abstract by A.K.)

PHILPOTTS, A.R., 1982a Compositions of immiscible liquids in volcanic rocks: Contrib. Mineral. Petrol., v. 80, p. 201-218. Author at Dept. Geol. & Geoph., and Inst. Materials Sci., Univ. Connecticut, Storrs, CT 06268, USA.

Immiscible liquids, preserved as chemically distinct, glassy globules (Si-rich and Fe-rich) occur in many tholeiitic basalts and some alkaline and calcalkaline lavas. The glasses typically form part of a dark mesostasis containing skeletal magnetite crystals. In thick flows, the Si-rich liquid may crystallize to granophyric patches, and the Fe-rich one to aggregates of hedenbergite, magnetite, and accessory phases. The mesostases containing these immiscible phases constitute from 20% of a primitive olivine tholeiite (MgO = 7.5%) to 50% of a highly fractionated quartz tholeiite (MgO = 2.8%), but may be less if the rock is oxidized. Abundant ferric iron promotes early crystallization of magnetite and prevents the iron enrichment necessary to reach the immiscibility field; thus, aa flows rarely exhibit immiscibility, whereas the more reduced pahoehoe ones do.

Alumina and alkalis are concentrated in the Si-rich liquid, whereas the remainder of the major elements are concentrated in the Fe-rich melt; but the partitioning of Fe, Mg, Ca, and P is less pronounced in alkaline rocks than in tholeiites. Conjugate liquids have compositions of granite and Fe-rich pyroxenite, though the Si-rich melt in alkaline rocks is more syenitic and the Fe-rich one contains considerable normative alkali feldspar. The liquids coexist with plagioclase and augite of, respectively, An_{50} and $Ca_{34}Mg_{19}Fe_{47}$ compositions in tholeiites, and An_{40} and $Ca_{42}Mg_{29}Fe_{29}$ in alkaline rocks. Immiscibility is not restricted to K-rich residual liquids, but the miscibility gap is narrower for Na-rich compositions. In tholeiitic basalts with 52% SiO_2, the Na_2O/K_2O ratios in conjugate liquids are equal, but at lower silica contents the Si-rich liquid is relatively more sodic, whereas at higher silica contents it is relatively more potassic. This may explain the association of sodic granites with mid ocean ridge basalts.

Immiscible liquids are present in sufficient amounts in so many volcanic rocks that magma unmixing should be considered a viable means of differentiation during the late stages of fractionation of common magmas, at least at low pressures. (Author's abstract)

PHILPOTTS, A.R., 1982b Silicate liquid immiscibility in alkaline lavas (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 587.

PICHAVANT, M., 1982, Potash metasomatism induced by circulation of boron-bearing fluids: experimental evidence (abst.): J. Geol. Soc. London, v. 138, part 1, p. 97-98.

PICHAVANT, M. and MANNING, D.A.C., 1982, The role of volatile elements, particularly boron and fluorine, on the petrology of granites: Coll. Intern. CNRS "Géochimie et Pétrologie des Granitoides", Clermont-Ferrand, p. (in French).

Boron and fluorine are generally found concentrated in different ways in certain particular granites, tourmaline leucogranites (enriched in B) and albitic granites with topaz and Li-mica (enriched in F). These granites are a characteristic sign of magmatic activity in the lithosphere. They share common characteristics: level of emplacement in the crust; petrographic and textural characteristics indicate that the majority of these granites have crystallized under fluid-saturated conditions (this is not the case for the majority of granites). These are peraluminous granites, composed of white micas, alumino-silicates, minerals rich in aluminum such as garnet, cordierite, oxides and characteristic accessory minerals. B and F are found in tourmaline, topaz, fluorite and micas, respectively. Geochemical data for major elements show low values of Ca, Mg and Fe, which makes these granites particularly suited to apply available experimental data in the reference system Qz-Or-Ab. Available data for REE, $^{16}O/^{18}O$, Rb/Sr are limited. Sn-W mineralizations are frequently spatially associated with these granites.

Recent experimental results provide new insights on their petrology. A fractional crystallization mechanism for fluorine-bearing granitic magmas can produce melts enriched in albite as well as define the position of the limit of the quartz-feldspar phase and the liquidus surface temperature in the system Qz-Ab-Or-H_2O with addition of F at P = 1 kbar. This possibly applies directly to certain granitic massifs with compositions abnormally rich in albite (Cornwall, England; Central Massif, France). Solidus temperatures for boron- or fluorine-bearing systems can be lowered to under 600°C at P = 1 kbar. Under these conditions, muscovite can crystallize directly and separate from the magma at lower pressures (more compatible with the geologic setting) than in systems with only H_2O. The presence of andalusite at magmatic temperatures as well as the crystallization of two alkali feldspars at relatively low pressures are also possibilities. In consideration of the presence of a fluid phase during crystallization, data for the partitioning between fluid and magma are used to discuss the behavior of REE and elements such as Sn and W. Starting with values of K_D (fluid/magma) for B and F and models of fractional crystallization, one can place restrictions on the origin of the volatiles. Natural abundances of B and F indicate that the experimental concentrations used are geologically reasonable. In conclusion, we discuss the mechanism of generation of these evolved granites starting with the following models: 1) differentiation by fractional crystallization, and 2) metasomatic melting. (Abstract translated courtesy R. Bodnar)

PICHAVANT, Michel, RAMBOZ, Claire and WEISBROD, Alain, 1982, Fluid immiscibility in natural processes: use and misuse of fluid inclusion data - I. Phase equilibria analysis - a theoretical and geometrical approach, in R. Kreulen and J. Touret (guest eds.), Current Research on Fluid Inclusions: Chem. Geol., v. 37, p. 1 - 27. First author at Centre de Rech. Pétrograph. et Géochim., 54501 Vandoeuvre-les-Nancy Cedex, France.

Many occurrences of fluid immiscibility in natural geologic systems have been reported recently, most often from fluid inclusion studies. However, the interpretation of fluid inclusion data in terms of immiscibility sometimes suffers from ambiguity of the vocabulary, insufficient knowledge of the immiscibility constraints and insufficient knowledge of the topology (in the TPX space) of natural fluid systems. For such reasons some authors have been misled to erroneous interpretations.

The term "chemical immiscibility" is unambiguously redefined as a multiphase multicomponent equilibrium. The consequences of this definition are directly derived from the phase rule and concern the possible equations that relate the various parameters (temperature, pressure, volumes, compositions) to each other. These equations already put constraints on the topology of the phase equilibria in fluid systems.

A particular expression of the phase rule is proposed, which takes into account the multiphase-constant bulk volume-constant bulk composition constraints in fluid inclusions. The consequences of such an expression are of major importance in fluid inclusion studies.

The phase relations of some simple systems that approximate quite efficiently the natural complex fluids are then detailed: H_2O-NaCl, CO_2-CH_4, H_2O-CO_2, H_2O-CO_2-NaCl. The effects of these topologies and of the supplementary constraints (constant bulk composition and constant bulk volume) assumed for fluid inclusions (isopleth-isochoric systems) are discussed. (Authors' abstract)

PICKTHORN, W.J., 1982, Stable isotope and fluid inclusion study of the Port Valdez gold district, southern Alaska: MS thesis, Univ. California, Los Angeles, California, 66 pp.

Indexed under Fluid Inclusions. (E.R.)

PIGAGE, L.C., 1982, Linear regression analysis of sillimanite-forming reactions at Azure Lake, British Columbia: Can. Mineral., v. 20, p. 349-378. Author at Cyprus Anvil Mining Corp., 300-355 Burrard St., Vancouver, British Columbia V6C 2G8.

Late replacement of fibrolite by muscovite is proposed as the K^+/H^+ ratio keeps changing in the fluid phase. (E.R.)

PIGFORD, T.H., 1982, Migration of brine inclusions in salt: Nucl. Technology, v. 56, p. 93.

A theoretical discussion indicating that there is a threshold thermal gradient below which no movement can occur, so the problem of migration of fluid inclusions in the thermal gradients around nuclear waste packages is not as severe as originally thought by some. (E.R.)

PIPEROV, N.B. and PENCHEV, N.P., 1982, Deuterium content of the inclusion water from hydrothermal galenas, Madan, Bulgaria: preliminary investigation: Econ. Geol., v. 77, p. 195-197. Authors at Inst. General & Inorganic Chem., Bulgarian Acad. Sci., 1040 Sofia, Bulgaria.

Water was extracted from large fluid inclusions in galena (Bonev, 1977, Fluid Inclusion Research--Proc. of COFFI, v. 10, 1977, p. 30), converted to hydrogen by hot zinc in a novel procedure, and analyzed for δD. A meteoric source seems likely, but deep-seated waters may also be involved. (E.R.)

PIPEROV, N.B., PENCHEV, N.P. and ZIDAROVA, B.P., 1982, Evidence for the chemical nature of fluorite-depositing solutions based on the fluid inclusion studies (Palat, Bulgaria) (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 230. First author at Inst. General & Inorganic Chem., Sofia, Bulgaria.

The fluorite mineralization in Palat deposit (Bulgaria) is probably related to a postvolcanic (pleistocene) hydrothermal activity. The mineral paragenesis, except fluorite, includes also quartz, calcite and some clay minerals. The fluorite crystals contain gas-liquid inclusions with Th in the 150-180°C range.

The decrepitation was studied by decreptobarometry. A Penning-gauge and a fast recorder were used to record the decrepitation of the single inclusions. The volatiles were also released on progressive heating in vacuum (EGA) and they were determined using a Pirani-gauge as a detector of the total pressure (H_2O) and a mass spectrometer for CO_2. Microcryometry was used to evaluate the salt concentration.

The mineral-forming solutions were found to be of low salinity (<1%), probably of the hydrogencarbonate type, and CO_2-saturated. (Authors' abstract)

PISUTHA-ARNOND, V., 1982, Thermal history, chemical and isotopic compositions of the ore-forming fluids responsible for the Kuroko massive sulfide deposits in the Hokuroku district of Japan: PhD dissertation, Pennsylvania State Univ., University Park, Pennsylvania, 168 pp.

Indexed under Fluid Inclusions. (E.R.)

PITZER, K.S. and MURDZEK, J.S., 1982, Thermodynamics of aqueous sodium sulfate: J. Solution Chem., v. 11, no. 6, p. 409-413. Authors at Dept. Chem. & Lawrence Berkeley Lab., Univ. California, Berkeley, CA 94720.

The activity coefficient of saturated aqueous Na_2SO_4 is calculated from the properties of the solid and the infinitely dilute solution as well as the solubility. These values are compared with those given by the equation of Rogers and Pitzer which is based on the measured dependence of heat capacity upon molality together with other solution properties at low temperature. Excellent agreement is found from 30 to 280°C. Consequently the equation of Rogers and Pitzer is given an extended range of validity to saturated molality and to 280°C. The trend of solubility with temperature is discussed in relation to the ΔC_p of solution. (Authors' abstract)

PLANETARY SCIENCES UNIT, UNIVERSITY OF CAMBRIDGE, 1982, Mantle methane - fool's gold?: Nature, v. 300, p. 312-313.

A review, the title to which is a play on words, referring to T. Gold's controversial hypothesis that methane is outgassing from the mantle in large amounts. The review cites much evidence against the hypothesis. (E.R.)

PLUMMER, L.N. and BUSENBERG, Eurybiades, 1982, The solubilities of calcite, aragonite and vaterite in CO_2-H_2O solutions between 0 and 90°C, and an evaluation of the aqueous model for the system $CaCO_3$-CO_2-H_2O: Geochimica Cosmo. Acta, v. 46, p. 1011-1040.

POKROVSKAYA, I.V., 1982, Mineralogy and formation conditions of polymetal deposits - Rudnyi Altay; Kazakh Branch of "Nauka" Publ. House, Alma-Ata, 128 pp. plus 23 photo plates, 1000 copies printed, price 2 rbls. 40 kopecks (in Russian).

The book contains reference Th and Td for the deposits: Strezhan, Tishin and Ridder-Sokol'noe, on p. 94-97. (A.K.)

POKROVSKII, V.A., 1982, Experimental investigation of the equilibrium of 1.5 albite - 0.5 KCl - HCl - 0.5 muscovite - 3 quartz - 1.5 NaCl at 300-500°C and under pressure of 1 kbar: Dokl. Akad. Nauk SSSR, v. 262, no. 2, p. 438-441 (in Russian).

POLAND, E.L., 1982, Stretching of fluid inclusions in fluorite at confining pressures up to 1 kilobar: Master's thesis, Univ. of California, Berkeley, 76 pp.

Stretching of inclusions in fluorite was investigated experimentally, and yielded an equation for Ps, the threshold internal pressure (in bars) above which stretching will take place in inclusions larger than a given volume: $Ps = -178.0 \text{ Log } V + 0.7 \text{ Pex} + 1018.9$, where V = volume in cubic micrometers and Pex = external pressure. Two apparently distinct types of inclusion wall failure have been observed, first stretching, believed to be a plastic failure, in a few cases followed by "superstretching," which is almost certainly a brittle failure. Finally, the fluid inclusions represent a new approach to determination of the strength of fluorite. The results of this study may ultimately contribute to the understanding of the relationship between elastic parameters, mechanisms of failure, and internal stresses necessary to initiate various levels of deformation in fluorite and other crystals. (Modified from the author's conclusions)

POLIAK, B.G., PRASOLOV, E.M. and CERMAK, V., 1982, Mantle helium in "juvenile" fluid and the nature of the geothermal anomaly of Krasne Hory (Czechoslovakia): Dokl. Akad. Nauk SSSR, v. 263, no. 3, p. 701-705 (in Russian).

(See also Polak, B.G., Kononov, V.I., Tolstikhin, I.M. and Khabarin, L.V., 1975, The helium isotopes in thermal fluids, <u>in</u> Proc. Int. Assoc. Hydrol. Sci., Symp., 1975, Grenoble.) (E.R.)

POLYKOVSKY, V.S., 1982, Thermobarogeochemical properties of fluorite deposit formation in the Tien Shan (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 230-231. Author at "Tashkentgeologia," Tashkent, USSR.

Fluorite mineralization was classified into pegmatite, skarn, pneumatolite-hydrothermal and hydrothermal genetic types. That in pegmatites occurred at the highest temperatures, with a wide Th range from 380 to 120°C, and at pressures 350-150 atm. A Th range of 330-90°C and pressure 500-400 atm. are typical of the fluorite-bearing rare-metallic greisens. Fluorite manifestations in contact-metasomatic and skarn deposits are characterized by Th 300-130°C and pressures 350-200 atm. Hydrothermal fluorite deposits were formed at temperatures ranging from 300 to 85°C and pressures from 500 to 90 atm. Temperatures from 280 to 150°C and pressures from 300 to 120 atm. are the most favorable for fluorite deposit formation. Low-temperature hydrothermal fluorite deposits of Middle Asia with Th from 220 to 80° and pressures from 250 to 60 atm. are of particular interest as sources of fluorspar ores relatively free of trace elements.

Salt concentration is 3.00 mg/100 g of sample; Na and Cl are the most abundant.

Investigations of gas composition of the solutions from fluorite deposits showed, for early quartz (Th 280-200°C) $H_2>N_2>CO_2$; fluorite and barite (Th 230-100°C) $N_2>>H_2$ and CO_2; late fluorite (Th 110-90°C) $H_2>CO_2>N_2$. (From the author's abstract)

POMÂRLEANU, Vasile and POMÂRLEANU, E.-A., 1982, Fluid inclusions in calcite of some ore deposits in Roumania, in R. Kreulen and J. Touret (guest eds.), Current Research on Fluid Inclusions: Chem. Geol., v. 37, p. 165-172. Authors at Inst. Geol. & Geoph., Lab. Geochem., Iassy and Res. Inst. of Anorganic Industry & Nefarious Metals, Bucharest, Roumania.

Calcites from hydrothermal, porphyry copper and skarn ore deposits from Roumania contain two-phase fluid inclusions (liquid + vapor) with a vapor phase of 2-90% of the inclusion volume. Calcite from pyroxene hornfels, associated with phlogopite, pyrrhotite, diopside and other minerals, contains inclusions with aqueous solution + vapor + halite.

Th of fluid inclusions in calcites from the first three groups of ore deposits lie in the range from 60° to 480°C and the salinities vary from 5 to 23 wt.% NaCl. In calcite from pyroxene hornfels , Th vary from 290° to 340°C and salinities range from 30 to 33 wt.% NaCl.

The relationship between the crystal habit of calcite and Th shows the possibility of using fluid inclusions in the study of crystallogenesis. (Authors' abstract)

PONOMAREVA, N.I., 1980, Comparison of the composition of gas-liquid inclusions in quartz of pegmatites of northern Karelia: Geol. Rudnykh Mestor., v. 22, no. 2, p. 18-26 (in Russian; translated in Int'l. Geol. Review, v. 24, no. 1, p. 135-142, 1982).

Abstract in Fluid Inclusion Research--Proceedings of COFFI, v. 13, p. 194, 1980. (E.R.)

POPIELAK, R.S., BLACK, S.R., OLSEN, R.L. and ELLINGSON, C.T., 1982, Investigation of pressurized brine pockets, WIPP site, Carlsbad, New Mexico (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 591.

POPIVNYAK, I.V., MYAZ, N.I., SIMKIV, Zh.A., KONDRAKHIN, S.I., DEMIN, B.G., LEVITSKY, V.V. and KLUFAS, M.O., 1982, Some uses of thermobarogeochemistry in the evaluation and exploration of kimberlite bodies (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 212-213. First author at L'vov State Univ., L'vov, USSR.

There are two trends in the study of kimberlites using the methods of thermobarochemistry: (1) investigation of the mantle mineralizing media in the inclusions and (2) detection of the heating aureoles in the host rocks of the kimberlite bodies.

A great variety of melt inclusions have been found in the colored garnets and olivines of deep-seated xenoliths and xenocrysts from Yakutian kimberlite pipes. They contain sparingly soluble (glass, silicates), and readily soluble components (various salts) and volatiles. The investigation data on the inclusions, their phase composition, aggregate state and filling temperature evidence a complex polygenic nature of the kimberlite bodies. Repeatedly alternating phenomena which induced creation of microfissures in early minerals and melting in intergranular spaces occurred during a single stage in the kimberlite magma moving from the lower to the upper levels of the Earth.

The method of multiple water extraction has been used to find the chemical composition of readily soluble components of the melt inclusions in the red garnet. The following ionic composition was observed (in %-equiv.): Li^+ -0.2; Na^+ 16.8; K^+ 5.3; Ca^{2+} 3.3; Mg^{2+} 72.5; Sr^{2+} 0.2; Ba^{2+} 0.9; Fe(tot.) 0.8; HCO_2^- 87.8; Cl^- 4.0; SO_4^{2-} 1.0; $HSiO_3^-$ 7.2.

Chromatography was used to estimate the chemical composition of the volatiles from the orange and red garnets and the olive-green olivine. The obtained compositions agree with the earlier published results of gas extractions from the violet pyrope, and with the mass-spectrometrically established composition of gaseous traces in diamonds. The close relations of C:N:O:H speak for a similarity of the fluid regime of crystallization of some pyropes, olivine and diamond. A whole gamut of hydrocarbons (HC) has been observed in the studied minerals in addition to N_2, H_2, O_2, CO_2, CH_4, N_2, which is highly prevalent among the volatiles, is supposed to be a catalyst, while HC the carbon source. The relations of C:N:O:H, the most important volatile elements, are proposed as a criterion to be used in exploration and evaluation of kimberlite bodies. The method of sectional decrepitation across contact strike used in the study of the host rocks of kimberlite bodies has revealed the "heating" zone. The decrepitation activity of the host rocks first increases away from the kimberlite pipes, then decreases varying from 200 to 4000 impulses. It drops noticeably and varies close around the background value (200 imp.) beyond a distance equal to the pipe diameter. Owing to the observed regularity, the proposed method can be applied in the exploration of kimberlite bodies. (From the authors' abstract)

POPIVNYAK, I.V. and SIMKIV, Zh.A., 1981, Soluble components of mantle-derived mineral-forming media: Dokl. Akad. Nauk SSSR, v. 256, no. 4, p. 966-969 (in Russian; translated in Dokl. Acad. Sci. USSR, v. 256, p. 181-184, 1982).

Abstract in Fluid Inclusion Research--Proceedings of COFFI, v. 14, p. 163-164. (E.R.)

POPOV, V.S., 1982, Liquation in magmas - illusion and reality (review of the foreign literature): Zapiski Vses. Min. Obshch., v. 111, no. 5, p. 614-621 (in Russian). Author at Inst. Min., Geochem. and Crystallochem. of Rare Elements (IMGRE), Moscow, USSR.

Analysis of the present foreign literature shows that extensive occurrence of textures of emulsion habit stimulates the enthusiasm of scientists intending the foundation of ideas about immiscibility in silicate magmas as important petrogenetic process. However, data of experimental and theoretical petrology make the limits for undoubted phenomena of immiscibility in iron-rich melts, and even in such melts immiscibility develops only in microscale. Macrotextures "liquid in liquid" and coeval formation of large volumes of magmas of various composition may be explained by a more probable mechanism proposed by the alternative hypothesis, which suggests the contemporaneous intrusion of magmas connected with different magmatic chambers, and the coexistence of two liquid phases during some time is explained by the slow mixing and dissolving. (Author's conclusions translated by A.K.)

POPOV, V.V., 1982, Geological conditions of formation of stratiform zinc-lead and pyrite deposits: Sovetskaya Geologiya, no. 8, p. 21-36 (in Russian).

The reported T of formation of metasomatic ore parageneses are in ranges 100-140°C, sometimes more. (A.K.)

PORTER, E.W. and RIPLEY, E.M., 1982, Golden Sunlight Au-Ag deposit, Montana: origin of mineralizing fluids (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 591.

PORTNOV, A.M., 1982, Self-oxidation of mantle fluid and the genesis of diamond of kimberlites: Dokl. Akad. Nauk SSSR, v. 267, no. 2, p. 942-945 (in Russian).

POWELL, R., 1982, Fluids and melting under upper amphibolite facies conditions (abst.): Geol. Soc. Newsletter (London), v. 11, no. 4, p. 17. Author at Univ. Leeds.

The formation of migmatites by partial melting is discussed in terms of internal buffering paths on temperature - $\underline{a}(H_2O)$ diagrams. Internal buffering along melting reactions causes lowering of $\underline{a}(H_2O)$ because of the considerable solubility of H_2O in silicate melts. There is a temperature interval between the temperature at which the time path of a rock intersects the solidus and the temperature at which substantial melting first occurs (where a dehydration reaction runs into the solidus). Over this temperature interval, $\underline{a}H_2O$ can be lowered substantially with little melt produced prior to more substantial melting and the production of obvious migmatites. Neosome/melanosome-palaeosome relations in migmatites are accounted for by melt segregation combined with H_2O-diffusion (driven by $\underline{a}(H_2O)$ gradients set up by localized partial melting). These ideas are illustrated using a model pelitic system and literature studies of upper amphibolite facies pelitic rocks. (Author's abstract)

PRASOLOV, E.M., VERKHOVSKIY, A.B. and POLYAK, B.G., 1982, Atmospheric noble gases of the present-day active hydrotherms (theoretical calculations and experimental data): Geokhimiya, no. 12, p. 1691-1704 (in Russian; English abstract). First author at All-Union Petro. Sci.-Res. Geol.-Prosp. Inst., Leningrad, USSR.

Pertinent to studies of G in fluid inclusions. (A.K.)

PREECE, R.K., III and BEANE, R.E., 1982, Contrasting evolutions of hydrothermal alteration in quartz monzonite and quartz diorite wall rocks at the Sierrita porphyry copper deposit, Arizona: Econ. Geol., v. 77, p. 1621-1641. First author at Geol. Dept., Phelps Dodge Corp., Morenci, AZ 85540.

Two wall-rock types of contrasting chemical composition host the causative Ruby Star quartz monzonite porphyry intrusion and hypogene mineralization at the Sierrita porphyry copper deposit. Vein-related hydrothermal alteration in the Harris Ranch quartz monzonite and biotite quartz diorite wall rocks consists of several mineralogically discrete assemblages. Temporal evolution of different alteration assemblages was established, in part, using petrographic relations within, and crosscutting relations among, individual veins. Temperature and salinity characteristics of hydrothermal fluids responsible for filling of individual veins were determined using primary fluid inclusions in vein-filling quartz. Each generation of primary vein filling introduced characteristic secondary fluid inclusions into earlier developed veins as well. Histograms of homogenization temperatures of primary and secondary fluid inclusions from different veins, and accompanying salinity data, permitted temporal correlations to be drawn between veins which either did not exhibit crosscutting relations in individual samples or which formed in different wall rocks and thus exhibited different alteration mineralogies.

Evolution of hydrothermal activity in the area sampled commenced with potassic alteration in both quartz monzonite and quartz diorite wall rocks from 10 to 12 molal (37-41 wt %) NaCl equivalent fluids, inclusions of which homogenize by halite dissolution in the approximate temperature range 300° to 370°C. Salinities of later fluids were in the range 2 to 3 molal (10-15 wt %) NaCl equivalent with only minor salinity variations for the remaining time span monitored by this study. Homogenization temperatures of primary fluid inclusions in veins formed from these lower salinity fluids began near 400°C and increased initially to approximately 430°C where boiling occurred. The pressure defined by boiling of these fluids is about 330 bars. A continuous decrease in fluid inclusion homogenization temperatures followed down to about 300°C, during which time deposition of quartz and K-feldspar with accessory biotite and/or hematite occurred in new and reopened veins in the quartz monzonite wall rock. Simultaneously in the quartz diorite, a sequence of veins and adjacent alteration halos formed, each consisting of an early assemblage of potassic affinity (quartz + biotite + K-feldspar + albite) which evolved to a propylitic assemblage (quartz + epidote + chlorite) as vein filling proceeded. With continued cooling of the solution below about 300°C, muscovite took the place of K-feldspar as the stable potassium-bearing mineral in the quartz monzonite. An analogue to this late-stage quartz + muscovite veining in the quartz monzonite could not be established in the quartz diorite but may consist of zeolite (stilbite) + anhydrite.

The bulk of hypogene copper mineralization in both wall-rock types was associated with approximately 2 molal (10 wt %) NaCl equivalent solutions. In the quartz diorite, significant chalcopyrite deposition is associated with fluid inclusions homogenizing from 370° down to about 320°C and always occurs with the later stage propylitic minerals in each vein. In the quartz monzonite wall rock, chalcopyrite was deposited during the transition from potassic and into phyllic alteration. Fluid inclusion homogenization temperatures for this mineralization range from about 330° down to 200°C. No primary chalcopyrite was seen to occur with earlier potassic veining formed from either high- or low-salinity fluids in the quartz monzonite. A very late stage of deposition of chalcopyrite, pyrite, and minor bornite filled the center of late phyllic veins in the quartz monzonite; correlated fluid inclusions have salinities from 1 to 5 molal (5-23 wt %) NaCl equivalent and homogenization temperatures in the range of 140° to 160°C. The different alteration and sulfide mineral assemblages interpreted to have formed simultaneously in the two wall rocks of contrasting chemical character can be reasonably assigned to different chemical interactions of each rock type with similar, or equivalent, hydrothermal fluids. (Authors' abstract)

PRICE, L.C., 1982a Organic geochemistry of core samples from an ultra-deep hot well (300°C, 7 km): Chem. Geol., v. 37, p. 215-228.

PRICE, L.C., 1982b, [Importance of high-temperature solubility of crude oil in methane to petroleum generation and maturation] (abst.): Geol. Survey Research 1981, U.S. Geol. Sur. Prof. Paper 1275, p. 40.
See 1982a and b items above. (E.R.)

PRICE, R.C., SNEERINGER, M.R. and FREY, F.A., 1982, Geochemistry of basalts from the West Indian triple junction (25°S, 70°E) (abst.): EOS, Trans. Am. Geophys. Union, v. 63, p. 473. First author at La Trobe Univ., Bundoora, Victoria 3083, Australia.

The boundaries of three major plates (Africa, India and Antarctica) meet in a triple junction near 25°S, 70°E in the Indian Ocean. Fresh basalts from the vicinity of this triple junction have major and trace element abundances of "normal" MORBs; e.g., K (762-925 ppm), Rb (1.07-1.30 ppm), Cs (0.015-0.22 ppm), Ba (13-15 ppm) and LREE/HREE abundance ratios less than chondritic ratios. Plume-type basalts which are common in the vicinity of the South Atlantic triple junction (near Bouvet Island) have not been dredged from the West Indian Ocean triple junction which lacks a bathymetric high. However, basalts from the West Indian Ocean triple junction have $^{87}Sr/^{86}Sr$ ratios (0.70317-0.70329) higher than "normal" MORBs and this feature is also characteristic of basalts from the Central Indian Ridge (Hedge et al., 1979).

The principal phenocryst phases in these glassy basalts are plagioclase and olivine and many of the plagioclase phenocrysts show resorption and reverse zoning. Glass inclusions within reverse-zoned plagioclase phenocrysts vary systematically in composition from core to rim of the host and glass inclusion compositions correlate with host plagioclase compositions. Glass inclusions in the rims of reverse zoned plagioclase phenocrysts have higher Mg numbers (0.66) than inclusions in the cores (Mg number = 0.55) and this suggests that disequilibrium features such as reverse zoning are a consequence of mixing between a relatively fractionated magma (Mg number $\leq$0.55) and a less evolved magma (Mg number $\geq$0.66). (Authors abstract)

PUGIN, V.A. and KHITAROV, N.I., 1982, Geochemistry of several elements during liquation in basaltic magmas: Geokhimiya, no. 1, p. 35-46 (in Russian). Authors at Inst. Geochem. and Anal. Chem., Moscow, USSR.

The paper describes partitioning of Co, Ni, V, Cr, Cu, Sr and Ba between varioles and matrix in variolites; pertinent to melt immiscibility in inclusions. (A.K.)

PURTOV, V.K. and YATLUK, G.M., 1982a Behavior of silica during action of HCl and NaCl solutions with rocks and rock-forming minerals at temperature 600-800°C and pressure 1000 kg/cm^3 (101.9 MPa): Akad. Nauk SSSR Doklady, v. 263, no. 2, p. 448-450 (in Russian). Authors at Inst. Geol. Geochem. of Ural Sci. Center of Acad. Sci. USSR, Sverdlovsk.

The investigations were made with HCl solutions of pH 1 to 6 and NaCl solutions of concentration 0.01-5 n and substances: liparite, basalt, hornblende, biotite, gabbro-norite and dunite. SiO_2 concentration in solutions after runs was in ranges 0.3-3 g/l. (A.K.)

PURTOV, V.K. and YATLUK, G.M., 1982b Mobilization of iron and magnesium from rocks and rock-forming minerals by solutions HCl and NaCl at temperature 600°C and pressure 1000 kg/cm^2 (101.9 MPa): Akad. Nauk SSSR Doklady, v. 262, no. 5, p. 1242-1245 (in Russian). Authors at Inst. Geol. Geochem. of the Ural Sci. Center of Acad. Sci. USSR, Sverdlovsk.

The experiments were made with gabbro-norite, dunite, basalt, liparite, hornblende and biotite. (A.K.)

PUZANOV, L.S., 1982a, Origin of magnetite ores of the Korshunovskoe deposit (data of studies of inclusions of mineral-forming media): Akad. Nauk SSSR Doklady, v. 266, no. 1, p. 209-211 (in Russian). Author at All-Union Sci.-Res. Inst. of Mineral Raw Materials, Moscow, USSR.

The deposit Korshunovskoe belongs to the Angara-Ilim region. Pyroxene-magnetite and carbonate-magnetite ores were studied. Diopside bears four types of inclusions: I. P melt-pneumatolytic (G 50-70 vol.%); II. P inclusions of melt-intrusive stage (glass, xls+G, polyphase); III. S pneumatolytic (G, G>>L); IV. S hydrothermal (L>G, L). Th were obtained for polyphase type II inclusions containing solids (65-80 vol.%), L (5-20 vol.%)

and G (10-20 vol.%). Five measurements gave 900°C. Td measurements were as follows: 800°C (six), 850°C (seven) and 880°C (nine). Also Th in ranges 760-840°C (twenty-six) were obtained. For inclusions with solids occupying 30-55 vol.%, Th 600-630°C. Pneumatolytic and hydrothermal inclusions yield Th 480-100°C. For the other Siberian deposits Th of inclusions in fassaite, diopside and spinel are 500-900°C, and in garnet, amphibole and scapolite 550-740°C. (Abstract by A.K.)

PUZANOV, L.S., 1982b, On the polygenic nature of the fluorspar mineralization (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 231-233. Author at All-Union Research Inst. of Min. Resources, Moscow, USSR.

In central Aldan and Buryatia, P inclusions in fluorite and quartz have Th 650-870°C; later crystallization at 450-520°C from brines. [The compositions appear to be various ratios of salts, silicates, and volatiles - E.R.] Hydrothermal [later?] mineralization occurred at 350-100°C. (From the author's abstract)

PUZANOV, L.S., 1982c, Origin of the apatite deposit Seligdar (Central Aldan), in N.P. Ermakov, ed., Thermobarogeochemistry in Geology - Materials of the Sixth All-Union Symposium on Thermobarogeochemistry: Vladivostok, Far East Sci. Center, Acad. Sci. USSR Pub. House, p. 108-111 (in Russian).

For abstract, see entry Puzanov and Partsevskiy in Fluid Inclusion Research--Proceedings of COFFI, vol. 11, 1978, p. 173; abstract of this paper was not published in the Abstract Volumes of the Vladivostok Symposium. (A.K.)

RAFALSKY, R.P., 1982, Solubility of sulfides of zinc, lead, and silver in hydrothermal solutions: Geokhimiya, no. 12, p. 1780-1797.

RAFAL'SKIY, R.P. and MASALOVICH, A.P., 1981, Determination of the instability constants of lead chloride complexes at elevated temperatures: Geokhimiya, no. 12, p. 1868-1885 (in Russian; translated in Geochem. Int'l., v. 18, no. 6, p. 158-174, 1982).

RAKCHEEV, A.D., 1982, Thermoelectroosmotic filtration of ascending metamorphosing fluids and solutions in the Earth's crust: Akad. Nauk SSSR, Dokl., v. 265, no. 2, p. 450-453 (in Russian).

RAKHMANOV, A.M., 1982, Evolution of state and composition of mineralizing solutions in the course of skarn rare-metal deposit formation in central Tajikistan (abst): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 250-251. Author at Tajik State Univ., Dushanbe, USSR.

Skarn-rare-metal deposits are widespread over the territory of Central Tajikistan. The great majority of the deposits occur at contact of the Upper Paleozoic moderately acidic granites with the Silurian, Devonian and Carboniferous carbonate complexes. According to the nature of ore mineralization the deposits can be classified into skarn-scheelite-cassiteritic (Maikhura), skarn-scheelitic (Kanjaz, Sarymat) and skarn-cassiterite-stannitic (Mushiston), etc. The ore-forming stages are realized here as a successive development of skarn, quartz-rare-metal, quartz-sulphide and quartz-carbonatic mineralization stages.

Homogenization and additional decrepitation of fluid inclusions on the deposits under study have provided estimation of the mineralization temperature ranges. They are: 660-150°C for Maikhura; 620-160°C for

Kanjaz; 660-160°C for Sarymat; 640-160°C for Mushistan; 620-170°C for Takfon; 660-180°C for Jilau. The most typical ranges of 660-390°C were found for the skarn stages; 480-220°C for the quartz-rare-metallic; 420-160°C for the quartz-sulphide; and 200-160°C for the quartz-carbonatic ones.

Pressures in the mineral-forming medium were calculated (using inclusions with carbon dioxide) to be 750-650 atm. in most cases.

Water leachates showed Na, K, Ca, HCO_3, F and Cl, plus minor Mg and Al. Later fluids were higher in F. Gas chromatography showed CO_2, CH_4, N_2, H_2 and O_2. (From the author's abstract)

RAMASAMY, R., 1982, Fluid inclusion geochemistry for rapid methods of mineral prospecting (abst.): [Proceedings & Abstracts], National Workshop on Fluid Inclusion Studies, 22-23 March, 1982, Indian Inst. Tech., Bombay, p. 40-41 (unpaginated). Author at Tamilnadu State Geol. Br., Madras-32.

The major Karur (N 10°57' - E 78°05') Gem tract of Tamilnadu is spread over 50 km to the north and south of Cauvery river and extending about 100 km length along the river. Ruby (pigeon blood), sapphire, magnesian spinel, cordierite, bronzite and garnet occur in anorthosites and ultrabasics while emerald, aquamarine, beryl, topaz, moonstone and piezoelectric quartz occur in granites and pegmatites. Sporadic occurrences of gem pockets are seen in many places and abandoned old workings are numerous. Fluid inclusion studies can be applied in order to develop mines in the most promising areas and to trace out migration of gem-forming fluids towards nests of mineralization. For prospecting of gem minerals the following procedure is outlined: (i) detailed geological mapping of the area, (ii) collection of pegmatite samples, (iii) crushing of pegmatites and hand sorting of quartz minerals, (iv) examination of quartz grains for fluid inclusions, (v) selection of pegmatites having fluid inclusions in quartz and regular sampling along their trends, (vi) petrographic observations under heating and freezing stages by using doubly polished thin sections, (vii) determination of loss on ignition of 2 gms of finely ground quartz, (viii) 2 gms of 60-80 mesh quartz may be subjected to decrepitation, (ix) 1 gm of 60-80 mesh quartz may be analyzed by gas chromatography, (x) 100 gms of 60-80 mesh quartz may be subjected to water and then weak acid leaching processes. Extracts may be made up to 100 ml and the soluble contents may be estimated by using the methods of routine water analysis, (xi) analytical data may be interpreted by using thermodynamic constants, geothermobarometers, chemical variation and model diagrams. The same procedure may be followed for the exploration of blind ore bodies of gold, polymetallic sulphides, micas and barites in Tamilnadu and elsewhere. Specific decrease in the ratios of H_2O/CO_2, SiO_2/CO_2, SiO_2/total volatiles in quartz serve as good indicators for the location of gem pockets, gold, piezoelectric quartz and contact metasomatic deposits. Increasing ratios of Cl/OH, K_2O/Na_2O and HF/HCl in quartz are indicative of apatite, fluorite, muscovite, beryl, topaz, Mo-W mineral deposits. Increasing tendencies of decrepitation activity, temperature of maximum decrepitation, Th, abundance of dms, increasing of salinity of fluid phases and pressure of fluids are marked features of the fluid inclusions found in quartz towards the approach of ore deposits. Geochemistry of ore-forming fluids is described in detail. (Author's abstract)

RAMBALDI, E.R. and WASSON, J.T., 1982, Fine, nickel-poor Fe-Ni grains in the olivine of unequilibrated ordinary chondrites: Geochimica Cosmo. Acta, v. 46, p. 929-939. Authors at Inst. Geoph. & Planetary Physics, Univ. California, Los Angeles, CA 90024, USA.

Fine (≤2 μm), Ni-poor (≤10 mg/g) Fe-Ni grains are common inclusions in the olivine in porphyritic chondrules in unequilibrated ordinary chondrites. The olivine grains appear to be relicts that survived chondrule formation without melting. The most common occurrence of this "dusty" metal is in the core of olivine grains having clear Fe-poor rims and surrounded either by small euhedral clear olivine grains zoned with FeO increasing toward the border of the grains or by large elongated Fe-poor orthopyroxenes oriented parallel to the chondrule surface and enclosing small round olivine grains. Various amounts of Ca, Al-rich glass are always present. The dusty metal is occasionally found in the rims of olivine grains either isolated in the matrix or included in chondrules. A rare occurrence is as bands in highly deformed olivines.

This dusty metal appears to be the product of in situ reduction of FeO from the host olivine. Among the possible reductants H_2 or carbonaceous matter $(CH_2)_n$ seem the most likely. Hydrogen may have been implanted by solar-wind or solar-flare irradiation, but this requires that dissipation of nebular gas occurred before the end of the chondrule formation process. Carbonaceous matter may have been implanted by shock. Less likely reductants are nebular CO or C dissolved in the olivine lattice. The large relict olivine grains may be nebular condensates or, more likely, fragments broken off earlier generations of chondrules. (Authors' abstract)

RAMBOZ, Claire, PICHAVANT, Michel and WEISBROD, Alain, 1982, Fluid immiscibility in natural processes: use and misuse of fluid inclusion data - II. Interpretation of fluid inclusion data in terms of immiscibility, in R. Kreulen and J. Touret (guest eds.), Current Research on Fluid Inclusions: Chem. Geol., v. 37, p. 29-48.

Phase equilibrium analysis of the relevant systems together with the application of the principles of chemical equilibrium put severe constraints on the interpretation of fluid inclusion data in terms of immiscibility. [See Pichavant et al., 1982, this volume.]

Following from that point, the major limits on the accuracy, and even the validity, of fluid inclusion quantitative data and their interpretation in terms of fluid composition and density are briefly discussed.

The practical implications of the general constraints (temperature, pressure, topology of the fluid systems) are envisaged. Emphasis is laid on some important consequences such as: the use of isochore intercepts (and the possible resulting interpretation of fluid mixing rather than unmixing), the case of highly saline inclusions, the identification and interpretation of heterogeneous trapping.

The composition and density constraints on coexisting fluids are presented, and illustrated by natural examples.

Taking into account all the measurable parameters in fluid inclusions (volume, temperature and nature of phase transitions, more or less complete individual spectroscopic analyses), all the availble experimental data, and all the theoretical constraints, may be long and difficult. However, it is most generally very informative and productive although part of these data is often sufficient to deny unmixing. Nevertheless, a final example on metamorphic fluids demonstrates how such an approach can "prove," and also characterize a fluid unmixing during a geologic process. (Authors' abstract)

RAMSAY, J.G., 1980, The crack-seal mechanism of rock deformation: Nature, v. 284, p. 135-139. Author at Geologisches Inst.,-ETH, Zentrum, CH 8092 Zurich, Switzerland.

Many naturally deformed crustal rocks contain mineral-filled extension veins. The crystals making up the vein filling often show a fibrous habit and seem to be built up by a succession of "crack-seal" increments: the elastically deforming rock fails by fracture, and the walls of the open micro-crack are sealed together by crystalline material derived by pressure solution in the rock matrix. (Author's abstract)

Bands of inclusions parallel with the crack mark previous openings. (E.R.)

RANAWAT, P.S., 1982, Environment of fluorspar mineralization in Rajasthan - as indicated by fluid inclusion studies (abst.): [Proceedings & Abstracts], National Workshop on Fluid Inclusion Studies, 22-23 March 1982, Indian Inst. Tech., Bombay, p. 33-34 (unpaginated). Author at Dept. Geol., Univ. Rajasthan, Udaipur, India.

Fluorspar mineralization in Rajasthan occurs at five localities, viz. Mando-ki-Pal (Dungarpur Distt., South Rajasthan), Jhalara (Udaipur Distt., South Rajasthan), Asind (Bhilwara Distt., Central Rajasthan), Chowkri-Chhapoli (Sikar-Jhunjhunu Distts., North Rajasthan), and Karara (Jhalore Distt., South West Rajasthan). Of these, the first four are located along a nearly NNE-SSW axis running across the state. Based on fluid inclusion studies, it is concluded that these deposits formed independently under varied physico-chemical environment of mineralization, and that they are not located along a major lineament having common source, as one would be inclined to believe because of their single linear trend (cf. Van Alstine, 1976).

At Mando-ki-Pal two-phase fluid inclusions with high degree of fill are found in fluorites and associated minerals occurring in cataclastic and granitic gneiss host rocks. The stratabound fluorspar veins in quartzite (Nawagaon) have inclusions of liquid CO_2 occasionally with halite daughter mineral. Liquid CO_2 has not been found in fluid inclusions in fluorite from Jhalara area. They are biphase inclusions with small vapor bubble. At Asind, the fluorite contains multiphase fluid inclusions with more than one daughter mineral. Dissolved CO_2 in the aqueous phase is suspected at Jhalara. At Chowkri-Chhapoli, the fluid inclusions are of lower degree of fill and have a halite daughter mineral. The associated first generation quartz has inclusions with halite daughter mineral while the inclusions in younger quartz contain a fibrous anisotropic daughter mineral.

Thus, a varied chemistry of mineralizing solutions depositing fluorspar in these areas is indicative of different sources and or different phases of fluorite mineralization. (Author's abstract)

RANAWAT, P.S. and DASHORA, R.S., 1982, Fluid inclusion study of the Karara fluorspar deposit, Rajasthan (abst.): [Proceedings & Abstracts], National Workshop on Fluid Inclusion Studies 22-23 March 1982, Indian Inst Tech., Bombay, p. 35 (unpaginated). First author at Dept. Geol., Univ. Rajasthan, Udaipur, India.

The paper deals with petrography and temperature of homogenization of fluid inclusions in fluorite, barite and quartz from Karara area. The fluorspar mineralization occurs in Malani Volcanic (flow and pyroclastic) rocks.

Fluid inclusions in fluorites from different veins and of different paragenesis show two-phase inclusions with a high degree of fill and low salt content. A wide range in temperature of formation of different generations of fluorite is recorded (60°-197.5°C). Quartz (I), which formed earlier than fluorite (I), gave the highest temperature (240°). Barite formed at 160°-210°C is columnar and acicular and low temperature barite, formed at 50°-90°C, is crystalline. Freezing data indicate that the mineralizing solutions were very low in dissolved salts. (From the authors' abstract)

RANKIN, A.H. and ALDERTON, D.H.M., 1982, Fluid inclusion evidence for the evolution of hydrothermal fluids in SW England (abst.): J. Geol. Soc. London, v. 139, part 1, p. 96.

Quartz from the granites of SW England contain a complex and varied assemblage of fluid inclusions. Several generations, each recording a particular hydrothermal event, are usually present, though it is difficult to establish an unequivocal paragenesis. Vapor-rich inclusions are common and homogenization temperatures range from less than 70°C up to about 600°C with salinities varying from 0 to greater than 50 equiv. wt% NaCl. Periodic boiling and influx of more dilute fluids of meteoric origin are invoked to explain these variations.

Marked differences in the distribution and abundance of different inclusion types occur on a regional scale. In particular, the Dartmoor granite contains a dominance of highly saline fluids characterized by high levels of Na, K, Ca and Fe chlorides (from SEM studies). Minor elements in these fluids (from ICP analysis of decrepitates) include B, S and traces of Sn, Cu, Pb, An and W. These inclusions are believed to represent the earliest fluids evolved from the cooling granite magma. The paucity of low salinity fluids indicate that later influx of meteoric fluids was restricted in this pluton. In other plutons, particularly in those parts where Sn-W-Cu mineralization is intense (e.g. N Carnmenellis), the inclusion population is often characterized by abundant low to moderate salinity fluids (Th ~150-450°C) believed to be dominantly meteoric in origin. The final phase of hydrothermal activity is represented in the granites of SW England by low temperature inclusions (less than about 150°C) which cross-cut all other generations. These fluids are particularly abundant in the kaolinized granites of St. Austell. (Authors' abstract)

RANKIN, A.H., ALDERTON, D.H.M., THOMPSON, M. and GOULTER, J.E., 1982, Determination of uranium: carbon ratios in fluid inclusion decrepitates by inductively coupled plasma emission spectroscopy: Min. Mag., v. 46, p. 179-186. First author at Dept. Geol., Imperial College, London SW7 2BP, England.

Uranium has been detected in fluid inclusion decrepitates from quartz of several granites of the British Isles and from vein quartz associated with the Hercynian granites of SW England using ICP. Material, ejected from the inclusions during decrepitation on heating the sample, is transferred into the plasma for qualitative analysis via a stream of argon. Several other elements have been detected in the decrepitate, of which carbon is of particular interest. It shows a strong positive correlation with U and indicates the importance of C (presumably as carbonate complexes) in the transport of U in hydrothermal systems. Approximate order of magnitude estimates of the average U contents of fluid inclusions from SW England samples, based on the assumption that U in the decrepitates is principally derived from the fluid inclusions, range from less than one to over a thousand ppm. Fluid inclusions may therefore be important in contributing to the levels of U reported in quartz (0.1 to 10 ppm). (Authors' abstract)

RASMUSSEN, D.H., 1982a Energetics of homogeneous nucleation - approach to a physical spinodal: J. Crys. Growth, v. 56, p. 45-55.

RASMUSSEN, D.H., 1982b Thermodynamics and nucleation phenomena - a set of experimental observations: J. Crys. Growth, v. 56, p. 56-66. Author at Dept. Chem. Engrg., Clarkson College of Tech., Potsdam, NY 13676, USA.

Classical nucleation theory assumes that the nucleus of a phase transformation is of the equilibrium composition and structure and that the undercooling to formation of this nucleus is a kinetically determined quantity. No relationship between the nucleation temperature and the corresponding equilibrium temperature is expected. Nonclassical theories of nucleation, notably the theory of a physical spinodal by the author, predict the nucleus is not necessarily of the equilibrium composition and structure and that there must be a relationship between maximum undercooling of a parent phase and the equilibrium temperature at the corresponding composition. These predictions are compared with experimental results on vapor to liquid condensation, liquid-liquid demixing, and nucleation of crystals from the melt and from solution. The experimental results support the view that a thermodynamic limit to undercooling exists and that nucleation at maximum undercooling in these three transitions corresponds to nucleation near this thermodynamic limit. (Author's abstract)

RASMUSSEN, R.A., KHALIL, M.A.K., DALLUGE, R.W., PENKETT, S.A. and JONES, B., 1982, Carbonyl sulfide and carbon disulfide from the eruptions of Mount St. Helens: Science, v. 215, p. 665-667.

Ash from the massive 18 May 1980 eruption of Mount St. Helens readily gave off large amounts of carbonyl sulfide and carbon disulfide gases at room temperature. These findings suggest that the sulfur that enhances the Junge sulfate layer in the stratosphere after volcanic eruptions could be carried directly to the upper atmosphere as carbonyl sulfide and carbon disulfide absorbed on ash particles from major volcanic eruptions. (Authors' abstract)

READ, A.J., 1982, Ionization constants of aqueous ammonia from 25 to 250°C and to 2000 bar: J. Solution Chem., v. 11, no. 9, p. 649-664.

REGISTER, J.K., 1981, Brine pocket occurrences in the Castile formation, southeastern New Mexico, March 1981: U.S. Dept. of Energy, Waste Isolation Pilot Plant Project Ofc., Report TME 3080, 27 pp.

The brine pockets (here renamed "brine reservoirs"), which are, in effect, huge intergranular fluid inclusions in halite beds, are described in detail. Flow rates from them have ranged up to 20,000 barrels/day. One analysis of gases with fluid shows 55 mole % CO_2, 32 H_2S, 5 N_2, 7 CH_4, and lesser amounts of 5 higher hydrocarbons. Four chemical analyses show very high NaCl, but low Ca, Mg and K. $SO_4 = \sim 0.1 \times Cl$, and represent redissolved evaporitic rocks, not Permian brines. (E.R.)

REICHMAN, F., 1982, Vertical zoning of fluorite deposits in Czechoslovakia (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 233. Author at Central Geol. Inst., Prague, Czechoslovakia.

Polyascendent lenticular fluorite veins in the Cesky Massif formed at 150-130°C; barite increases upward and quartz downward. (E.R.)

REKHARSKIY, V.I., PASHKOV, Yu.N., KAPSAMUN, V.P., KANTSEL', A.V., BOGUSHEVSKIY, E.M., DIKOV, Yu.P., KUDRIN, A.V., VAR'YASH, L.N., LANGE, Ye.K., DEDY, V.Yu. and GOLOVIN, A.F., 1982, Molybdenum and copper, p. 38-101, in Geochemistry of ore-formation processes: "Nauka," Moscow, 272 pp., 900 copies printed, price 3 rbls 50 kopecks (in Russian).

Quartz of the feldspar-quartz hydrothermal-metasomatic formation of the Cu-Mo deposit Kal'makyr bears inclusions of the following types: LH_2O + LCO_2 + G, LH_2O + G ± trapped feldspars + dm sylvite, Th 290-360°C and 250-280°C, respectively. By G chromatography also H_2 and N_2 were found in inclusions. Quartz of the quartz-sericite formation bears inclusions filled with LH_2O + G + dms (halite and sylvite), Th 220-280°C, total salt content 400-430 g/l, gases consist of CO_2 and N_2. (Abstract by A.K.)

REYF, F.G. and BAZHEEV, Ye.D., 1982, Magmatic process and tungsten ore mineralization: Siberian Branch of "Nauka" Publ. House, Novosibirsk, 160 pp., 1000 copies printed, price 1 rbl. 70 kopecks (in Russian). Authors at Geol. Inst. of Buryat Div. of Siberian Branch of Acad. Sci. USSR, Ulan-Ude, USSR.

The authors studied the most important W deposits of Transbaikalia and associated granitoid intrusions by thermobarogeochemical methods. Spokoynoe ore field granite quartz (Spokoynoe massif) yielded Th (°C) of melt inclusions 1020-985 (88, number of determinations), G + LH_2O + dms + LCO_2 >835 (55), melt inclusions (late) 1025-875 (21), G + LCO_2 + LH_2O ~300 (20); same (Khangilay massif), melt inclusions 950 (24), G + LH_2O + dms 480 (8), same location, greisen commercial ores LH_2O + LCO_2 + G 295-315, dissolution of salt dms +6.8 to 10.4°C, P 550-570 atm, quartz-vein commercial ores LH_2O + LCO_2 + G 300-290, dissolution of salt dms ~+10°C, P 550-570 atm., post-ore stage, S inclusions G/L 125-270, in all above cases Te -26.5 to -21.8°C. Dzhida ore field, quartz in granitoids of Gudzhir intrusion, melt inclusion in phenocrysts 730-1220, water content in inclusion melt, wt.% 3.6-5.0, melt inclusions in quartz of matrix 800-1000, water content in inclusion melt, wt.% 3.3-6.1, Dzhida Mo-W-rare metal deposit, inclusions in quartz, fluorite, huebnerite, beryl, types dms + L + G, G/L, G + LH_2O + LCO_2, Th 180-310 and more (decrepitation before homogenization), Te -31.6 to -27.1, Tm dms, -7.9 to +8.5, P 310 to 2200 atm. Mariktika ore mineralized point, quartz from granitoids bears melt inclusions that on heating (at ~980°C) separate silicate melt and H_2O-salt ± gas phase condensing on cooling to LH_2O salt melt and G bubble, Th 1050-1120 and in outer zones of quartz crystals from miaroles Th 915-930. Hydrothermal ore parageneses bear salt-dm-rich + LH_2O + G inclusions, Th 490-550, and if ore mineral is present in inclusion, it dissolves at 690-900°C. Soktuy ore junction granitoids also bear inclusions consisting of silicate melt + salt melt, Th 1090-1235, hydrothermal ore parageneses Th 142-683, Te -60.7 to -20.5, P 2200-2900 atm. The book presents discussion of the petrological aspects of the features described for magmatic rocks, including H_2O and salt solubility in silicate melts and inclusion features that may help in prospecting for various types of tungsten mineralization. (Abstract by A.K.)

REYF, F.G. and ISHKOV, Yu.M., 1982, Possibilities of use of the laser microanalyzer for studies of composition of liquid phase of individual inclusions, in Use of methods of thermobarogeochemistry during prospecting and studies of ore deposits, N.P. Laverov, ed.: Moscow, "Nedra" Publ. House, p. 14-31 (in Russian).

The Nd-glass laser was used for inclusion opening, working in the regime of free generation; spectra were recorded photographically in the spectrograph PGS-2. Standard solutions were prepared from chemical reagents (3 to 220 g of element per liter), drop of solution was put on the fresh epoxy, mixed with it and this way artifical inclusions were formed and used as standards after epoxy polymerization. Five compounds were tested and accepted for standards: Na_2WO_4, Na_2MoO_4, $MnSO_4$, $K_3Fe(CN)_6$ and H_3BO_3.

Hence, in L phase in inclusions W, Mo, Fe, Mn and B were determined quantitatively (6 to 185 g/l) and Mg, Ca, Al, Sn, Be, Cu, Ti, Zn qualitatively. (Abstract by A.K.)

RICE, C.M., HARMON, R.S. and SHEPHERD, T.J., 1982, Porphyry molybdenum-style mineralization near Central City, Colorado (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 598. First author at Univ. Aberdeen, Aberdeen AB9 1AS, Scotland.

A Laramide alkaline intrusive complex (c.63Ma) lies within concentric zones of molybdenite and fluorite mineralization. The intrusive sequence is: small plugs of quartz monzonite and syenite porphyry, early breccia pipe (explosion breccia followed by high Si ash flow tuff), monzodiorite dikes, trachyte dikes, late breccia pipe. The mineralization sequence is: early quartz-pyrite-MoS_2 veins, classic Au-Ag veins (c.59Ma), late fluorite and MoS_2 as veins and as matrix in the late breccia pipe. A Mo-W sediment anomaly extends for 8 km downstream.

Inclusion homogenization temperatures are: early Mo veins, CO_2-rich and rare halite-bearing giving 340-420°C and 240-340°C respectively; Au-Ag veins, aqueous 2-phase giving 220-380°C; late F veins, aqueous 2-phase giving 200-280°C. Salinities (as ≡ wt.% NaCl) are 34-42 for halite-bearing and 2-12 for other types. Trapping pressures of CO_2-rich are 1.3-1.8 kb.

Quartz $\delta^{18}O$ values for early Mo and Au-Ag veins are 10.2-13.1‰ and 8.1-15.9‰ respectively. Quartz fluid inclusion δD values for early Mo and Au-Ag veins are -98 to -51‰ and -90 to -45‰ respectively, whereas δD values for fluorite and quartz fluid inclusions in late F veins are -79 to -57‰. Sericite associated with Au-Ag mineralization has respective ranges in $\delta^{18}O$ and δD of 4.5 to 12.2‰ and -111 to -62‰. Country rock $\delta^{18}O$ values range from 6.0 to 16.0‰.

These data suggest that (1) early Mo mineralization was deposited from magmatic CO_2-rich fluids expelled from a differentiated quartz monzonite stock, (2) Au-Ag mineralization was deposited from mixed magmatic-meteoric fluids marking the collapse of the hydrothermal system as the pluton cooled, (3) F mineralization was deposited from late magmatic fluids and (4) Au-Ag mineralization represents a high structural level in a porphyry Mo-style system that existed for ~4 Ma. (Authors' abstract)

RICH, R.A. and BARABAS, A.H., 1982, Genetic implications of preliminary mineralogical, paragenetic and fluid inclusion data for the Schwartzwalder uranium mine, Colorado, in Vein-Type and Similar Uranium Deposits in Rocks Younger than Proterozoic, Panel Proc. Series: Vienna, Int'l. Atomic Energy Agency, IAEA-TC-295/19, p. 181-193. First author at Yankee Atomic Electric Co., Westborough, MA.

Epigenetic uranium mineralization at the Schwartzwalder mine occurs in veins and breccia zones associated with Laramide faulting and fracturing in Precambrian metasedimentary rocks. Vein paragenesis consists of three major stages separated by fracturing events: (1) adularia-pitchblende-jordisite-carbonaceous matter; (2) ankerite-marcasite/pyrite-base metal sulphides; and (3) calcite-pyrite. Adularia and possibly jordisite were in part co-deposited with pitchblende. The precise paragenetic position of the epigenetic carbonaceous matter is unclear, but the occurrence of this material is restricted to stage 1 structures. Haematitic alteration haloes are spatially and probably genetically related to stage 1 structures. Fluid inclusions in stage 2 sphalerite and stage 3 calcite are characterized by low filling temperatures (75-165°C) and low to intermediate salinity (19 to less than 3 equivalent wt.% NaCl) aqueous solutions. Fluid inclusions in stage 1 adularia and stage 2 ankerite, however, exhibit microthermometry characteristics atypical of aqueous inclusions; crushing-stage work indicates the absence of CO_2 or other gases under pressure in these inclusions. The above observations suggest the following genetic implications: (1) The presence of haematitic alteration haloes about stage 1 structures and the sequence of deposition of vein minerals indicate a trend with time from a relatively oxidizing to a relatively reducing mineralizing fluid and suggest a possible redox mechanism for uranium precipitation; (2) the presence of epigenetic carbonaceous matter in stage 1 structures and fluid inclusion data for minerals deposited before, during and after pitchblende suggest that uranium may have been transported to the site of deposition in a condensed organic or organo-aqueous fluid; (3) the mineralogy, paragenesis and uranium/carbonaceous matter association suggests a striking geochemical similarity between the Schwartzwalder deposit and certain sandstone-type uranium deposits. (Authors' abstract)

ROBINSON, Andrew and SPOONER, E.T.C., 1982, Source of the detrital components of uraniferous conglomerates, Quirke ore zone, Elliot Lake, Ontario, Canada: Nature, v. 299, p. 622-624. First author at Billiton Int'l. Metals, BV, 19 Louis Couperusplein, Box 190, The Hague, The Netherlands.

Large volumes of pyritic quartz-pebble conglomerate in the Elliot Lake district of Ontario contain at least 300,000 tonnes U_3O_8 recoverable at a grade of 0.1% (ref. 1), with much greater tonnages available at lower recovery grades. The Quirke zone alone contains in excess of 224,000 tonnes U_3O_8 at ~0.1% (refs 2-4) and is, accordingly, one of the world's largest known uranium deposits. Situated 40 km north of the North Channel of Lake Huron, 400 km north-west of Toronto, ore conglomerates occur in the Matinenda Formation, locally the basal unit of the Huronian Supergroup, and, although their age is not well constrained, they are probably close to 2,350 Myr old. Uraninite, the most important primary ore mineral, occurs as poorly rounded to euhedral grains 0.05-0.2 mm across within the matrix between quartz pebbles. While its chemical and morphological characteristics have led most workers to consider that the uraninite is detrital, there has hitherto been no attempt to characterize its source lithology, a matter of considerable significance as regards mineral exploration. This was the aim of the present study. We have examined the mineral and fluid inclusions observed in the quartz pebbles in the conglomerate and conclude that they are derived from a pegmatitic, potassic (alaskitic) granite. We have also demonstrated that in this source lithology, pebble-sized quartz was spatially associated with radioactive minerals, by inference, uraninite. The postulated characteristics of such a source are remarkably similar in several respects to the uraniferous alaskites of the Rössing deposit in Namibia. (Authors' abstract)

The inclusions are small and generally consist of L+V, ± a prismatic dm. Others contain many solid minerals, and some contain liquid CO_2.(E.R.)

ROBINSON, A.G. and SPOONER, E.T.C., 1982, Petrological evidence for the detrital uraninite in the uraniferous conglomerate ore horizons of the Quirke zone, Elliot Lake, Ontario (abst.): Geol. Assoc. Canada/Min. Assoc. Canada Program with Abstracts, v. 7, p. 76. Authors at Dept. Geol., Univ. Toronto, Toronto, Ontario, M5S 1A1, Canada.

The uraninite grains in the Quirke ore zone, Elliot Lake, are thought to be detrital because of shape (sub-angular with crystal faces), a restricted size range (~0.1 mm), chemistry (~6.5% ThO_2, ~2.5% Y_2O_3 and $\leq$~0.9% Ce_2O_3) and clear relationships to sedimentary features (e.g. 0.5-1 cm "uraninite sandstone" layers). Detrital minerals which may have been associated with uraninite in the primary source include coarse, smoky quartz (~0.5-6 cm), microcline/orthoclase, magnetite with ilmenite exsolution lamellae on $\{111\}$, monazite and zircon. Plagioclase feldspar is rare. Smoky quartz occurs in minor amounts with milky quartz in barren quartzite between reefs, and vice versa. Hence, the smokiness of the quartz, which is a product of irradiation, is a pre-depositional feature and is consistent with a uraninite/smoky quartz association in the source. Observed mineral inclusions in ore horizon quartz include K-feldspar, zircon, biotite and rutile needles. This suite is similar to the detrital suite, and suggests that the ore horizon quartz is not "vein quartz," but "granitic;" a deduction which is consistent with the occurrence of (?) primary fluid inclusions in ore horizon quartz which are (i) CO_2-rich and (ii) H_2O rich with high salinities (daughter crystals present including halite). Hence, the source is inferred to have been a variably pegmatitic, potassic alkali feldspar granite, or alaskite, containing a significant uraninite concentation. The Rössing U deposit in Namibia/S.W. Africa is a striking analogue in petrology (smoky quartz, microcline, biotite, minor plagioclase and muscovite, zircon, monazite and uraninite), grain size (~0.5-5 cm), uraninite characteristics (e.g. g.s. = ~0.05-0.1 mm; ThO_2 = ~7%), and fluid inclusions. It is also comparable in size and grade (~200 x 10^6 tons/0.05% U_3O_8) to the Quirke zone (~200 x 10^6 tons/0.1% U_3O_8, minimum). (Authors' abstract)

ROBINSON, B.W. and FARRAND, M.G., 1982, Sulfur isotopes and the origin of stibnite mineralization in New England, Australia: Mineral. Deposita, v. 17, p. 161-174. First author at Geol. Dept., Kuwait Univ., P.O. Box 5969, Kuwait.

Stibnite mineralization in the antimony province of New England can be divided into Central type ores (veins of stibnite + quartz ± berthierite) and Peripheral type ores of stibnite + quartz + native antimony ± berthierite. The 'Central' stibnites have $\delta^{34}S$(CDT) values of -5 ± 2‰ (1σ) which may represent equilibrium precipitation from mantle sulfur at about 200°C. 'Peripheral' stibnites have $\delta^{34}S$ values between 0 and -25‰, with a large group at 0 ± 2‰. They represent precipitation from a limited supply of mantle sulfur and the acquisition of sedimentary sulfur. We consider that the different ore types were produced from distinct ore solutions derived from two immiscible melts. These originated in the deep mantle, were mobilized by tectonic activity and supplied the antimony and most of the sulfur to the ores. (Authors' abstract)

ROBINSON, M.S., SMITH, T.E., BUNDTZEN, T.K. and METZ, P.A., 1982, Cleary sequence of the Fairbanks mining district; primary stratigraphic control of lode gold/antimony mineralization (abst.): Geol. Soc. Am. Program with Abstracts, v. 14, p. 228. First author at Alaska State Div. Geol. & Geophys. Surveys, P.O. Box 80007, College, AK 99708.

Bedrock exposed in the Fairbanks Mining District comprise three polymetamorphosed stratigraphic packages which appear to be in thrust contact. The lowest sequence, known as the Fairbanks schist, is mainly brown to gray quartzite and muscovite-quartz schist. Mineral assemblages in this 4,000-ft thick unit are indicative of greenschist-facies metamorphism. Above this is the Goldstream sequence, a unit dominated by garnet-muscovite schist, amphibolite, micaceous quartzite and impure marble, mineral assemblages indicate lower amphibolite-facies metamorphism. The Chatanika terrane, in the northern part of the district, is also in thrust contact with the Fairbanks schist. This unit is composed of garnet-clinopyroxene rocks, garnet amphibolite black quartzite and impure marble; mineral assemblages indicate upper amphibolite and possibly eclogite-facies metamorphism. Interstratified near the center of the Fairbanks schist is a 400-ft thick sequence of interlensing felsic schist, laminated white micaceous quartzite, actinolitic greenschist, graphitic schist, metabasite, metarhyolite, and calcsilicate beds and quartzite and muscovite-quartz schist indistinguishable from the Fairbanks-schist host rocks. This group of rocks, the Cleary sequence, appears to be largely of distal volcanogenic origin and hosts many of the gold and antimony occurrences in the district. The Fairbanks District has produced 7,500,000 oz gold and 4,200,000 lb antimony. Lead isotopes, fluid inclusion data and field evidence suggest that most of the gold and antimony mineralization is the result of remobilization of metals in the Cleary sequence and redeposition of the metals in dilatant zones and fractures associated with structural arching and the emplacement of Mesozoic synkinematic plutons. (Authors' abstract)

ROBINSON, R.W., 1981a, Ore mineralogy and fluid inclusion study of the southern Amethyst vein system, Creede Mining District, Colorado: M.S. thesis, New Mexico Inst. Mining & Technol., Socorro, NM, 85 pp.

See Robinson and Norman, 1981, in Fluid Inclusion Research--Proceedings of COFFI, v. 14, p. 172-173. (E.R.)

ROBINSON, R., 1981b, Mineralization along the southern Amethyst vein, Creede district, Colorado, in Field Trip Notes; Creede Mining District, San Juan Volcanic Province, Colorado, J.W. Lindemann, J.W. Babcock and J.R. King, eds.: Pub., Denver Reg. Explor. Geol. Soc., p. 43-50. Author at Rocky Mountain Energy, USA.

See Robinson and Norman, 1981, in Fluid Inclusion Research--Proceedings of COFFI, v. 14, p. 172-173. (E.R.)

ROBUL, V.M., L982, Typomorphic generations of accessory minerals: Mineralog. Sbornik, v. 36, no. 2, p. 44-48 (in Russian; English abstract). Author at Odessa Univ., Odesa, Ukrainian SSR.

In granitoid massifs of the Ukrainian shield, Kirovograd block, in pegmatites most of zircon, monazite, apatite, cyrtolite, garnet and xenotime has Th about 350°C; pneumatolytic-hydrothermal zircon, apatite, monazite, anatase, cyrtolite, fluorite, topaz, cassiterite, tourmaline and molybdenite(sic, A.K.) - 200-250°C. (Abstract by A.K.)

ROEDDER, E., 1982a, Igneous fluid inclusion geothermometry (abst.): EOS, Trans. Am. Geophys. Union, v. 63, p. 471. Author at 959 USGS, Reston, VA 22092.

Inclusions (I) of trapped fluids (gas, liquid, or melt) can provide temperature (T) data on the history of many igneous rocks. This paper reviews the types of data available and their major limitations.

T of trapping (Tt) can be obtained from the homogenization T (Th) of silicate melt I with shrinkage vapor bubbles. Melt compressibilities are so low that Tt-Th (i.e. the "pressure correction") is only ~20°C/kb. T of phase changes on cooling, such as precipitation of daughter crystals or saturation with sulfide melt can be obtained from I already having such phases. The phase assemblage can provide constraints on maximum and minimum cooling rates.

T of more compressible fluids (H_2O or CO_2), plus the limited physical strength of the host crystal provide constraints on the P-T history after trapping. If the P-T path for the rock is far below the isochore for the trapped fluid, recognizable natural decrepitation will occur. If an independent geothermometer is available, I of compressible fluids provide a reliable geobarometer (e.g., CO_2 in nodules).

The obvious major limitation on such thermometry needs reiteration: usable I must be present. Many deep-seated rocks have few or none. All phase equilibria are limited to those phases present, as metastability is common in these small systems. High viscosities and hence sluggish equilibria, plus possible leakage of H_2 during long runs and other experimental problems, make some determinations difficult or impossible. However, carefully selected I can provide excellent data. Comparison with other igneous geothermometers is seldom possible, as these several other methods generally measure different events in the history of the rock. (Author's abstract)

ROEDDER, E., 1982b, [Melt inclusions in Murchison chondrite meteorite not solar nebula condensates] (abst.): Geol. Survey Research 1981, U.S. Geol. Sur. Prof. Paper 1275, p. 164.

See Roedder, 1980b, Fluid Inclusion Research--Proceedings of COFFI, v. 13, p. 209-210. (E.R.)

ROEDDER, Edwin, 1982c, Fluid-inclusion evidence bearing on the environments of gold deposition (abst.): Abstracts and Information, Gold '82 Symp., 24-28 May, 1982, Zimbabwe: Harare, Zimbabwe, Geol. Soc. Zimbabwe, p. 23. Author at 959 U.S. Geol. Survey, Reston, VA 22092, USA.

The gold in most primary gold deposits in the world was dissolved, transported, and deposited in its present location by hot aqueous solutions under pressure. Any data on the temperature, pressure, density, and composition of these fluids can aid in understanding the processes of formation and hence may help in exploration.

With few possible exceptions, the only samples of these fluids are the fluid inclusions within minerals of the deposits. This paper 1) reviews briefly the general nature of inclusions and the data they can provide; 2) details some caveats particularly applicable to inclusion studies of gold deposits; 3) summarizes the extensive literature on fluid inclusions from gold deposits; and 4) considers briefly the uses of such inclusion data in exploration and mining. Many gold ores have not yet been examined for fluid inclusions, and some of the very fine grained materials may simply not have inclusions of suitable size (i.e. $>\sim 5\ \mu m$). A literature survey of 151 pre-1978 fluid-inclusion studies of the major gold stage in a wide variety of deposits other than porphyry coppers, mainly in the USSR, showed homogenization temperatures ranging generally from 100 to 400°C. In some of these deposits, major gold deposition took place over a wide temperature range, but the average range was only 100 degrees. Inclusions in earlier and later gangue and ore-metal stages typically cover much broader ranges. When given, the salinities were generally <10 wt% NaCl equivalent. The gold-depositing fluids were frequently rich in CO_2, particularly those from metamorphic and sediment-hosted (Carlin-type) deposits. A second, gas-rich fluid phase (i.e. "boiling") was common in many of the epithermal deposits. Precipitation of only a few parts per billion from the ore-forming fluid may be adequate to form major gold deposits; the specific cause of precipitation is obscure, however, and probably differs from one deposit type to another. (Author's abstract)

ROEDDER, Edwin, 1982d, Application of studies of fluid inclusions in salt samples to the problems of nuclear waste storage: Acta Geol. Polonica, v. 32, no. 1-2, p. 109-133.

The fluids present as fluid inclusions in salt samples from various bedded and domal salt deposits provide a surprising amount of information on the saline environment throughout the geological history of the deposit. Such information is valuable in considerations of the possible future history of these deposits, should they be used for long-term nuclear waste storage sites. In addition, however, the fluid inclusions (and other varieties of water) present in the salt are of considerable importance to the safe design and operation of such sites, and most analyses of salt for water are erroneously low. Fluid inclusions will generally migrate up the thermal gradients, toward the waste canisters, and contain highly corrosive fluids. (Author's abstract)

This review paper summarizes material from 6 earlier publications. (E.R.)

ROEDDER, Edwin, 1982e, Fluid inclusions in gemstones: valuable defects, in International Gemological Symp. Proc. 1982, D.M. Eash, ed.: Gemological Inst. of Am., p. 479-502. Author at U.S. Geol. Survey, Reston, VA.

Fluid inclusions are small volumes of ancient fluids found within many gems. They occupy various types of defects or imperfections that have formed in the crystal during the otherwise more perfect crystal growth that is the prime characteristic of gems. Inclusions may be trapped during the growth of the host crystal (primary inclusions) or during the healing of fractures in the crystals at some later time (secondary inclusions). Both types of inclusions provide data on the environment of formation and history of gemstones that can be useful to gemology.

This paper summarizes: 1) the formation of fluid inclusions, 2) changes that take place after trapping, 3) types of data that can be obtained from the inclusions, 4) available published data on fluid inclusions in peridot, quartz, topaz, emerald (including some unpublished data), and diamond, and 5) some of the possible uses of such data. (Author's abstract)

ROEDDER, Edwin, 1982f, Fluid inclusion studies, in U.S. Geological Survey Research in Radioactive Waste Dispoal--Fiscal Year 1979: U.S. Geol. Survey Circular 847, p. 16-17.

A review of past work on inclusions in salt, mostly referenced in previous COFFI volumes. (E.R.)

ROEDDER, E. and BASSETT, R.L., 1982, [Water content of rock salt] (abst.): Geol. Survey Research 1981, U.S. Geol. Sur. Prof. Paper 1275, p. 234.

See same authors, 1981, Fluid Inclusion Research--Proceedings of COFFI, v. 14, p. 175-176, 1981. (E.R.)

ROEDDER, E. and BELKIN, H.E., 1982, [Brine migration in salt in radioactive waste repositories] (abst.): Geol. Survey Research 1981, U.S. Geol. Sur. Prof. Paper 1275, p. 233.

See same authors, 1980a, Fluid Inclusion Research--Proceedings of COFFI, v. 13, p. 210 (1980). (E.R.)

ROEDDER, E. and BIGGAR, G.M., 1982, Experimental and analytical problems in the system K_2O-FeO-Al_2O_3-SiO_2 (abst.): Geol. Survey Research 1981, U.S. Geol. Surv. Prof. Paper 1275, p. 146.

A series of published and unpublished studies of phase equilibria in the low-temperature immiscible liquid field in the system leucite-fayalite-silica within the general system K_2O-FeO-Al_2O_3-SiO_2 has yielded in part discordant data on the composition of the two liquids and on the temperature and extent of the field of immiscibility. From a reexamination of the various studies and some interlaboratory comparisons, the authors concluded that there are four major causes of these discrepancies: (1) severe alkali loss in small-volume samples exposed to the furnace atmosphere, particularly in those starting as gels; (2) state of oxidation and local variations in the total iron content within the sample, due to several experimental problems; (3) limited ranges of compositions and temperatures of the quench runs used to delineate the field of immiscibility; and (4) difficulty in obtaining accurate, quantitative, electron microprobe analyses of the glasses, particularly for light and (or) volatile elements in the presence of large and grossly variable amounts of iron.

Almost all electron microprobe analyses of pairs of immiscible liquids made from starting compositions in the system leucite-fayalite-silica (that is, with a 1:1 K/Al molar ratio) have ratios less than 1.0 for both melts, and the ratio for the high-iron melt is much lower than that for the conjugate high-silica melt. It is concluded that these differences stem from a combination of three effects: (1) loss of potassium in the experimental work, (2) low-potassium values in the electron microprobe analysis, particularly on the high-iron melts, and (3) real differences in the partitioning of potassium and aluminum between the two liquids. In support of this last effect, analyses of several examples of natural immiscibility, including some made by classical wet chemistry rather than electron microproe, show considerably lower values for (K+Na)/(Al) in the high-iron parts of the pairs. (From the authors' abstract)

ROEDDER, E. and BODNAR, R.J., 1982, [Errors in geologic pressure determinations from fluid inclusion studies] (abst.): Geol. Survey Research 1981, U.S. Geol. Sur. Prof. Paper 1275, p. 148.

See Roedder and Bodnar, 1980a, Fluid Inclusion Reserach--Proceedings of COFFI, v. 13, p. 210-211 (1980). (E.R.)

ROEDDER, Edwin and CHOU, I-Ming, 1982, A critique of "Brine migration in salt and its implications in the geologic disposl of nuclear waste," Oak Ridge Nat'l. Lab. Rept. 5818, by G.H. Jenks and H.C. Claiborne: U.S. Geol. Survey Open File Rept. 82-1131, 31 pp. Authors at U.S. Geol. Survey, 959 Nat'l. Center, Reston, VA 22092.

Jenks and Claiborne in 1981 published a 164 page "...comprehensive review and analysis of available information relating to brine migration in salt surrounding radioactive waste in a salt repository." Calculations are presented in that publication, that are called "reasonably conservative," to show that the rates and total volumes of brine expected to migrate into a given emplacement hole in bedded salt over the first 100 years are sufficiently low (e.g., $\leq$250 ml/year) that they are of relatively minor concern in the engineering design of a nuclear waste repository. We believe that because the values used for the major input parameters are either nonconservative, selected numbers, or are based on inadequate data, the results of these calculations are invalid. Neither we nor others are able to make a truly valid calculation at this time as there are too many uncertainties, but we show that conservative estimates should be larger, and perhaps two orders of magnitude larger, than those made by Jenks and Claiborne. (Authors' abstract)

ROGERS, P.S.Z. and PITZER, K.S., 1982, Volumetric properties of aqueous sodium chloride solutions: J. Phys. Chem. Ref. Data, v. 11, no. 1, p. 15-80. Authors at Dept. Chem. and Lawrence Berkeley Lab., Univ. California, Berkeley, CA 94720.

Literature data for the volumetric properties of sodium chloride solutions to concentrations of 5.5 molal have been compiled and critically evaluated. A semi-empirical equation of the same type found to be effective in describing the thermal properties of NaCl solutions has been used to reproduce the volumetric data from 0°C to 300°C and 1 bar to 1000 bar. Tables of values are given for the specific volume, expansivity, and compressibility. Equations also are given for calculating the pressure dependence of the free energy, enthalpy, and heat capacity. These equations can be combined with a treatment of thermal properties to form a complete equation of state for sodium chloride solutions. (Authors' abstract)

ROMANCHEV, B.P. and KUZNETSOVA, S.Ya., 1982, Condition of crystallization of nosean in alkaline melts: Izvestiya Akad. Nauk SSSR - Ser. Geol., no. 1, p. 134-137 (in Russian). Authors at Inst. Geochem. and Anal. Chem., Moscow, USSR.

The studied sodalite trachytes were collected in the St. Helen Island, ordanshites - in the Gran Canaria Island. In the minerals of ordanshite Th of melt inclusions are 1030-1100°C (in pyroxene), 1030-1060°C (in apatite), 980-1000°C (in nosean), 1040-1080 (in plagioclase). Inclusions in plagioclase are large (up to 150 μm) and they bear glass and dms: glass melts at 840°C, dm nosean at ~1000°C with formation of two immiscible melts, at 1040°C apatite and magnetite melt; during dms melting process the amount of immiscible salt melt decreases and immiscibility gap was closed at 1060°C, further T increase caused melting of pyroxene dm and homogenization of G bubble. Dms were identified by optical properties. Melt immiscibility was found also in minerals from phonolites and trachytes from St. Helen Island, suggesting the liquation origin of the mineral group nosean-hauyne. Inclusions in these minerals bear dms: halite and nosean. The paper characterizes briefly the immiscibility in feldspathoid syenites in the Lovozero Massif (USSR) and role of the gases of the H_2O-CO_2-SO_2 system during formation of the nosean group minerals from magmatic melts. (Abstract by A.K.)

ROMBERGER, S.B., 1982, Transport and deposition of gold hydrothermal systems at temperatures up to 300°C (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 602.

RONA, P.A., BOSTROM, K., WIDENFALK, L., CRONAN, D.S., JENKINS, W.J. and MALLETTE, M., 1982, Hydrothermal mineralization of Mid-Atlantic Ridge 0-27°N (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 602.

ROSE, W.I., Jr., STOIBER, R.E. and MALINCONICO, L.L., 1982, Eruptive gas compositions and fluxes of explosive volcanoes: budget of S and Cl emitted from Fuego volcano, Guatemala, in R.S. Thorpe, ed., Andesites, John Wiley & Sons, New York, p. 669-676. First author at Dept. Geol. & Geological Engrg., Michigan Tech. Univ., Houghton, MI 49931, USA.

Because of the force of such eruptions, direct eruptive gas determinations in major explosive eruptions have not been obtained. Nevertheless, the S and Cl budget of explosive eruptions can be constrained by several measurements including: (1) microprobe analyses of glass inclusions in phenocrysts; (2) analyses of scavenged acids on fresh ash; (3) analyses of residual S and Cl trapped in tephra; (4) remote correlation spectrometry of gases emitted by volcanoes in quiet intervals between eruptions; (5) determination of gas/particle ratios of S and Cl by airborne sampling inside small eruption clouds; and (6) direct measurements of Cl/S in passive emissions from craters.

Data determined by all the above methods, some of which were obtained at a low level of activity, are available for the recent activity at Fuego volcano, Guatemala. The large eruption of October 1974 released 2.2 x 10^{14} g of ash. Constrained extrapolation allows us to estimate that it also released 1.6 x 10^{12} g of S and 6.2 x 10^{10} of Cl. The flux of S and

Cl for 3 years of passive emission following October 1974, when added to the eruptive gases, make the emission totals equal 2.0 x 10^{12} g S and 4.7 x 10^{11}-11 x 10^{11} g Cl. Based on the pre-eruption S and Cl content of Fuego magma, estimated from glass inclusions, the mass of magma required is 1 x 10^{15} g, about five times the amount erupted. Most of the S released and only a small fraction of the Cl was in the short-lived 1974 eruption. S is thus preferentially emitted during explosive eruptions and Cl during low level activity. The data suggest that rates of S emission during major eruptions are more than 100 times the largest measured rates during low level emissions. (Authors' abstract)

ROVETTA, M.R. and MATHEZ, E.A., 1982, Magnesite and other minerals in fluid inclusions in a lherzolite xenolith from an alkali basalt (abst.): Terra Cognita, v. 2, p. 229. First author at Los Alamos Nat'l. Lab., Los Alamos, NM 87545, USA.

Magnesite has been observed in CO_2-rich fluid inclusions in a typical Cr-diopside and spinel-bearing lherzolite recovered from the 1824 eruption of Lanzarote volcano, Canary Islands. The carbonate, which exists as 2-4 μm diameter crystals on inclusion walls, was identified by its rhombohedral form and electron beam-generated EDS and WDS characteristic x-ray spectra in which C and Mg are major elements. The carbonate occurs as the sole phase in individual inclusions and has only been found in those inclusions enclosed in olivine. Phases present in other inclusions in olivine include Fe-oxide (probably pure magnetite), Fe- and Cu-Fe-sulfides, and silica. Although sulfides and magnetite may exist together in the same inclusion, most magnetite-bearing inclusions contain no other phases.

Regardless of the phases in them, mineral-bearing inclusions tend to possess irregular shapes, are relatively large (10-30 μm) and exist together in arrays which define non-crystallographic surfaces. These features distinguish them as a group from all other inclusion populations in which daughter minerals are absent.

The production of carbonate by reaction of olivine and CO_2-rich fluid requires only that CO_2 fugacities be sufficiently high for any set of assumed conditions, i.e., the mere presence of magnesite yields no information on the T and P at which it formed. However, the apparent lack of phases more siliceous than olivine, e.g., enstatite or glass, in association with magnesite (or magnetite) means that either olivine in the immediate vicinity of the inclusion is non-stoichiometric, or the carbonate crystallized in a microfracture before annealing of olivine and formation of the inclusion, presumably at mantle P-T conditions. (Authors' abstract)

ROYZENMAN, F.M. and FORTUNATOV, S.P., 1982, Use of thermobarogeochemical methods in prospecting for phlogopite deposits in Aldan, in Use of methods of thermobarogeochemistry during prospecting and studies of ore deposits, N.P. Laverov, ed.: Moscow, "Nedra" Publ. House, p. 220-225 (in Russian).

Commercial phlogopite bodies are zones of Mg skarns formed by metasomatism of diopside schists. The phlogopite bodies bear minerals that yield a specific peak on decrepigrams at T ⩽320°C. For decrepitometric mapping the following index was used: D = No. of impulses up to 300°C/No. of impulses up to 800°C x 100. The decrepitometric map of the ore field was made on the basis of Td measurements of 2000 samples. The distinct anomalies agree well with contours of ore bodies in 63% of cases, and 37% were "false" anomalies (i.e. barren rocks of high decrepitation activity). (Abstract by A.K.)

RUI, Zongyao, LI, Yinqing and CHANG, Hongtao, 1982, Discrimination between ore-bearing porphyry and barren porphyry from fluid inclusions in the Yulong porphyry copper (molybdenum) deposit belt of the eastern Tibet Autonomous Region [China]: Zhongguo Dizhi Kexueyuan Kuangchan Dizhi Yanjiuso Sokan, no. 4, p. 65-78 (in Chinese). Authors at Inst. Miner. Deposits, Chin. Acad. Geol. Sci., Beijing, Peop. Rep. China.

Along the Yulong belt of porphyry Cu deposits, ore-bearing porphyries contain a diverse collection of gas, liq., and polyphase inclusions characterized by: (1) Th 180-600°, (2) Ph 240-1800 atm, (3) salinity $<(10-18)$ m NaCl + KCl, (4) gas/liq. ratios 5-95%, and (5) daughter minerals halite, sylvite, hematite, anhydrite, and (probably) pyrite. The fluids included in the ore-bearing porphyries appear to have undergone repeated revival boiling and represent the derivs. of both magmatic fluids and meteoric groundwaters. In contrast, the liq. (predominant) and polyphase (scarce) inclusions in ore-barren porphyries yield (1) Th 100-350°, (2) Ph 240-747 atm; (3) salinity <10 m NaCl, (4) gas/liq. ratios 5-35%, and (5) halite as the only daughter mineral. These fluids have not undergone revival boiling and are predominantly intermediate- to low-temp. derivs. of meteoric groundwaters. (CA 98: 146837y)

RUMBLE, Douglas, III, 1982a Polythermal, polybaric models of stable isotope fractionation during metamorphic devolatilization reactions: Carnegie Inst. Wash. Year Book 81, p. 377-380.

RUMBLE, D., III, 1982b-Oxygen isotope equilibration and permeability enhancement during metamorphism (abst.): Geol. Soc. Newsletter (London), v. 11, no. 4, p. 15. Author at Geophy. Lab., WA.

The degree to which oxygen isotope equilibrium has been achieved between the minerals of contiguous rock layers correlates with evidence of mechanisms of permeability enhancement in metamorphic rocks. Quartz separated from interbedded rocks such as calc-silicate, mica schist, amphibolite, quartzite, and metachert is homogeneous (±0.2%) where rocks either (1) have experienced devolatization reactions producing 10 wt.%, or more, of fluid, or (2) have been intensely fractured and veined. Quartz from interlayered rocks lacking evidence of permeability enhancement differs by 1-2% in samples separated by only 1 cm. These results suggest intergranular diffusion through static pore fluid is not an efficacious process for exchanging oxygen isotopes between different rock types. Infiltrating pore fluid, however, can serve a a medium of isotope exchange over distances of meters where rocks are sufficiently permeable for fluid flow to occur. (Author's abstract)

RUMBLE, Douglas, III, 1982c Stable isotope fractionation during metamorphic devolatization reactions (abst.): EOS, Trans. Am. Geophys. Union, v. 63, p. 448-449.

RUMBLE, D., III, FERRY, J.M., HOERING, T.C. and BOUCOT, A.J., 1982, Fluid flow during metamorphism at the Beaver Brook fossil locality, New Hampshire: Am. J. Sci., v. 282, p. 886-919. First author at Geoph. Lab., Carnegie Inst. of Washington, Washington, DC, 20008.

Rocks at the Beaver Brook fossil locality were regionally metamorphosed at 3.5 kb and 600°C. Metamorphic fluids were water-rich, $X_{H_2O}>0.80$ (mole fraction), and contained variable amounts of CO_2 and CH_4 as controlled by the buffer capacity of different mineral assemblages in individual sedimentary beds. The minimum amount of fluid that flowed through the beds during metamorphism has been estimated using mineralogic and oxygen isotopic evidence. The mineralogic evidence is the extent to which decarbonation reactions have gone to completion as measured by petrographic modal analysis. The isotopic evidence is the inferred metamorphic change in the oxygen isotopic composition of fossil brachiopods. Fluid-rock ratios of 1.5 to 4.0 (minimum estimate, by volume) are obtained from the mineralogic evidence, and ratios of 4.0 to 6.0 from the isotopic evidence. The large amounts of fluid flow observed at Beaver Brook are believed to be a consequence of metamorphic decarbonation reactions. These reactions, not in themselves capable of producing the computed amounts of fluid, nevertheless, are responsible for enhancing permeability sufficiently so that fluid flow could occur. (Authors' abstract)

RUMYANTSEV, V.N. and GANEEV, I.G., 1982, Spatial chemical differentiation as essential mechanism of evolution of acidity-alkalinity of hydrothermal solutions, p. 137-141 in Acid-basic properties of chemical elements, minerals, rocks and natural solutions: "Nauka," Moscow, 216 pp., 1100 copies printed, price 2 rbls 50 kopecks (in Russian).

KCl solution at T 150-350°C has acid reaction, but at 350°C it changes to alkaline. Spatial separation of hydrolysis products causes the acid-alkaline differentiation of the original electrolytes. The "wave" of acid solutions is caused by presence of high-volatile acid components (conclusions of isothermic-isobaric experiments). (A.K.)

RUSSELL, M.J. and SAMSON I.M., 1982, Solutions feeding Irish Zn+Pb (+Ba) and other "non-volcanogenic" exhalative deposits (abst.): J. geol. Soc. London, v. 139, p. 98

The properties of the hydrothermal solutions that fed the Irish exhalative Zn+Pb ore deposits have been estimated from fluid inclusion studies, geological and geochemical modelling [Russell et al., Mineral. Deposita (in press)] and experimental rock/water interactions at elevated temperatures and pressures [Bischoff et al., Econ. Geol. (in press)]. Salinities ranged from 10 to 25 equiv. NaCl wt.% and the solutions are considered to represent some ground water but the dominant fraction is probably modified highly saline early Carboniferous seawater. Metals mainly occurred in solution as chloride complexes. K/Na ratios were about 0.2. H_2S concentration was X0 ppm.

Saline seawater modification was by reaction with hot Lower Palaeozoic greywackes. The process was probably downward penetrating convection. Solutions were 1 pH unit on the acid side of neutral and were saturated with pyrite. Temperatures of the (boiling) solutions feeding Silvermines rose to at least 265°C and at Tynagh temperatures are assumed to have increased with time to perhaps >300°C to account for the later copper. Increase in temperature with time possibly reflects deepening of convection cells as the upper crust is cooled (Russell et al., op. cit.).

Non-volcanogenic exhalative deposits which formed in tensional environments elsewhere in the world (e.g. Mount Isa, Sullivan) probably had similar origins. Variations between deposits may be explained in terms of differences in fluid and source rock chemistry. Where source rock allows a modified seawater mineralizer of normal salinity (~3 wt.% NaCl), this may give rise to exhalative antimony deposits. Convection of solutions in a pile of mafic and felsic volcanics may result in some P_2O_3 (sic) and F accompanying Pb+Zn ore (e.g. Broken Hill, Australia). Where the upper crust contains anomalous B and Sn, exhalative tin deposits may occur.

The main causes of precipitation of sulphides in these deposits is boiling in the feeder zones (Finlow-Bates, T. & Large, D.E. 1978, Geol. Jb. D30, 27-39) and mixing with seawater just below and on exhalation onto the seafloor. Boiling in the feeder zones causes a rise in pH and a sudden drop in temperature which results in the precipitation of very fine-grained sulphide which may be carried in the rising solutions to be rained onto the seafloor from the bottom-hugging fraction of a double diffusive plume. (Authors' abstract)

RUSSELL, Norman, SEAWARD, Michael RIVERA, José McCURDY, Karr, KESLER, S.E., CUMMING, G.L. and SUTTER, J.F., 1980, Geology and geochemistry of the Pueblo Viejo gold-silver deposit and its host Los Ranchos Formation, Dominican Republic: Conferencia Geol. Del Caribe v. 1, no. 9, p 263-271. First author at Rosario Dominicana S.A., Apartado Postal 944, Santo Domingo, Dominican Republic.

See similar abstract in Fluid Inclusion Research--Proceedings of COFFI, v. 14, p. 178 (1981). (E.R.)

RYABCHIKOV, I.D., 1982a, Mantle sources of hydrothermal solutions (based on experimental data) (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 40-41.

RYABCHIKOV, I.D., 1982b, Solubility decrease of high-density crystalline phases in hydrothermal fluids during increase in pressure: Akad. Nauk SSSR Doklady, v. 262, no. 3, p. 698-700 (in Russian). Author at Oceanology Inst. of Acad. Sci. USSR, Moscow.

The problem is discussed with use of jadeite-diopside-water system at 900°C, 2-3x10^9 Pa and literature data on relations of albite, sanidine, phlogopite, forsterite, and clinopyroxene with water. Conclusions bear remark that mantle fractions producing Na- or K-rich magmas should be separate. (A.K.)

RYABCHIKOV, I.D., GREEN, D.H., WALL, W.J. and BREY, G.P., 1981, The oxidation state of carbon in the reduced-velocity zone: Geokhimiya, 1981, no. 2, p. 221-232 (in Russian; translated in Geochem. Int'l., v. 18, no. 1, p. 148-158, 1982).

RYABCHIKOV, I.D., REKHARSKIY, V.I. and KUDRIN, A.V., 1981, Mobilization of molybdenum by fluids during the crystallization of granite melts: Geokhimiya, no. 8, p. 1243-1246 (in Russian; translated in Geochem. Int'l., v. 18, no. 4, p. 183-186, 1982).

RYABCHIKOV, I.D., SCHREIER, W. and ABRAHAM, K., 1982a, Composition of fluids in the systems forsterite-silica-water and jadeite-diopside-water under conditions of the upper mantle: Izvestiya Akad. Nauk SSSR - Ser. Geol., no. 5, p. 13-21 (in Russian). First author at IGEM of Acad. Sci. USSR, Moscow.

The paper presents fluid composition in the above systems under P up to $3\cdot10^9$ Pa and T 990-1100°C. (A.K.)

RYABCHIKOV, I.D., SCHREYER, W. and ABRAHAM, K., 1982b, Compositions of aqueous fluids in equilibrium with pyroxenes and olivines at mantle pressures and temperatures: Contrib. Mineral. Petrol., v. 79, p. 80-84. First author at IGEM, 35 Staromonetny, Moscow 109017, USSR.

Solubility experiments were performed at 30 kbars in the system Mg_2SiO_4-SiO_2-H_2O, and at 20 and 30 kbars on omphacitic pyroxene-water mixtures. They confirm that the solubility of the forsterite component in aqueous fluids remains rather low (up to 5 wt.%), whereas the solubility of the SiO_2 component from solids of appropriate SiO_2-rich compositions in the system Mg_2SiO_4-SiO_2-H_2O increases with temperature up to some 75% at 1,100°C. At this temperature a simplified harzburgite consisting of forsterite and enstatite coexists with a fluid containing about 35% (MgO + SiO_2). Hydrous fluids coexisting with omphacitic clinopyroxenes leach sodium silicate component from the solid leaving less jadeitic pyroxenes behind. Most interestingly, the amount of sodium leached at constant temperature increased with decreasing pressure.

Comparison of the results with previous solubility studies in the system K_2O-MgO-Al_2O_3-SiO_2-H_2O indicates that hydrous fluids in the mantle must be alkaline rather than silica-normative. Alkali metasomatism caused by such fluids would lead to postassium enrichment in deeper portions of the upper mantle and to sodium enrichment at shallower levels, where amphiboles become stable. This K/Na fractionation in the upper mantle may explain the generation of K-rich or of Na-rich magmas through partial melting at different depths. (Authors' abstract)

RYE, D.M. and BRADBURY, H.J., 1982, Migration of fluids through Pyrenean thrust sheets (abst.): EOS, Trans. Am. Geophys. Union, v. 63, p. 428.

RYE, R.O., HALL, W.E., CUNNINGHAM, C.G., CZAMANSKE, G.K., AFIFI, A.M. and STACEY, J.S., 1982, Preliminary mineralogic, fluid inclusion, and stable isotope study of the Mahd adh Dhahab gold mine, Kingdom of Saudi Arabia: USGS Open-File Report OF-03-4 (also listed as U.S.G.S. Open-File Report 83-291), 26 pp. First author at U.S. Geol. Survey, Denver, CO.

The Mahd adh Dhahab mine, located about 280 km northeast of Jiddah, Kingdom of Saudi Arabia, has yielded more than 2 million ounces of gold from periodic production during the past 3,000 years. A new orebody on the southern side of the ancient workings, known as the South orebody, is being developed by Gold Fields-Mahd adh Dhahab Limited. A suite of samples was collected from the newly exposed orebody for preliminary mineralogic, stable isotope, fluid inclusion, and geochemical studies.

The Mahd adh Dhahab deposit is in the carapace of a Proterozoic epizonal rhyolite stock that domed pyroclastic and metasedimentary rocks of the Proterozoic Halaban group. Ore of gold, silver, copper, zinc, tellurium, and lead is associated with north-trending, steeply dipping quartz veins in a zone 1,000 m long and 400 m wide. The veins include an assemblage of quartz-chlorite-pyrite-hematite-chalcopyrite-sphalerite-precious metals, which is similar to the mineral assemblage at the epithermal deposit at Creede, Colorado.

The primary ore contains abundant chalcopyrite, sphalerite, and pyrite in addition to a complex precious metal assemblage. Gold and silver occur principally as minute grains of telluride minerals disseminated in quartz-chlorite-hematite and as inclusions in chalcopyrite and sphalerite. Telluride minerals include petzite, hessite, and sylvanite. Free gold is present but not abundant.

All of the vein-quartz sample contained abundant, minute inclusions of both low-density, vapor-rich fluids and liquid-rich fluids. Primary fluid inclusions yielded Th of from 110° to 238°C. Preliminary light-stable isotope studies of the sulfide minerals and quartz showed that all of the $\delta^{34}S$ values are between 1.2 and 6.3 per mil, which is a typical range for hydrothermal sulfide minerals that derive their sulfur from an igneous source. The data suggest that the sulfide sulfur isotope geochemistry was controlled by exchange with a large sulfur isotope reservoir at depth.

The $\delta^{18}O$ values of all stages of vein quartz in the South orebody range between 8.5 and 11.1 per mil. This range is similar to that for quartz from the North orebody and indicates that the hydrothermal system consisted of dominantly exchanged meteoric water, which was uniform in temperature and $\delta^{18}O$ content throughout the area during the entire period of mineralization.

Lead isotope analyses of two galena samples indicate that the lead in the South orebody is less radiogenic than that from the North orebody and confirm that the lead was derived from oceanic crust approximately 700 Ma ago. (Authors' abstract)

RYZHENKO, B.N., MEL'NIKOVA, G.L. and SHVAROV, Yu.V., 1981, Computer modeling of formation of the chemical composition of natural solutions during interaction in the water-rock system: Geokhimiya, no. 4, p. 481-495 (in Russian; translated in Geochem. Int'l., v. 18, no. 2, p. 94-108, 1982).

Abstract in Fluid Inclusion Research--Proceedings of COFFI, v. 14, p. 180. (E.R.)

SAFRONOV, A.F. and NIKISHOV, K.N., 1982, Fluid regime of upper mantle and mineral associations in diamonds: Akad. Nauk SSSR Doklady, v. 262, no. 4, p. 961-964 (in Russian). Authors at Inst. Geol. Yakutian Div. of Siberian Branch of Acad. Sci. USSR, Yakutsk.

The paper presents results of calculation of composition of G mixture in equilibrium with lherzolite from basalt (CO_2, CO, H_2, O, H_2) for T 900 and 1400°C, P up to 20 kbars. (A.K.)

SAHU, K.C., 1982, Fluid inclusions indicative of multiple evolution of hydrothermal solutions: [Proceedings & Abstracts], National Workshop on Fluid Inclusion Studies, 22-23 March, 1982, Indian Inst Tech., Bombay, p. 1-17 (unpaginated). Author at Indian Inst. Tech., Bombay-76, India.

A review which also presents data on Tm NaCl, Tm KCl, and Th L-V for inclusions in the Khetri Cu-Zn deposit from an unpublished Indian government report by K.C. Sahu and V. Panchapakesan (1981). The ranges are: Tm NaCl 175-365°C; Tm KCl 79-138°C; Th L-V 269-400°C. (E.R.)

SAKAI, Hitoshi, CASADEVALL T.J. and MOORE J.G, 1982, Chemistry and isotope ratios of sulfur in basalts and volcanic gases at Kilauea Volcano, Hawaii: Geochimica Cosmo. Acta, v. 46, p. 729-738 First author at Inst. for Therm. Spring Res., Okayama Univ., Misasa, Tottori-Ken, Japan 682-02.

Eighteen basalts and some volcanic gases from the submarine and subaerial parts of Kilauea volcano were analyzed for the concentration and isotope ratios of sulfur. By means of a newly developed technique, sulfide and sulfate sulfur in the basalts were separtely but simultaneously determined. The submarine basalt has 700 ± 100 ppm total sulfur with $\delta^{34}S_{\Sigma S}$ of 0.7 ± 0.1‰. The sulfate/sulfide molar ratio ranges from 0.15 to 0.56 and the fractionation factor between sulfate and sulfide is +7.5 ± 1.5‰. On the other hand, the concentration and $\delta^{34}S_{\Sigma S}$ values of the total sulfur in the subaerial basalt are reduced to 150 ± 50 ppm and -0.8 ± 0.2‰, respectively. The sulfate to sulfide ratio and the fractionation factor between them are also smaller, 0.01 to 0.25 and +3.0‰, respectively. Chemical and isotopic evidence strongly suggests that sulfate and sulfide in the submarine basalt are in chemical and isotopic equilibria with each other at magmatic conditions. Their relative abundance and the isotope fractionation factors may be used to estimate the f-O_2 and temperature of these basalts at the time of their extrusion onto the sea floor. The observed change in sulfur chemistry and isotopic ratios from the submarine to subaerial basalts can be interpreted as degassing of the SO_2 from basalt thereby depleting sulfate and ^{34}S in basalt.

The volcanic sulfur gases, predominantly SO_2, from the 1971 and 1974 fissures in Kilauea Crater have $\delta^{34}S$ values of 0.8 to 0.9‰, slightly heavier than the total sulfur in the submarine basalts and definitely heavier than the subaerial basalts in accord with the above model. However, the $\delta^{34}S$ value of sulfur gases (largely SO_2) from Sulfur Bank is 8.0‰, implying a secondary origin of the sulfur. The $\delta^{34}S$ values of native sulfur deposits at various sites of Kilauea and Mauna Loa volcanos, sulfate ions of four deep wells and hydrogen sulfide from a geothermal well along the east rift zone are also reported. The high $\delta^{34}S$ values (+5 to +6‰) found for the hydrogen sulfide might be an indication of hot basalt-seawater reaction beneath the east rift zone. (Authors' abstract)

SAKHAROVA, M.S., BATRAKOVA, Yu.A. and RYAKHOVSKAYKA, S.K., 1981, The effects of pH on the deposition of gold and silver from aqueous solution: Geokhimiya, 1981, no. 3, p. 371-378 (in Russian; translated in Geochem. Int'l., v. 18, no. 2, p. 28-34, 1982).

SAMORUKOVA, L.M. and KOZAKOV, I.K., 1982, Results of studies of melt inclusions in Precambrian granitoids of the Western Sangilen (Tuva ASSR), *in* N.P. Ermakov, ed., Thermobarogeochemistry in Geology - Materials of the Sixth All-Union Symposium on Thermobarogeochemistry: Vladivostok, Far East Sci. Center, Acad. Sci. USSR Pub. House, p. 66-69 (in Russian).
For abstract, see entry Samorukova in Fluid Inclusion Research--Proceedings of COFFI, vol. 11, 1978, p. 188. (A.K.)

SAMSONOV, A.Ya., 1982, Peculiarities of structure of the Irtysh sulfide-polymetal deposit: Geol. Rudn. Mest., v. 24, no. 6, p. 85-93 (in Russian). Author at Moscow State Univ., Moscow, USSR.
Inclusions in ore-bearing quartz have Th 560-620°C, P 5-6 kbar; essential component is CO_2. (A.K.)

SATO, T., 1982, Epithermal gold-silver mineralization at Kushikino, southern Kyushu, Japan - a fossil geothermal system (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 42. Author at Geol. Survey Japan, Yatabe Higashi, Ibaraki, Japan.
The gold-silver veins of the Kushikino mine are of typical epithermal type occurring in Miocene propylite and have produced seven million tons of ore averaging 6.2 g/t Au and 52 g/t Ag.
As the result of integrated studies of fluid inclusions, stable isotopes, wallrock alteration, gravimetric data and deep diamond drillings, the mineralizing system was reconstructed and interpreted as remnants of ancient geothermal system, of which the hydrothermal fluid is of local meteoric orign and the heat source is quartz diorite porphyry intrusions. The mass and heat transport processes, fluid dynamics and site of gold-silver precipitation of this fossil geothermal system are discussed in comparison with present-day volcanic geothermal areas in Japan. (Author's abstract)

SAWKINS, F.J., 1982a The formation of Kuroko-type deposits viewed within the broader context of ore genesis theory: Mining Geol., v. 32, no. 1, p. 25-33. Author at Dept. Geol. & Geophy., Univ. Minnesota, Minneapolis, MN 55455, USA.
Kuroko-type massive sulfide deposits exhibit similarities to certain epigenetic polymetallic Cordilleran deposits in base metal ratios, paragenesis and time-space association with felsic magmatism. In addition, the transport and deposition of Kuroko-type ores occurs within seawater-dominated convective systems.

Consideration of empirical data from the Taupo Volcanic Zone, New Zealand indicates strong similarities to the general setting of Kuroko ore deposition, and implies large volumes of intrusive magma to provide the necessary heatflux.

The metal content of certain postmagmatic fluids and δD constraints on Kuroko-type ore fluids suggest a model for Kuroko-type ore genesis in which host-rock leaching is not the major source of the metals involved. The preferred model envisages a magmatic source for the bulk of the metals in Kuroko-type ores, with the overlying convective systems acting as focussing mechanisms for ore fluid discharge and as contributors of reduced sulfur for metal sulfide deposition. (Author's abstract)

SAWKINS, F.J., 1982b A comprehensive model for the genesis of Kuroko-type massive sulfide deposits (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 42-43. Author at Univ. Minnesota, Minneapolis, MN, USA.

There is virtually universal acceptance of the fact that Kuroko-type massive sulfide deposits form by exhalation of metalliferous fluids at the seawater interface. Concurrence on the source(s) of the metals involved and the reason why such deposits tend to be limited to specific stratigraphic horizons has not been achieved.

The empirical data indicate that Kuroko-type deposits exhibit a time-space relationship to felsic magmatism, form in the temperature range of ~250-300°C, and are associated with active seawater-dominated hydrothermal convection. Based on stratigraphic relationships a paragenesis from copper to lead plus zinc and barite is indicated.

A number of features of the deposits suggest that a simple model of leaching, transport and exhalation of metals by heated seawater is inadequate. For example, Kuroko-type deposits exhibit strong similarities to typical postmagmatic deposits (e.g., skarn deposits) in terms of both their metal ratios and paragenesis, and their time-space relationship to felsic magmatism.

Recent work on postmagmatic deposits has demonstrated that postmagmatic ore fluids can contain in excess of 10,000 ppm of base metals in solution. It is also apparent from studies of the Taupo Volcanic Zone in New Zealand that the widespread meteoric water-dominated hydrothermal activity present must be thermally driven by large intrusive bodies at depth. The structural setting of the Taupo Volcanic Zone exhibits strong similarities to that of the Miocene green tuff region of Japan in which the Kuroko deposits developed.

These observations, coupled with a considerable body of δD data on Kuroko fluid inclusions and alteration minerals that indicate δD values of the ore fluids as intermediate in composition between seawater ($\delta d = 0$) and typical magmatic water ($\delta D = -50$), support the concept of magmatic water involvement in the genesis of Kuroko-type deposits.

A genetic model involving relatively long-lived seawater convection cells combined with short term addition of metal-rich postmagmatic fluids is suggested. Such a model is capable of explaining all the geologic, geochemical and isotopic features of Kuroko-type deposits. Furthermore, the limitation of Kuroko-type deposits to specific stratigraphic horizons within volcanic sequences is mirrored by the chronology of magmatic events in certain postmagmatic deposits. For example, at Bingham in Utah a six million year sequence of magmatic activity has been chronicled by radiometric dating, but only a single ore-forming event occurred within that time.

An important aspect of the model is the effect of the seawater convection systems in focussing the discharge of deeper magmatic fluids at specific points. It is at, and adjacent to, such discharge points that Kuroko-type deposits form. (Author's abstract)

SAWKINS, F.J., 1982c Overview of types of gold deposits in subaerial environments (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 608. Author at Dept. Geol. & Geoph., Univ. Minnesota, Minneapolis, MN 55455.

Gold deposits formed in subaerial environments occur primarily in subduction-related volcanics or volcanics related to back-arc extension. Disseminated deposits form at extremely shallow depth in situations where caprocks have undergone pervasive fracturing. Vein deposits generally exhibit well-defined favorable zones (200-500 vertical extent) within more extensive structures. Such zones typically form at shallow depth (<1 km). Base metal sulfides are generally a minor component, but in some instances they increase conspicuously downwards.

In ensimatic arcs Ag/Au ratios tend to be low (~1), whereas in continental arcs ratios are higher (>20), and tend to increase from the principal arc towards the inner arc. Ag/Au ratios within specific vein districts can provide interesting systematics, useful to further exploration. Gangue mineralogy is dominated by quartz (incl. chalcedony), but calcite, adularia and Mn silicates are important locally. Alteration phases developed are mainly chlorite, sericite, clays, and pyrite, and many districts occur within areas of regional propylitization.

Fluid inclusion and isotopic studies indicate vein mineralization occurs mainly in the range 240-280°C and disseminated mineralization at <200°C. The fluids involved were essentially of local meteoric origin. Despite the above generalities, variability in these deposits in zoning characteristics and alteration intensity is marked. Furthermore, the controls of favorable zone development and the ultimate source of gold remain problematic. Two factors important in exploration for such deposits in young volcanic terrains are recognition that vein structures can weaken markedly above favorable zones, and sets of veins exhibit spacings similar to geothermal convection cells (~5 km). (Author's abstract)

SCHERKENBACH, D.A., 1982, Geologic, mineralogic, fluid inclusion and geochemical studies of the mineralized breccias at Cumobabi, Sonora, Mexico: Ph.D. disseration, Univ. Minnesota, Minneapolis, MN, 240 pp.

Indexed under Fluid Inclusions. (See next item.)

SCHERKENBACK, D.A. and SAWKINS, F.J., 1982, The molybdenum deposit of Cumobabi, northern Sonora, Mexico (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 609. Authors at Dept. Geol. & Geoph., Univ. Minnesota, Minneapolis, MN 55455.

At Cumobabi a series of Mo-Cu mineralized breccias are associated with 56 m.a. felsic intrusives. Of the 35 breccia bodies known only a few contain significant ore-grade mineralization. Detailed geologic, alteration, fluid inclusion, and geochemical studies indicate two distinctive stages of post-brecciation alteration and metallization. Stage I involved strong potassic (+ anhydrite) alteration of centrally located breccias and deposition of molybdenite-pyrite-quartz assemblages. Stage II involved development of crosscutting quartz-sericite alteration and deposition of chalcopyrite and lesser tetrahedrite, as replacements of pyrite.

Stage I quartz contains excellent primary fluid inclusions of three types: low-salinity, high-salinity, and vapor-dominated. Detailed studies of these indicate episodic boiling events within the temperature range 440-350°C, related to repeated fluctuations from lithostatic to hydrostatic pressures at depths of 1.0-1.5 km. Relationships indicate an original low-salinity fluid (6-9 wt% alk. chl.) split into high salinity and vapor phases during episodes of pressure reduction. Daughter mineral suites in high-salinity fluid inclusions are spectacular, and at least 12 phases, including chalcopyrite, have been identified by S.E.M. techniques. The presence of chalcopyrite daughters in some vapor dominated inclusions is noteworthy. Both volumetric analysis of cpy daughters and quantitative chemical analyses of fluid inclusions indicate several thousand p.p.m. of iron and copper in the ore fluids as well as significant zinc (550 to 1,700 p.p.m.). Apparently base metal amounts were greater than those of reduced sulfur, suggesting availability of the latter may be a crucial factor in postmagmatic ore deposition. (Authors' abstract)

SCHIFFRIES, C.M., 1982, The petrogenesis of a platiniferous dunite pipe in the Bushveld Complex: infiltration metasomatism by a chloride solution: Econ. Geol., v. 77, p. 1439-1453. Author at Dept. Geol. Sci., Harvard Univ., Cambridge, MA 02138.

It is proposed that a high-temperature chloride solution flowed through irregular channel-ways along a structural weakness near the axis of the pipe and reacted with the noritic host rocks, leading ultimately to the formation of dunite. Reaction fronts advanced at different rates outward from the channelways and produced a sequence of metasomatic zones.

Aqueous chloride complexes are also believed to have played an important role in the transport and precipitation of the platinum-group elements, the base metals, and other cations. Interdependent chemical reactions involving a chloride solution, olivine, magnetite, and the platinum-group elements can account for the preferential association of the ore with iron-rich olivine. Infiltration metasomatism by a high-temperature chloride solution may have an important bearing on the interpretation of other features of the Bushveld Complex. (From the author's abstract)

SEDOVA, I.S., 1982, Quartz-plagioclase metasomatites - a low-temperature rock analogous to ultrametamorphic granitoids, in N.P. Ermakov, ed., Thermobarogeochemistry in Geology - Materials of the Sixth All-Union Symposium on Thermobarogeochemistry: Vladivostok, Far East Sci. Center, Acad. Sci. USSR Pub. House, p. 14-21 (in Russian).

For the abstract, see Fluid Inclusion Research--Proceedings of COFFI, vol. 11, 1978, p. 190. (A.K.)

SEDOVA, I.S. and GLEBOVITSKIY, V.A., 1982, Migmatization and granitization during metamorphism of the andalusite-sillimanite type in the Ladoga series: Dokl. Akad. Nauk SSSR, v. 264, no. 2, p. 431-434 (in Russian).

SEDOVA, I.S., NGUY, T.N. and KAMENTSEV, I.Ye., 1982, Structural state of K-Na feldspars of migmatites and ultrametamorphic granitoids in connection with conditions of their formation: Zapiski Vses. Min. Obshch., v. 111, no. 5, p. 514-528 (in Russian). First author at Inst. of Geol. and Geochronol. of Precambrium of Acad. Sci. USSR, Leningrad, USSR.

Rocks of granulite facies yielded Th of fluid inclusions: SW Pamirs 780°C, Belomor'ye 835-850°C; high-T amphibolite facies: SW Pamirs 790°C, 725°C, 620°C, Central Pamirs (Shatput) 700°C, region Vitim-Kalar 740°C, region Katugin 635°C, Tynda River 650°C, N. Priladozh'ye (=N. side of the Ladoga Lake) 700-715°C; parautochthonic and allochthonic granitoids: SW Pamirs 800°C, Central Pamirs 710, 740 and 765°C. The above Th values and fluid composition (H_2O, H_2, CO_2, CO, CH_4) determined by gas chromatography were considered to display certain role in formation of structural state of metamorphic K-Na feldspars. (Abstract by A.K.)

SELIN, P.F., 1982, Geological peculiarities of deep levels and mineral zoning of the mercury deposit Chagan-Uzun: Geol. Rudn. Mest., v. 24, no. 5, p. 57-62 (in Russian). Author at the Kura Geol.-Prosp. Group, USSR.
The paper refers to some Th data from the literature. (A.K.)

SELVERSTONE, Jane, 1982, Fluid inclusions as petrogenetic indicators in granulite xenoliths, Pali-Aike volcanic field, Chile: Contrib. Mineral. Petrol, v. 79, p. 28-36. Author at Dept. Geol. Sci., Univ. Colorado, Boulder, CO 80309, USA.

Granulite xenoliths within alkali olivine basalts of the Pali-Aike volcanic field, southern Chile, contain the mineral assemblage orthopyroxene + clinopyroxene + plagioclase + olivine + green spinel. These granulites are thought to be accidental inclusions of the lower crust incorporated in the mantle-derived basalt during its rise to the surface. Symplectic intergrowths of pyroxene and spinel developed between olivine and plagioclase imply that the reaction

$$\text{olivine + plagioclase = Al-orthopyroxene + Al-clinopyroxene + spinel} \quad (1)$$

occurred during subsolidus cooling and recrystallization of a gabbroic protolith of the granulites.

Examination of fluid inclusions in the granulites indicates the ubiquitous presence of an essentially pure CO_2 fluid phase. Inclusions of three different parageneses have been recognized: Type I inclusions occur along exsolution lamellae in clinopyroxene and are thought to represent precipitation of structurally-bound C or CO_2 during cooling of the gabbro. These are considered the most primary inclusions present. Type II inclusions occur as evenly distributed clusters not associated with any fractures. These inclusions probably represent entrapment of a free fluid phase during recrystallization of the host grains. IIa inclusions are found in granoblastic grains and have densities of 0.68-0.88 g/cm^3. Higher density (ρ = 0.90-1.02 g/cm^3) IIb inclusions occur only in symplectite phases. Secondary Type III CO_2+glass inclusions with ρ =0.47-0.78 g/cm^3 occur along healed fractures where basalt has penetrated the xenoliths. Type III inclusions appear related to exsolution of CO_2 from the host basalt during its ascent to the surface. These data suggest that CO_2 is an important constituent of the lower crust under conditions of granulite facies metamorphism, indicated by Type I and II fluid inclusions, and of the mantle, as indicated by Type III inclusions.

Correlation of fluid inclusion densities with P-T conditions calculated from both two-pyroxene geothermometry and reaction (1) indicate emplacement of a gabbroic pluton at 1,200-1,300°C, 4-6 kb; cooling was accompanied by a slight increase in pressure due to crustal thickening, and symplectite formation occurred at 850 ±35°C, 5-7 kb. Capture of the xenoliths by the basalt resulted in heating of the granulites, and CO_2 from the basalt was continuously entrapped by the xenoliths over the range 1,000-1,200°C, 4-6 kb. Examination of fluid inclusions of different generations can thus be used in conjunction with other petrologic data to place tight constraints on the specific P-T path followed by the granulite suite, in addition to indicating the nature of the fluid phase present at depth. (Author's abstract)

SHABO, Z.V., ALEKSEEVA, N.I., MAMCHUR, G.P. and MANZHAR, N.I., 1982, Organic compounds of the Slavyanskoe ore mineralization and their connection with endogene mineral formation: Geol. Rudn. Mest., v. 24, no. 5,

p. 63-73 (in Russian). Authors at Inst. Geol. and Geochem. of Mineral Fuels of Acad. Sci. of Ukr. SSR, L'vov, Ukrainian SSR.

The deposit Slavyanskoe occurs in the SE part of the Dnepr-Donets basin. Wall-rocks are Paleozoic to Tertiary evaporites, coals, limestones, sandstones and mudstones. Ores consist of pyrite, marcasite, galena, sphalerite, molybdenite and cinnabar. Organic substance varies from solid and semi-solid (asphalts, elaterites), viscous (ozokerite-like) to liquid (oil-type). Sometimes grains of solid organic substance are cut by cinnabar veinlets, or they form intergrowths. Early mineral association (quartz, fluorite, scapolite, topaz, tourmaline, muscovite, pyrite, graphite) yield Th 330-440°C. Ore mineralization formed at 350-170°C, pH 6.0-6.2. G consists mostly of CO_2 (46.3%), CH_4 (38.9%) plus N_2 (11.9%), O_2 (5.2%) and H_2 (0.3%). LH_2O is highly concentrated solution (Cl 238, Ca 50, Na 150-200, Mg 25 g per 1, K not found). P was $650 \cdot 10^5$-$420 \cdot 10^5$ Pa. The sequence of organic substance alteration was also discussed on the basis of the above parameters. (Abstract by A.K.)

SHAPENKO, V.V., 1982, Genetic peculiarities of tungsten mineralization in the Dzhida ore field (South-West Transbaikalia): Geol. Rudn. Mest., v. 24, no. 5, p. 18-29 (in Russian). Author at Inst. Geochem. and Anal. Chem. of Acad. Sci. USSR, Moscow.

Crystallization of granites of Pervomayskaya intrusive, with which the tungsten ores of the Dzhida ore field associate, began at 810-750°C (Th) from silicate melt bearing 5.2-6.6 wt.% of H_2O, P 2.4-4.9 kbar. Intrusion of melt might activate the ore-forming process. Tungsten mineralization is the same in the whole ore field, as is confirmed by similar composition of huebnerite, tetrahedrites and bismuth sulfosalts taken in various parts of the ore field. Ore formation process developed in two stages and under "thermostatic" conditions. Huebnerite stage minerals yielded Th 300-240°C and CO_2 concentration in solutions up to 100 g/kg of H_2O. Posthuebnerite stage has typical Th 280-150°C and no CO_2. Ore formation was accompanied by degassing of solutions. P of fluid were 480-380 bars for the deposit Inkur and 760-450, rarely 1200 bar for the deposit Kholtoson. Total number of the studied inclusions exceeded 1000. (Author's conclusions translated by A.K.)

SHARMA, K.K. and PATIL, R.R., 1982, Significance of combinative fission track and fluid inclusion studies as chrono-thermometers (abst.): [Proceedings & Abstracts], National Workshop on Fluid Inclusion Studies, 22-23 March, 1982, Indian Inst. Tech., Bombay, p. 44 (unpaginated). Authors at Wadia Inst. Himalayan Geol., Dehradun - 1.

The combined fission track and fluid inclusion studies in some minerals such as apatite, sphene, epidote and zircon occurring in the granite pluton, pegmatites and mineralized veins can be used as complimentary paleothermometric techniques. These combined studies can throw much light on the nature of the fluid activity during the cooling history of such bodies, which neither of these well-established techniques alone can provide. The authors feel that such combined studies can throw much light on thermo-tectonic evolution of the Himalaya. They suggest fission track ages can be used to calculate the tentative depth of emplacement of such bodies and hence the possibility of calculating the lithostatic pressure for the correction of Th determinations, the main handicap in the inclusion thermometry. (From the authors' abstract)

SHATAGIN, N.N., 1982, Division of decreptograms and other analytical curves into components (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 115-116.

SHATAGIN, N.N., DOROGOVIN, B.A., KROPACHEV, S.M. and ALESIKO, B.L., 1982, Zonal distribution of inclusions of mineral-forming media in granite massifs, in N.P. Ermakov, ed., Thermobarogeochemistry in Geology - Materials of the Sixth All-Union Symposium on Thermobarogeochemistry: Vladivostok, Far East Sci. Center, Acad. Sci. USSR Pub. House, p. 48-55 (in Russian).

In granite massifs of small and moderate depths of formation, zoning was observed in the distribution of gas-liquid inclusions, expressed mainly in the gradual increase of inclusion filling coefficient from 0.1 at the contact to 0.9 in the center of the massif, and in presence of polyphase (with dms: halite, sylvite, carbonates, ore minerals) inclusions in periphery and apical parts of massifs. Zonal distribution of gas-liquid inclusions may be used for solution of certain geological problems, especially for determination of ancient erosion levels of granite massifs. Use of the proposed method is shown on the example of Verkhubinskiy region in Rudnyi Altai. Complex series of determinations made possible the estimation of average erosion level of the Krasnomaralikhinskiy massif in the Upper Devonian time. (Authors' abstract, translated by A.K.; see also entry Shatagin and Dorogovin in Fluid Inclusion Research--Proceedings of COFFI, vol. 11, 1978, p. 193, A.K.)

SHCHEGLOV, A.D. and SMIRNOV, V.I., eds., 1982, IAGOD, VI Symposium, Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, 334 pp. (in English).

Contains many abstracts of interest to inclusion study; all these are abstracted in this volume. (E.R.)

SHCHERBAN, I.P., 1982, Physico-chemical modelling of formation of medium- and low-temperature metasomatic rocks and their associated ores (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 47-48.

SHEFELBINE, H.C., 1982, Brine migration: a summary report: Sandia Report SAND 82-015, 53 pp.

Includes summaries of the literature data on analyses of water content of rock salt from McNutt Member of the Salado Formation in New Mexico, and the composition of the brines (in part present as fluid inclusions). (E.R.)

SHELTON, K.L., 1982, Evolution of the porphyry copper and skarn deposits at Murdochville, Gaspé Peninsula, Quebec: a geochemical, stable isotopic, and fluid inclusion study: Ph.D. dissertation, Yale Univ., 1982.

Mines Gaspé is a Paleozoic porphyry copper and skarn deposit developed almost entirely in carbonate-bearing wall rocks. The ore deposits of Mines Gaspé are of two types: (1) Early stage skarn-type replacement ore bodies, and (2) Late stage porphyry-type veins.

Sulfur isotopic patterns of sulfides and sulfates in ore assemblages from Mines Gaspé suggest that the source of sulfur in both the Early stage skarn-type and Late stage porphyry-type ore was dominantly an igneous source. Isotopic compositions of coprecipitated Late stage anhydrites and sulfides yield apparent isotopic depositional temperatures much greater than Th obtained from primary fluid inclusions. The coprecipitated anhydrite-sulfide pairs are thus in sulfur isotopic disequilibrium. However, the sulfur isotopic compositions of coprecipitated anhydrites and sulfides covary: as the $\delta^{34}S$(anhydrite) values become more positive, the corresponding $\delta^{34}S$(sulfide) values become more negative. This systematic isotopic disequilibrium between anhydrite and sulfides in Late stage porphyry-type vein assemblages is due to the relatively slower rate of isotopic equilibration between aqueous sulfate and H_2S compared to the rate of isotopic equilibration between sulfides and H_2S, and the rate of mineral precipitation. The observed anhydrite-sulfide isotopic disequilibrium and the $\delta^{34}S(\Sigma S)$ value (+4.3‰) for Late stage anhydrite-bearing assemblages are compatible with a model in which a SO_2-rich magmatic fluid disproportionated into HSO_4^- and H_2S. As the fluid cooled it dissolved earlier ore and alteration mineralization at depth and deposited anhydrite-sulfide assemblages in sulfur isotopic disequilibrium higher in the deposit. The time scale of precipitation of individual anhydrite-bearing veins was likely less than ten weeks.

Fluid inclusion data from Mines Gaspé suggest that the skarn and porphyry copper hydrothermal systems each evolved from an early magmatic-dominated stage to a late meteoric-dominated stage. Three distinct thermal fluids are associated with Late stage porphyry-type ore deposition and each type reflects an important change in the hydrology of the porphyry copper hydrothermal system:

(1) A magmatic-dominant 350°C fluid was responsible for the majority of the copper and molybdenum deposited in the central porphyry hydrothermal system.

(2) A magmatic-meteoric 250°C fluid was responsible for Late stage lead and zinc mineralization.

(3) A meteoric-dominant 150°C fluid was responsible for Late stage non-ore zeolite-bearing mineralization and alteration.

The coincidence of the distribution of these three fluids and the distribution of Late stage ore mineralization suggests that Late stage ore was transported and localized as a result of both convective cooling and stratigraphically controlled fluid flow.

Carbon and oxygen isotopic compositions of hostrock calcites from the skarn-type replacement ore bodies of Mines Gaspé suggest stratigraphically controlled fluid flow within preferred ore-fluid aquifers. The oxygen isotopic compositions of skarn ore calcites suggest that the hydrothermal fluid responsible for ore deposition and isotopic alteration of the host rocks was dominantly meteoric water. The degree of depletion of ^{13}C and ^{18}O of the hostrock calcites within the skarn-type ore bodies is related to the copper ore grade. It may therefore be possible to outline the extent of ore mineralization, using the isotopic compositions of the hostrock calcites as an exploration tool and ore guide.

Carbon and oxygen isotopic compositions of calcite from the porphyry system suggest isotopic alteration of the hostrock calcites as a function of increasing water to rock ratios. Both the distribution of the data on a $\delta^{13}C$ and $\delta^{18}O$ diagram and the calculated water to rock ratios are compatible with isotopic alteration of the host rocks in a convecting hydrothermal system. The oxygen isotopic compositions of these calcites suggest that the hydrothermal fluid responsible for peripheral Late stage mineralization and hostrock alteration was dominantly meteoric. (Author's abstract)

SHEN, K., CHAMPIGNY, N. and SINCLAIR, A.J., 1982, Fluid inclusion and sulphur isotope data in relation to genesis of the Cinola gold deposit, Queen Charlotte Islands, B.C.: Geology of Canadian Gold Deposits, Proc. CIM Symp. 1980, R.W. Hodder and William Petruk, eds.: Spec. Vol. 24, Can. Inst. Min. and Metal., p. 255-257. Authors at Dept. Geol. Sci., Univ. British Columbia, Vancouver, BC.

Fluid inclusion studies from the Cinola deposit indicate low salinities and low CO_2 contents of the ore fluid. This supports a suggestion that the mineralizing fluids originated from pore water in the fluviatile host rock (mid-Miocene Skonun Formation). Bimodal distribution of filling temperatures suggests the existence of at least two temperature regimes centered on 160°C and 270°C during mineral deposition. Independent age and stratigraphic evidence indicates that depth of mineralization is between 1.1 and 1.8 km, corresponding to a hydrostatic load of between 110 and 170 bars. (Authors' abstract)

SHEN, K. and SINCLAIR, A.J., 1982, Preliminary results of a fluid inclusion study of Sam Goosly deposit, Equity Mines Ltd., Houston, in Geological Fieldwork 1981, a summary of field activities of the Geological Branch, Mineral Resources Division, Paper 1982-1: Ministry of Energy, Mines & Petrol. Resources, British Columbia, p. 229-233. Authors at Dept. Geol. Sci., Univ. British Columbia.

The Sam Goosly copper-silver deposit consists mainly of pyrite, tetrahedrite and chalcopyrite with less abundant arsenopyrite, galena, sphalerite, pyrrhotite, and various sulphosalts, as stockworks, veins, and disseminations. Locally they form massive zones. Dominant gangue minerals are quartz and sericite with lesser amounts of chlorite, tourmaline, corundum, andalusite, calcite, and pyrophyllite. The two ore zones are part of a single, larger mineralized zone that is apparently epigenetic and crosscuts stratigraphy.

Three types of inclusions are recognized based on phase relations at room temperature: Type I: Liquid and 10-20 vol.% gas; Type II: Liquid plus >60 vol.% vapor; and Type III: Multi-phase inclusions consisting of liquid, a small bubble (~15 vol.%), and one or more (up to four) solid phases (most commonly halite although hematite has been identified and sylvite is suspected in some).

A Th histogram of 147 inclusions (but of unspecified type) shows a wide range of values, mostly 200-440°C, and a wide range of melting temperatures, from -26 to +8. A mixing model is proposed, involving saline magmatic fluids and fresh meteoric water. (E.R.)

SHEPHERD, T.J. and DARBYSHIRE, D.P.F., 1982, Fluid inclusion Rb-Sr geochronometers (abst.): J. Geol. Soc. London, v. 139, part 1, p. 97.

The precise dating of mineral deposits has important implications for understanding the lifetime of ore-forming systems and their temporal relationship to magmatism and other geological events. However, not all deposits provide material suitable for conventional radiometric dating, or data which are amenable to unequivocal interpretation. Nor is it always easy to verify that such samples have remained isotopically "closed" since their formation. Fluid inclusions provide an alternative closed system approach. By analyzing the isotopic composition of Rb and Sr in inclusions within quartz from the Carrock Fell tungsten vein deposits, Cumbria, we are able to demonstrate the feasibility of obtaining Rb-Sr fluid inclusion isochrons. The age for the mineralization, 392 ± 5 Ma, is in good agreement with the mean K-Ar age, 387 ± 6 Ma for the vein micas. Preliminary data was also presented for the North Pennine orefield. (Authors' abstract)

SHEPHERD, T.J., DARBYSHIRE, D.P.F., MOORE, G.R. and GREENWOOD, D.A., 1982, Rare earth element and isotopic geochemistry of the North Pennine ore deposits: Bull. BRGM, Sec. II, v. 2. no. 4, p. 371-377 (in English). First author at Isotope Geol. Unit, Inst. Geol. Sci., 64 Grays Inn Rd., London WC1, Great Britain.

Complementary fluid inclusion and REE data for fluorites from the North Pennine Pb-Zn-F-Ba orefield permit a distinction to be made between inherited REE patterns and those due to differential anion complexing. The total REE content varies between 20-800 ppm and is independent of ore fluid temperature and bulk chemistry. In general, there is an overall sympathetic relationship between high REE content and the more strongly colored green and purple fluorites. Rare earth spectra (La, Ce, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Yb and Lu) are characterized by a pronounced enrichment of the heavier LREE and lighter HREE centered on Tb. For the redox sensitive lanthanides Eu and Ce, a positive Eu anomaly is usually accompanied by a negative Ce anomaly in accordance with their antipathetic behavior under reducing conditions. This information is being used to evaluate the exploration potential of REE in fluorite as a guide to fluorite oreshoots within an extensive system of mineralized veins. Stable isotope data for the ore fluids confirm the dominant role played by formational fluids and gives no support to the magmatic-hydrothermal model proposed by some workers. Similarly, fluid inclusion Rb-Sr isochron studies suggest that the age of the mineralization is Triassic and not Permo-Carboniferous as hitherto believed. (Authors' abstract)

SHEPHERD, T.J. and WILSON, A.A., 1982, Mineral flats in the Dinantian of the Beckermonds Scar borehole and a fluid inclusion study of fluorite: Proc. Yorkshire Geol. Soc., v. 44, part 1, p. 83-86.

P inclusions in fluorite show Th of 172-207°C; secondaries 120-149. Last melting temperatures range from -18° (hydrohalite) to (-21 to -24) (ice). (E.R.)

SHIKINA, N.D., ZOTOV, A.V. and KHODAKOVSKII, I.L., 1981, An experimental investigation of equilibria in the α-HgS-H_2S-H_2O system at 90 and 150°C: Geokhimiya, 1981, no. 4, p. 496-503 (in Russian; translated in Geochem. Int'l., v. 18, no. 2, p. 109-117, 1982).

SHKODZINSKIY, V.S., 1981, Evolution of phase composition and genesis of granitic magma: Geokhimiya, no. 1, p. 45-62 (in Russian, translated in Geochem. Int'l., v. 18, no 1, p. 25-41, 1982).

Abstract in Fluid Inclusion Research--Proceedings of COFFI, v. 14, p. 190. (E.R.)

SHMULOVICH, K.I. and KOTOVA, P.P., L982, Mineral equilibria in high-temperature fluid H_2O-CO_2-electrolyte: Geokhimiya, no. 10, p. 1440-1453 (in Russian; English abstract).

SHMULOVICH, K.I., TERESHCHENKO, Ye.N. and KALINICHEV, A.G., 1982, Equation of state and isochores of non-polar gases to 2000K and 10GPa: Geokhimiya, no. 11, p. 1598-1613 (in Russian; English abstract). First author at Inst. Exper. Minerals, Chernogolovka, USSR.

The paper describes properties of Ar, N_2, CO, CO_2, H_2 and CH_4. (A.K.)

SHMURAEVA, L.Ya. and MOSKALYUK, A.A., 1982, Contribution to geochemistry of hydrothermal solutions forming alkaline metasomatites in the central part of the Ukrainian Shield, in N.P. Ermakov, ed., Thermobarogeochemistry in Geology - Materials of the Sixth All-Union Symposium on Thermobarogeochemistry: Vladivostok, Far East Sci. Center, Acad. Sci. USSR Pub. House, p. 21-24 (in Russian).

Albitite bodies occur in the rocks of the Precambrian migmatite-granite formation. Their location is controlled by faults. Albitite bodies are surrounded by haloes of epidote-chlorite (greenstone) alteration. Water leachates from metasomatized rocks were analyzed for Na, K, Ca, Mg, NH_4, F, Cl, SO_4, and HCO_3 contents, yielding the differences for various metasomatites. Extensive albitization was caused by solutions having

Na/K>>1. Greenstones, albitites and apatite-bearing albitites formed from genetically similar solutions. The same relation occurs between various albite-microcline metasomatites. (Abstract by A.K.; note: abstract of this paper was not published in the Abstract Volumes of the Vladivostok Symposium, A.K.)

SHNJUKOV, E.F., KALJUZHNY, V.A., SHCHIRITSA, A.S., TELEPKO, L.F., SVOREN, Y.M., ALAUI, G.G. and KRUGLOV, O.S., 1982, Gas fluids of contact basalts of the Indian Ocean bottom (according to relic inclusions) (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 214-215. First author at Geol. Inst., Kiev, USSR.

Melt inclusions in microscopic olivine phenocrysts and volatile components enclosed in the basaltic glass have been studied.

The melt inclusions were determined in very small (0.01-0.05 mm) rare faceted olivine crystals, occurring in glass. Olivine has the form of faceted crystals. They homogenized at 1100-1150°C.

In addition to olivine, the glass contains scarce spherical gas inclusions: bubbles (0.01 to 0.50 mm).

The thin plates of dark-brown glass becomes opaque when heated in the air or in a high vacuum (with an oxygen-consuming reagent). Darkening begins at the temperatures of softening (750-780°C); at 1100-1150°C it becomes completely liquid.

The gas bubbles have an unusual inner surface reflecting the specific conditions of their appearance in the cooled lava. SEM replicas have shown that the external side of the sphere surface is covered with very small spherical bubbles opening into the main bubble cavity. The internal pressure in the bubbles, measured under normal conditions by breaking them in a liquid inert medium, was $45 \cdot 10^5$ - $50 \cdot 10^5$ Pa.

The composition of separate gas bubbles and bulk gas composition obtained by crushing a sample in the vacuum, was examined by mass-spectrometers MCK-3A and MX-1303. Only CO_2 was found in individual gas bubbles; (see Table below); bulk analyses have revealed CO_2 and also about 2% of water. The composition of gases isolat[ed] from the samples during their heating up to 800°C has been defined in the matter crushed directly in the mass-spectrometer vacuum system(sic).

Therefore, at the moment when the basaltic lava reached the ocean bottom surface, its gas fluids consisted mainly of carbon dioxide. Water contained in the glass structure is removed from the samples only with their crushing or heating. Degasification of the basic lava occurred in two stages: (1) intratelluric (1100-1150°C) and (2) after superficial lava flow (1000°C), which is evidenced by very fine bubbles around the main bubbles, which open into the main cavity. It is likely that the carbon-dioxide gases released during the glass heating, are components of subcrustal fluids.

Depending on the internal pressure value, the carbon-dioxide partial pressure was $200 \cdot 10^5$ Pa - $200 \cdot 10^5$ Pa at 1000-1100°C, which is much lower than the water column pressure of the present-day ocean level ($380 \cdot 10^5$ Pa). This once more indicates that the glass consumed a part of the fluids (predominantly, water) in the process of cooling of the effluent lava. (Authors' abstract)

SHOJI, Hitoshi and LANGWAY, C.C., Jr., 1982, Air hydrate inclusions in fresh ice core: Nature, v. 298, p. 548-550. Authors at Ice Core Lab. Dept. Geol. Sci., State Univ. New York at Buffalo, 4240 Ridge Lea Road, Amherst, NY 14226, USA.

One of the characteristic features of polar glacier ice is the abundance of air bubbles. With increasing depth from the surface of the ice sheet, the size of the bubbles generally decreases in response to the change of overburden pressure. Below a certain depth, the bubbles start to shrink faster than expected and finally become invisible. Although not visible to the naked eye, unit mass of the bubble-free (clear) ice includes almost the same volume of air as unit mass of bubbly ice. It is hypothesized that the air exists in the ice structure probably in the form of clathrate hydrates as suggested by Miller but until now the location of the air has been unknown. Direct observations of air hydrate inclusions were carried out for the first time in fresh ice cores from Dye-3, Greenland. When the ice structure surrounding air hydrate was melted, an explosive transition occurred releasing a gas bubble into the melt cavity. (Authors' abstract)

SHRIER, Tracy and PARRY, W.T., 1982, A hydrothermal model for the North Canning uranium deposit, Owl Creek Mountains, Wyoming: Econ. Geol., v. 77, p. 632-645. First author at Kennecott Min. Co., Utah Copper Div., P.O. Box 232, Bingham Canyon, UT 84006.

Analyses of six drill cores from and surrounding the North Canning uranium deposit in the Copper Mountain uranium district, Wyoming, suggest that a low-temperature hydrothermal system may have transported and precipitated uranium. Uranium is found in highly altered breccia zones and fractures in Archean granite and in overlying Tertiary sediment. Na montmorillonite invariably forms the matrix around stable and secondary K-feldspar and quartz in the breccias. Uraninite and amorphous pitchblende occur as disseminated fracture fillings and as encrustations on lithic fragments in the breccias. Hematite staining commonly occurs around uranium mineralization, and pyrite is disseminated in fractures and is intimately associated with uraninite. In the granite host rocks, sericite replaces plagioclase, epidote replaces plagioclase and biotite, and chlorite sporadically replaces biotite. Homogenization temperatures of fluid inclusions in quartz microveinlets average 136°C.

Anomalous uranium concentrations occur in the Copper Mountain granite (5 ppm regionally, but more than 20 ppm in a central core). Isotope systematics show 30 to 50 percent uranium losses in Tertiary time, from which preloss values greater than 35 ppm are calculated. The heat-generating capacity of this granite, using the back-calculated U value and averages of 28 ppm Th and 4.5 percent K_2O is 11.2 $\mu W/m^3$. Steady state conductive temperatures greater than 150°C would have been generated under 4.5 km of Cambrian to Cretaceous sediments. Laramide faulting opened the heated rock to convective water circulation, allowing silicate alteration, mobilization of uranium within the granite, and then deposition of uranium in the breccia zones.

Activity diagrams show solution reaction paths associated with alteration and stability relationships for uraninite. Unaltered K-feldspar and plagioclase altered to sericite and Na montmorillonite suggest constant aK^+/aH^+ and increasing aNa^+/aH^+ ratios. The assemblage uraninite-pyrite-hematite is stable within fO_2 values of 10^{-44} to 10^{-35} and fS_2 values of 10^{-20} to $10^{-6.5}$ atm at an assumed $PCO_2 = 10^{-2}$ atm and $\Sigma U = 10^2$ ppb in the hydrothermal fluid. Oxidation of magnetite and sulfide solution species to hematite and hydrothermal pyrite caused reduction and precipitation of uranium from solution. (Authors' abstract)

SHUGUROVA, N.A. and PROSKURYAKOV, A.A., 1982, The PTX and volumetric analysis data of inclusions used as evaluation criteria for the productivity of ore-bearing zones on some gold deposits in middle Asia and Siberia (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 215-216. First author at Inst. Geol. & Geoph., Novosibirsk, USSR.

A complex thermobarogeochemical analysis has defined the main physico-chemical parameters of endogenous mineralization of the postmagmatic stage, the thermobaric and gaseous conditions of formation of productive "pyrite-arsenopyrite" gold-bearing affinities. These data resulted in comparative evaluation of the depth of formation of different ore zones of the deposits.

With temperature decrease the compositions of the ore-bearing solutions altered from an essentially carbonaceous fluid at early stages to an alkaline-chloride one at later stages. The gaseous phase of the solutions was mainly composed of CO_2, the content of which grows in ascending the section. At lower levels of the deposits the fraction of the reducing gases (CH_4, H_2, CO) is higher. The zones of abnormally high CO_2 contents in the rocks, which frequently deviate from the high metal concentration areas, are particularly notable. These areas are characterized by the alkaline-chloride composition of the solutions.

The complex analysis of the physico-chemical conditions of ore formation performed with account of the geologic environments in certain ore deposits can be used for prospecting. (From the authors' abstract)

SHUGUROVA, N.A. and SHOKHONOVA, L.A., 1982, Methodology recommendations for gas phase analysis of individual inclusions in minerals, in N.P. Ermakov, ed., Thermobarogeochemistry in Geology - Materials of the Sixth All-Union Symposium on Thermobarogeochemistry: Vladivostok, Far East Sci. Center, Acad. Sci. USSR Pub. House, p. 151-156 (in Russian). (See Translations)

SHUKAYLO, L.G., 1982, Typomorphic peculiarities of certain accessory minerals from quartz diorite porphyrites of the Vyshkovo ore field of Ukrainian Carpathians: Mineralog. Sbornik, v. 36, no. 2, p. 49-60 (in Russian; English abstract). Author at Mining Inst., Dnepropetrovsk, Ukrainian SSR.

Fluorapatite bears melt inclusions (chlorite+glass, hydromica+glass and glass+hydromica+G bubble, Th of the latter type 1260-1300°C). Inclusions were analyzed by electron microprobe. Normative composition of inclusion melts was calculated. Melt inclusions in zircons have variable SiO_2 content, from 57.7 to 89.1 wt.%. Some inclusion are open to the crystal surface. Complete homogenization was not achieved for inclusions in zircon (55 runs) even at T 1500°C. (Abstract by A.K.)

SHUKOLYUKOV, Yu.A., VERKHOVSKIY, A.B., DRUBETSKOY, Ye.R., OLEYNIKOV, B.V., OKRUGIN, A.V., BIBIKOVA, Ye.V., MAKAROV, V.A., KIRNOZOVA, T.I., PRASOLOV, E.M., MESHIK, A.P., SUBBOTIN, Ye.P. and ZUYEV, B.K., 1981, Isotope indicators of a mantle origin for native metals in trap rocks: Geokhimiya, no. 10, p. 1442-1452 (in Russian; translated in Geochem. Int'l., v. 18, no. 5, p. 100-111, 1982). First author at Inst. Geochem. & Anal. Chem., Moscow, USSR.

Studies have been made on the trap rocks in the Ozernyy Hills region and in the Ust Khannya and Billeekh intrusions, which have shown isotopic and geochemical signs of mantle origin. Chemical compositions have been determined for the native iron and for the gas phase in microscopic inclusions in the rock, and the isotope composition and content of helium have been determined in the silicate part of the rock and in the native iron. The isotope composition of the lead has been examined for alloys of lead, tin, and antimony observed in these rocks. The isotopic composition of the helium in the native iron from the Ozernyy hills and from the silicate fraction in the trap bodies does not indicate the presence of mantle helium, since there is a typical crustal isotope ratio. The gases in the native iron and in the rock-forming minerals have an essentially methane-hydrogen composition, with the hydrogen concentration on the whole low. The contents of dissolved gases in the metallic and silicate phases are identical. (Authors' abstract)

SHVEDENKOV, G.Yu. and SHVEDENKOVA, S.V., 1982, Feldspars under pressure of water and carbon dioxide; Siberian Branch of the "Nauka" Publ. House, Novosibirsk, 168 pp., 1000 copies printed, price 1 rbl. 70 kopecks (in Russian).

The book contains data on H_2O-CO_2, Al_2O_3-SiO_2-H_2O, CaO-Al_2O_3-SiO_2-H_2O-CO_2 and similar albite- and potassium feldspar-bearing systems. Results of many experiments at T up to 750°C and P $\sim$1 kbar are presented. (A.K.)

SIDEROV, A.A. and NOVOZHILOV, Y.I., 1982, Are there "roots" in epithermal deposits? (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 143-144. Authors at Cent. Res. Inst. of Geol. Survey of Non-Ferrous & Precious Metals, Moscow, USSR.

The thermobarogeochemical investigations of quartz from the upper part of the impregnated ore zones have shown that ore deposition proceeded at sufficiently high temperatures (320-100°C) and pressures (800-700 atm.). The similar PT conditions and high salt concentrations in the ore-forming solutions (up to 15%) characterize the lowermost root parts of volcanogenic deposits of gold-silver formation. (From the authors' abstract)

SIDOROV, A.A. and VOLKOV, A.V., 1982, Antimonite mineralization in gold-ore deposits: Dokl. Akad. Nauk SSSR, v. 266, no. 2, p. 433-435 (in Russian).

SIGURDSSON, Haraldur, 1982, Volcanic pollution and climate: the 1783 Laki eruption: EOS, v. 63, p. 601-602. Author at Grad. Sch. Oceanography, Univ. Rhode Island, Kingston, RI.

Includes determinations of S and Cl in three glass inclusions and in matrix glass. The inclusions are much higher in S (800-1020 ppm) vs 120-170, but similar in Cl (160-200 vs 150-170 ppm). (E.R.)

SIMAKIN, A.G., 1982, One factor of hydrodynamic layering of crystallizing magma: Akad. Nauk SSSR Doklady, v. 263, no. 2, p. 431-434 (in Russian). Author at Inst. Exper. Miner. of Acad. Sci. USSR, Chernogolovka near Moscow, USSR.

The possible role of volatiles as factor of hydrodynamic stratification is discussed for crystallization of melt in the bottom part of magma chamber. (A.K.)

SIMMONS, S., 1982, Fluid inclusion and alteration studies of the Washington Mine, Sonora, Mexico: MS thesis, Univ. Minnesota, Minneapolis, Minnesota.

Indexed under Fluid Inclusions. (E.R.)

SIMONEIT, B.R.T. and LONSDALE, P.F., 1982, Hydrothermal petroleum in mineralized mounds at the seabed of Guaymas Basin: Nature, v. 295, p. 198-202. First author at Sch. Oceanogr., Oregon State Univ., Corvallis, OR 97331, USA.

Petroleum has been dredged from an active hydrothermal mound area in the southern rift of Guaymas Basin, Gulf of California. This organic matter is composed of gasoline-range aliphatic and aromatic hydrocarbons and predominantly residual polar asphaltic material. The aliphatic hydrocarbons of two bitumen samples have very different boiling range and composition. Both samples contain polynuclear aromatic hydrocarbons and olefins, which indicate formation at pyrolytic temperatures. The overall compositional data indicate an origin from biological detritus by thermal alteration and rapid quenching by hydrothermal removal, followed by condensation at the seabed. (Authors' abstract)

SINKANKAS, John, ed., 1981, Emerald and other beryls: Chilton Book Co., Radnor, PA, 665 pp.

Includes 12 pages on inclusions in beryl. (E.R.)

SITARAMAYYA S., 1982, Decrepitometric mapping - a useful prospecting method (abst.): [Proceedings & Abstracts], National Workshop on Fluid Inclusion Studies, 22-23 March, 1982, Indian Inst. Tech., Bombay, p. 42 (unpaginated). Author at Centre of Explor. Geophy., Osmania Univ., Hyderabad-7.

For the purpose of decrepitometric mapping, samples are collected in a grid pattern and a known amount of the separated mineral, generally quartz, is progressively heated up to 750°C and the number of decrepitations are automatically recorded at intervals of 20°C. The number of decrepitations increases towards the ore body and these data, when plotted and contoured on the grid, focus attention on the location of the ore body. This method generally yields extensive aureoles around the ore deposits which extend much beyond the usual geochemical aureoles.

This method is particularly useful in locating blind ore bodies and various types of hydrothermal ore deposits and has a great potential for prospecting ores in India. (From the author's abstract)

SLIVKO, T.A., STEPINA, S.B., POLETAEV, I.F. and LYUDOMIRSKAYA, A.P., 1982, The system Cs^+, $K^+||Cl^-$, F^- - H_2O at 25°C: Zhurn. Neorg. Khimii, v. 27, no. 4, p. 1080-1081 (in Russian). Authors at Moscow Inst. of Fine Chem. Technology, USSR.

Solubility in the system Cs^+, $K^+||Cl^-$, F - H_2O at 25°C was studied using the isothermal method. Boundaries of crystallization fields were found for $KF \cdot 2H_2O$, KF, $CsF \cdot 1.5H_2O$ and solid solutions K(Cs)Cl and Cs(K)Cl. The compositions of triple points, two transitional and one eutectic, were determined. (Authors' abstract translated by A.K.)

SMALLEY, R.E., 1982, Mass-selective laser photoionization: J. Chem. Education, v. 59, no. 11, p. 934-939. Author at Rice Quantum Inst. & Dept. Chem., Rice Univ., Houston, TX 77251.

Possibly the ultimate procedure in analysis, as presumably single ions can be detected. (E.R.)

(Note that the issue number is incorrect as printed on the article itself.)

SMIRNOV, V.I., 1982, Problems of ore formation: Geol. Rudn. Mest., v. 24, no. 6, p. 3-12 (in Russian). Author at Moscow State Univ., Moscow, USSR.

Review of problems discussed during the VI IAGOD Meeting in Tbilisi, 1982, including fluid inclusion lectures. (A.K.)

SMITH, D.L., EVANS, Brian and WANAMAKER, B.J., 1982, Crack healing in silicates: experimental observations on quartz and olivine (abst.): EOS, Trans. Am. Geophys. Union, v. 63, p. 437. Authors at Dept. Geol. & Geophys. Sci., Princeton Univ., Princeton, NJ 08544.

Crack healing may occur in porous silicates by diffusional rearrangement of the solid silicate phase and need not involve the introduction of new matrix material. The morphology of the porosity may be modified by diffusional transport of material through the silicate lattice, along silicate/fluid interfaces, or through fluid filled inclusions provided that the cracked solid is annealed for sufficient time at temperature. We are observing the kinetics of crack healing in closed systems of olivine, with and without melt and in quartz with water present as a pore fluid. Experimentally healed cracks formed in both olivine and quartz bear a strong resemblance to healed cracks previously observed in natural samples and in ceramics.

The length of time necessary to completely heal a microcrack depends on temperature, the presence or absence of a pore fluid and on the initial aspect ratio of the crack. The healing of microcracks in both quartz and olivine is fast enough to observe in the laboratory at temperatures of 400°-600°C and 1000°-1200°C respectively. Crack regression rates in quartz seem to be influenced by crystallographic orientation either because of irregularities in the original crack surface or because diffusion rates are anisotropic. Additionally, the fluid inclusions which are formed are not spherical in all cases, possibly an indication of anisotropic free surface energy. The experiments may be useful in predicting the lifetime of connected porosity in natural situations. (Authors' abstract)

SMITH, D.M., Jr., ALBINSON, Tawn and SAWKINS, F.J., 1982, Geologic and fluid inclusion studies of the Tayoltita silver-gold vein deposit, Durango, Mexico: Econ. Geol., v. 77, p. 1120-1145. First author at Rocky Mountain Explor. Div., ASARCO Inc., 9305 W. Alameda Pkwy., Lakewood, CO 80226.

Precious metal production from veins of the Tayoltita mine totals more than 10^7 kg of silver and 2×10^5 kg of gold. The deposit, the largest in the San Dimas mining district, occurs in the central part of the Sierra Madre Occidental volcanic pile which contains rocks reflecting two separate periods of magmatism. K-Ar dating by McDowell and Keizer (1977) demonstrates that these were active between 100 and 45 m.y. and 32 and 23 m.y. ago. Encasing the veins are rhyolitic, andesitic, and granodioritic rocks of the older magmatic episode. Ignimbritic rocks of the younger period of magmatism postdate the mineralizing event, which occurred about 40 m.y. ago. With only one exception, the N 15° W Arana fault vein, economic mineralization is restricted to fractures striking east-west to north-northeast. Regional normal faults trending north-northwest cut the rocks of both magmatic episodes and divide the district into tilted blocks dipping east.

Supergene processes played an insignificant role in the formation of ore. Hypogene open-space fillings can be divided into three paragenetic stages: (1) quartz with or without abundant sphalerite, and galena with or without minor silver-gold values; (2) quartz with or without three mutually exclusive gangue suites all occurring with ore-grade (+200 ppm Ag and +2 ppm Au) precious metal values, but each with or without dark green hydrothermal chlorite and copper-lead-zinc sulfides: quartz-rhodonite/johannsenite-albite, quartz-adularia, and quartz-calcite; (3) white to amethystine vuggy quartz. Small amounts of pearceite, native silver, chalcopyrite, calcite, and zeolites were deposited in stage 3 vugs during the waning stage of the hydrothermal system.

Silver and gold were deposited within a horizontal favorable zone minimally estimated to have been 600 m thick which essentially paralleled the untilted volcanic pile. The distributions of both metals are zoned vein by vein with respect to two small granodiorite stocks with Ag/Au varying from 44 to 105 with the lowest Ag/Au closest to the intrusions. Filling temperatures for quartz of stage 2 (250° to 290°C) and stage 3 (250° to 310°C) show little time-space variation of temperature during the mineralizing event. Indications of boiling in stage 3 quartz are found over a broad three-dimensional range. Salinities of the inclusion fluids range from 4.1 to 9.7 equivalent weight percent NaCl in stage 1, 3.3 to 8.4 weight percent in stage 2, and 1.9 to 9.7 weight percent in stage 3. Fluid inclusion data and field relationships indicate an approximate 400-m depth below the surface for the top of the favorable zone at the time of vein formation.

Gas analyses of thermally decrepitated fluid inclusions indicate that water constituted over 99.5 mole percent of the liquid and gas phases with CO_2 comprising most of the remainder. The $\delta^{18}O$ values of stages 2 and 3 vein quartz range from 3.9 to 4.8 per mil, suggesting that meteoric water dominated the hydrothermal system. (Authors' abstract)

SMITH, J.V., 1982, Storage of volatiles in the mantle (abst.): EOS, Trans. Am. Geophys. Union, v. 63, p. 449. Author at Dept. Geophys. Sci., The Univ. Chicago, Chicago, IL 60637.

Important hosts in the upper mantle are apatite (halogens), mica and amphibole (H, halogens), carbonates and diamond (C), and fluid phases. Mass-balance calculations are difficult because of uncertainty in the bulk composition of the earth and its zones, and because magmas and xenoliths provide information on unusual parts of the upper mantle.

For halogens, mantle reservoirs contain less than one-third of the Cl and Br, and this may provide some control on mechanisms for recycling crust into mantle. Ion microprobe analyses for anhydrous silicates show a peak at mass 19 tentatively assigned to F, but quantitative evaluation is still needed. Estimates for the bulk Earth are F $\sim 10x10^{19}$Kg, Cl $<66x10^{18}$, Br $<17x10^{16}$.

Micas and amphiboles from kimberlites, lamprophyres, and peridotite xenoliths show complex chemical variations tentatively attributed to hybridization of Ti-poor peridotite with Ti-rich magmas, to crystal-liquid differentiation generally to Fe, Ti-rich compositions, and to metamorphism. The sources of Ti-rich magmas are uncertain, and subducted crust may be important.

A large fraction of the carbon may have entered the metallic core during accretion of reduced material. Loss of H from the early Earth may be important for subsequent oxidation of elemental C in the mantle. Although abundant CO_2 from the mantle is an attractive source for granulite metamorphism, there is no firm control on the genesis of the requisite mantle reservoir. Dolomite is very rare in peridotite xenoliths, and secondary calcite is common. There is no mineralogical evidence in support of a massive reservoir of methane in the mantle.

Rare gases have no obvious mineral host. Perhaps mechanical processes release atoms accidentally occluded in refractory minerals that crystallized during accretion. (Author's abstract)

SNEERINGER, M.A., WATSON, E.B. and ROSS, A., 1982, Diffusion of CO_2 in a simple silicate melt (abst.): EOS, v. 63, p. 450. First author at Geol. Dept., Rensselaer Polytech. Inst., Troy, NY 12181.

The diffusivity of dissolved carbonate in a sodium aluminosilicate melt was measured. The new diffusivity data are applicable to many magmatic processes that involve CO_2 transport, e.g., exsolution of CO_2-rich vapors and liquids from kimberlite and other alkalic magmas of deep origin. (From the authors' abstract)

SOBOLEV, A.V. and SLUTSKY, A.B., 1982, Melt compositions and crystallization conditions of Troodos massif lavas (Cyprus) based on melt inclusions investigation data (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 216-217. Authors at Inst. Geochem. & Analy. Chem., Moscow, USSR.

Olivine porphyry lavas (MgO = 37-25 wt.%) of the Upper Pillow-Lava Unit from Troodos massif, Cyprus have been studied. Optical investigation of olivine megacrysts and subphenocrystals have revealed the following types of magma inclusions: partly crystallized melt inclusions, fluid inclusions and anomalous ones, consisting of various amounts of melt, fluid and chromite. Optical and microprobe study suggests that melt inclusions contain gas phase, andesite glass and high-alumina clinopyroxene.

Temperature investigations were carried out using a low inertia high temperature apparatus, which permits performing optical observations and sample heating in the required atmosphere.

The inclusions are characterized by very low temperatures of start of glass melting (650-700°C), that suggest not less than 5 wt.% H_2O content in the glass. Homogenization temperatures in olivine inclusions depend on host crystal composition, ranging from 1420 to 1300°C. Melt inclusions in clinopyroxene are homogenized under 1100-1150°C.

The homogenized inclusions vary in composition from primary picrite (MgO = 20 wt.%, Tn = 1430°C) to tholeiitic basalt of island arc type (Tn = 1100°C).

The freezing data on fluid inclusions indicate that they represent a phase of low density (filling degree less than 10 vol.%)(sic).

Investigation data suggest that rocks under study are olivine cumulates of the picrite magma, crystallized under 1430-1100°C and low pressures (P = 1-2 kbar) due to its saturation by water-rich fluid.

The possibility of gas regime changes in the inclusion caused by hydrogen diffusion through the crystalline shell of host mineral, as well as the indirect signs of water content in melt inclusions are discussed in the paper. (Authors' abstract)

SOBOLEV, V.S., 1982, The present state and aims of thermobarogeochemical studies, in Use of methods of thermobarogeochemistry during prospecting and studies of ore deposits, N.P. Laverov, ed.: Moscow, "Nedra" Publ. House, p. 4-6 (in Russian).

The author presents the most important topics of the fluid inclusion studies in the last years: investigations of melt inclusions (glassy and crystallized). However, Soviet scientists have worse results in determinations of melt composition (by microprobe methods) than their foreign colleagues. As the outstanding results are quoted the works of Clocchiatti (France) with biotite crystallization in melt inclusions in liparites and Roedder's studies of high-pressure CO_2 inclusions in magmatic minerals. Also further development of theory is important. Soviet scientists, being relatively short in the modern devices, continuously improve heating stages, and they are able to determine Th more exactly than abroad. Individual melt inclusions were studied also for determination of H_2O and some gas contents, but in metamorphic rocks, after first successes in CO_2 inclusion studies by Soviet scientist, more detailed studies were performed by foreign investigators. In 1980 at the International Geol. Congress in Paris, the President of COFFI, E. Roedder, made critical remarks on the use of inexact and incorrect P determination methods by Soviet scientists. Some of the remarks are true and this criticism should be necessarily answered by Soviet scientists in print in extended form, but only after hard work and well-founded theoretical studies. The author hopes that Soviet scientists will come back to the leading group of the world inclusioneers. (Abstract by A.K.)

SOKOLOV, S.V., 1981, Temperature variation in the production of alkali-ultrabasic rocks with carbonatite intrusions: Geokhimiya, no. 2, p. 249-256 (in Russian; translated in Geochem. Int'l., v. 18, no. 1, p. 159-166, 1982).

Abstract in Fluid Inclusion Research--Proceedings of COFFI, v. 14, p. 197. (E.R.)

SOKOLOV, S.V., 1982, Problems of studies of inclusions of various phases in coexisting minerals, *in* Use of methods of thermobarogeochemistry during prospecting and studies of ore deposits, N.P. Laverov, ed.: Moscow, "Nedra" Publ. House, p. 146-154 (in Russian).

Studies of inclusions in forsterite and apatite from carbonatite yielded the following conclusions:

1. Sharp nonuniformity in phase composition (quantitative and qualitative) of inclusions syngenetic one with another and with host mineral in many cases indicates heterogeneous state of mineral-forming melts and solutions.
2. Differences in phase composition and Th of P inclusions are not unambiquous confirmation of their anomalous nature and may be explained by local fluctuations of density and concentration of mineral-forming medium.
3. Th and phase composition cannot be used as criteria of P or S nature of inclusions.
4. Most objective data may be obtained from studies of inclusions in all minerals of the association, not in one of them. (From the author's conclusions, translated by A.K.)

SOLOVOVA, I.P., RYABCHIKOV, I.D., KOVALENKO, V.I. and NAUMOV, V.B., 1982, Inclusions of high-denisty CO_2 in mantle lherzolites: Akad. Nauk SSSR Doklady, v. 263, no. 1, p. 179-182 (in Russian). First author at Inst. of Geol. of Ore Deposits, Petrography, Mineralogy and Geochemistry of Acad. Sci. USSR, Moscow.

A lherzolite nodule from the region Dreiser Weicher, Eifel, W. Germany, consists of olivine Fo 95, ortho- and clinopyroxene, single grains of amphibole, spinel, sulfides and some glass. Lherzolite slides contain following inclusions: crystal, P and S melt, P and S fluid; 80-90% of the latter have leaked. T of melting of fluid inclusions (-57 to -58°C) indicate that they are filled by almost pure LCO_2; Th of P LCO_2 inclusions range from -35 to -57°C proving a high density of CO_2. Olivine and orthopyroxene bear single magmatic melt inclusions with crystal phases that start to melt at 1090-1100°C, at 1300°C inclusions bear only melt and G, later inclusions decrepitate, but phase ratios indicate a possible Th 1350-1400°C. S melt inclusions have Th 1150-1170°C. LCO_2 and GCO_2 in S melt inclusions homogenize at 24.0-26.5°C (hence density of CO_2 0.69-0.73 g/cm^3, amount of CO_2 in melt of S inclusions equals 2.9 ± 1.0 wt. %. Pressure for P inclusions of CO_2 was 9.7-10.8 kbar (depth ~35-40 km); S inclusions that may reflect the stage of reworking of lherzolite nodule in intermediate magma chamber (P 4-4.5 kbar, depth 14.5-16 km). The dominate fluid in the deep zones of the Earth is CO_2 under $P \geqslant 11$ kbar. (Abstract by A.K.)

SOLYANIK, AN.N., 1982, Apatite-bearing gabbro-syenite intrusives and genesis of apatite-ilmenite-titanomagnetite ore mineralizations in the Dzhugdzhur Ridge: Geol. Rudn. Mest., v. 24, no. 4, p. 8-17 (in Russian). Author at Far East geol. Inst. of Far East Sci. Center of Acad. Sci. of

USSR, Vladivostok.

The paper bears some literature data on Th of melt inclusions and Th of fluid inclusions in apatite equal 440-518, 320-416, 100-200°C. (A.K.)

SOMMER, M.A. and SCHRAMM, L.S., 1982, Volatiles in the cyclic Bandelier Tuff, Jemez Mountains, New Mexico (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 622. First author at Dept. Geol, Florida State Univ., Tallahassee, FL 32306.

We have developed a new method for the quantitative measurement of the amounts of volatiles in silicate melt inclusions in phenocrysts. The analytical system utilizes a partial pressure capacitance manometer determination of volatiles released upon vacuum heating of quartz phenocrysts. Glass concentrations within phenocrysts were determined by a combination of glass-specific element analysis by electron microprobe and total phenocryst element concentrations by atomic absorption-emission spectroscopy. This technique was applied to the cyclic airfall/airflow deposits of the Bandelier Tuff. Water concentrations in the initial airfall deposits of each cycle were proportionally higher than those of the subsequent ashflow deposits. Melt inclusions in quartz phenocrysts of the Lower Member airfall have an average of 3.99 wt. % water; in the Upper member airfall have an average water content of 2.11 wt. %. Melt inclusions in quartz phenocrysts of the Lower Member ashflow have an average of 1.71 wt. % water; in the Upper Member ashflow have an average water content of 0.79 wt. %.

From the volatile determinations of the Bandelier Tuff, we have reconstructed the intratelluric environment and volcanic evolution of the Bandelier magma where volatile (primarily water) concentrations in a shallow magma chamber increase until overburden pressure is exceeded and explosive eruption occurs with subsequent airfall emplacement. The volatile driving force is then relieved by magma boiling, resulting in an increasingly quiet discharge (i.e., ashflow eruption). Theoretical calculations based on the constraints of the data yield a total energy of each Bandelier eruption to be about 7 x 10^{27} ergs; among the largest of any known eruption. (Authors' abstract)

SONG, Zhigao, 1982, The environments of formation of the Baiyinchang massive sulfide deposit and the implication of its origin: Geol. Review, v. 28, 1982, p. 335-343 (in Chinese; English abst.). Author at Xi'an Instit. Geol. & Mineral. Resources, Chinese Acad. Geol. Sci.

The Baiyinchang massive sulfide deposit is one of a number of stratabound volcanogenic base-metal deposits in the eastern part of the Qilian Mountains, northwest China. This deposit is associated with lower Paleozoic marine volcanic and sedimentary rock sequences, the volcanic rocks being mainly represented by a spilite-keratophyre sequence. It occurs in Middle Cambrian acidic volcanic rocks. The orebody is made up of pyrite with some sphalerite and chalcopyrite, and minor pyrrhotite, magnetite and arsenopyrite. The gangue minerals are chiefly quartz, chlorite and sericite. An important feature of the texture of the massive ore is that microbands from a few tens of micron to several mm in thickness are observed between different kinds of sulfide or between sulfide and magnetite.

The sulfur isotope measurements gave the following results: pyrite, δS^{34} = 0.88-8.72‰ (dominantly 4.04‰); chalcopyrite, δS^{34} = 4.10‰. The lead isotope data (near the Xiaotieshan Pb-Zn-Cu polymetallic deposit) are: Pb^{208}/Pb^{204} = 17.60; Pb^{207}/Pb^{204} = 15.30 and Pb^{206}/Pb^{204} = 37.85. The study on fluid inclusions in quartz from the orebodies gave a filling temperature of 200-374°C.

Based on the above mentioned data, the author concludes that the Baiyinchang massive sulfide deposit represents the chemical sediments derived from mineralizing fluids migrating along the sea floor. The Cu-Zn mineralizations appear to result from the intrusion of the late-stage mineralizing hydrothermal fluids along or through massive sulfide bodies or the country rocks beneath them. The mineralization, mineralogy and chemistry show that the Baiyinchange deposit bears a strong resemblance to other volcanogenic massive sulfide deposits in Australia, Canada and Japan. (Author's abstract)

SOTNIKOV, V.I., KASTRYKIN, Yu.P. and NIKITINA, Ye.I., 1981, Distributions of chlorine and fluorine in the minerals of intrusive and postmagmatic rock bodies of molybdenum shows in the Stanovoy Range: Geokhimiya, 1981, no. 3, p. 361-370 (in Russian; translated in Geochem. Int'l., v. 18, no. 2, p. 18-27, 1982). Authors at Inst. Geol. & Geophy., Siberian Div., Acad. Sci. USSR, Novosibirsk, and Aerogeol. Prod. Union, Moscow, USSR.

Microprobe studies have been made on biotite and apatite from granitoids of various ages and states of alteration occurring in the area of the molybdenum shows related to the Stanovoy deep fault; the geochemistry of chlorine and fluorine in the endogenous process is considered. The rocks of a potentially ore-bearing igneous complex are usually characterized by relatively high chlorine specialization (the F/Cl ratios in the minerals are reduced). Conditions are more favorable to accumulation of chlorine in the minerals at relatively small depths in a setting facilitating the accumulation of chlorine. Hydrothermal alteration is characterized by increase in the F/Cl ratio in the recrystallized and newly formed minerals. (Authors' abstract)

SOUTHWOOD, M.J., 1982, The geological setting of the sulphide deposits at Morfa Du, Parys Mountain, Anglesey (abst.), in Applied Earth Sci., Transactions Sec. B., v. 92 p. B99: Ph.D. thesis, Univ. College, Cardiff, England.

Stratiform volcanogenic sulphide deposits at Parys Mountain are associated with a thin but complex bimodal volcanic sequence, dominated by submarine rhyolitic ash flows, with subordinate rhyolitic and basaltic lavas and epigenetic sediments.

The two major styles of mineralization are low-grade disseminated sulphides, hosted by siliceous sinter (Quartz Rock), and high-grade massive sulphides. The major ore minerals are pyrite, sphalerite, galena and chalcopyrite. Fluid inclusion studies indicate that the sulphides in the Quartz Rock were deposited from warm hydrothermal solutions (temperature ≅ 175-200°C; salinity ≅ 8 wt% NaCl equivalent), which were exhaled on to the sea-floor. Turbulent mixing of the ascending ore solutions with the ambient sea water led to rapid quenching and hence deposition of the ore minerals. (From the author's abstract)

SPIRAKIS, C.S., 1982, Effects of sulfur kinetics on redox reactions and implications for the genesis of epithermal ore deposits (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 43-44.

SREBRODOL'SKIY, B.I., 1982, The amber deposit Klesovo in Volyn: Izvestiya Akad. Nauk SSSR - Ser. Geol., no. 4, p. 79-86 (in Russian). Author at Inst. Geol. Geochem. of Mineral Fuels, L'vov Ukrainian SSR.

Amber bears inclusions of plant, mineral and atmospheric origin.

Mineral inclusions comprise calcite, pyrite and clay minerals. Atmospheric inclusions are filled by G and G+L, and they are up to 2 mm long. G phase makes up a variable part of inclusions in amber. (A.K.)

STALDER, H.A. and RYKART, R., 1980, Negative [crystal] forms of epidote in quartz crystals: Schweizer Strahler, v. 5, no. 8, p. 320-327 (in German).

It is shown that on changing from a CO_2-poor to a (relatively) CO_2-rich fluid (Th = 240°-258°C, 9 equiv. weight % NaCl, 8-12 vol.% of CO_2 with a density of 0.22 g/cm^3) epidote crystals in alpine fissure quartz become unstable. (Abstract by H.A. Stalder)

STAROSTIN, V.I., LYCHANKOV, V.A. and SERGEYEVA, Nat.Ye., 1981, Metamorphogenic redistribution of elements in pyrite-polymetal ores: Geol. Rudnykh Mestor., no. 4, p. 30-43 (in Russian; translated in Int'l. Geol. Review, v. 24, no. 10, p. 1163-1173, 1982). Authors at Lomonosov Moscow Univ.

Results of microanalytical study of three types of pyrite-polymetal ores, weakly metamorphosed (rhythmically stratified), metamorphosed (crushed in longitudinal bending folds), and metamorphogenic (completely altered) are presented.

It is found that, in systems in structural equilibrium, the spatial distribution of isoconcentration contours for impurity elements and the compositions of complex sulfides within the folds correspond to the shape of the paleotectonic stress field which existed during the period of their formation. The data from study of inclusions in quartz and the iron-sulfur ratio in spherical pyrite segregations indicate that the metamorphogenic ores formed at 560-920°C and 3-6 x 10^6 GPa in the presence of liquid CO_2. (Authors' abstract)

STAUDACHER, Thomas and ALLÈGRE, C.J., 1982, Terrestrial xenology: Earth & Planet. Sci. Letters, v. 60, p. 389-406. Authors at Lab. Géochimie Cosmochimie, Inst. Phys. Globe et Dept. Sci. de la Terre, Univ. Paris 6 et 7, 4, Place Jussieu, 75230 Paris Cedex 05, France.

The xenon isotopic composition measured in samples from various origins shows that variations relative to the atmospheric standard are common. Excesses in ^{129}Xe and fissiogenic xenon, derived from the extinct radioactivities ^{129}I and ^{244}Pu respectively, are characteristic of mid-ocean ridge basalts, whereas ^{238}U-fission xenon excesses are only found in granitoid samples or in samples which are contaminated by the continental crust. Hence, the xenon isotopes can be used as tracers in geodynamics. A model for the degassing of the terrestrial mantle is developed and reflections on the time interval between the formation of meteorites and the formation of the Earth are made. (Authors' abstract)

STEMPROK, Miroslav, 1982, Tin-fluorine relationships in ore-bearing assemblages, in Metallization Associated with Acid Magmatism, A.M. Evans, ed.: New York, J. Wiley, p. 321-337. Author at Geol. Survey, Prague.

The association of tin- and fluorine-bearing minerals in nature is often explained by the pneumatolytic transportation of tin as SnF_4. Using a granite glass strongly enriched in SnO_2 the volatilization of Sn was tested in a stream of NH_4F. The distribution of Sn between immiscible alkaline fluoride melts and the granite glass was followed by microprobe analysis. The results show that tin is little volatilized from a silicate environment by NH_4F even though the same reaction is characteristic of NH_4I. Tin is also not significantly partitioned into immiscible NaF or LiF melts and remains in the silicate liquid. The association of tin and fluorine in many natural assemblages may be explained by their mutual complexing in hydrothermal environments or independent concentration in residual alkaline melts resulting from the crystallization of granitic melts. (Author's abstract)

STENINA, N.G., CHEPUROV, A.I. and TITOV, A.T., 1982, Electron microscope studies of inclusions in natural quartz, in N.P. Ermakov, ed., Thermobarogeochemistry in Geology - Materials of the Sixth All-Union Symposium on Thermobarogeochemistry: Vladivostok, Far East Sci. Center, Acad. Sci. USSR Pub. House, p. 147-151 (in Russian).

For abstract, see Fluid Inclusion Research--Proceedings of COFFI, vol. 13, 1980, p. 245. (A.K.)

STOESSELL, R.K., 1982, Chemical constraints and origins of four Gulf Coast reservoir fluids (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 626.

STOESSELL, R.K. and BYRNE, P.A., 1982, Salting-out of methane in single-salt solutions at 25°C and below 800 psia: Geochimica Cosmo. Acta, v. 46, p. 1327-1332.

STOLPER, Edward, 1982a, Water in silicate glasses: an infrared spectroscopic study: Contrib. Mineral. Petrol., v. 81, p. 1-17. Author at Div. Geol. & Planet. Sci., California Inst. Tech., Pasadena, CA 91125, USA.

Infrared and near-infrared transmission spectra have been taken on 19 volcanic and synthetic silicate glasses with known H_2O contents (0.06-6.9 wt.%).

Quantitative determinations of total H_2O contents and of the concentrations of molecular water and hydroxyl groups in silicate glasses are possible using these molar absorptivities, although they are limited in their accuracy by the accuracy of the reported water contents of the glasses used to calibrate these molar absorptivities. The most important uses of this technique may stem from its applicability to microsamples ($\geqslant$100 μm) and to the determination of the concentrations of hydroxyl groups and molecular water in quenched silicate melts.

Hydroxyl groups are the dominant hydrogen-bearing species in water-bearing glasses at low total water contents, but molecular H_2O was detected in all samples with $\geqslant$0.5 weight percent total water. Molecular water in these glasses is probably structurally bound rather than present as fluid inclusions as a separate phase, since ice bands were not observed in spectra taken at 78K and since samples were free of visible bubbles.

It is proposed that the speciation of water in silicate glass formed by rapid quenching from melt equilibrated at high temperatures reflects that of the melt. According to this hypothesis, neither high water contents nor high pressures are needed to stabilize substantial quantities of molecular water in melts. This hypothesis, that water dissolves in silicate melts as both molecular water and hydroxyl groups in proportions similar to those measured in water-bearing glasses, can explain the variations in viscosity, electrical conductivity, diffusivity of "water," diffusivity of cesium, and phase relationships that are observed in melts as functions of total water content. It also explains the observation that at vapor-saturation at high pressures, where most of the dissolved water is expected to be present as molecular water, water solubilities are similar for all melts but that at low pressures and water contents, where most dissolved water is present in dissociated form as hydroxyl groups, vapor-saturated water solubilities differ from different melt compositions. The linear relationship between water fugacity and the square of the mole fraction of total dissolved water observed for silicate melts at low water contents and the observed deviations from this linear relationship at high total water contents can be accounted for by this hypothesis. (From the author's abstract)

STOLPER, Edward, 1982b, The speciation of water in silicate melts: Geochimica Cosmo. Acta, v. 46, p. 2609-2620. Author at Div. Geol. & Planet. Sci., California Inst. Tech., Pasadena, CA 91125, USA.
See also previous abstract. (E.R.)

STOLPER, E., 1982c The speciation of water in silicate melts: a model based on infrared spectroscopic studies of silicate glasses (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 626.

STOLYAROV, Yu.M., 1982, New data on zoning of molybdenum deposit Shakhtama (Eastern Transbaikalia): Akad. Nauk SSSR Doklady, v. 262, no. 5, p. 1219-1222 (in Russian). Author at Div. of Exper. Studies of Central Sci.-Research Geol.-Prosp. Inst., Tula, USSR.
Quartz-molybdenite association yielded Th 405-320°C and P 1125-1100 atm, quartz-pyrite 280-250°C and carbonate-polymetal 240-100°C. Explosive breccias and ore (Mo) mineralization in them formed at T up to 650°C and P to 2500 atm. (A.K.)

STUDEMEISTER, P.A., KERRICH, R. and FYFE, W.S., 1982, Geochemistry and field relations of lode gold deposits in felsic igneous intrusions, *in* Geoscience Research Grant Program, Summary of Research 1981-82, E.G. Pye, ed.: Ontario Geol. Survey Miscellaneous Paper 103, p. 185-209. Authors at Dept. Gol., Univ. Western Ontario Canada.
Initial contact metamorphism of volcanic rocks at T = 450°C to 550°C and P <2 kbar by a trondhjemite stock culminated in an aureole of epidote-hornblende hornfels. Subsequent regional metamorphism at T = 325°C to 450°C and P = 2 to 3 kbar overprinted a lower greenschist assemblage on the stock and its aureole. The retrogression of hornfels and trondhjemite by metamorphogenic fluids (Th 250-340°C) triggered the precipitation of native gold, pyrite, and quartz along fractures. (From the authors' abstract)

SUSHCHEVSKAYA, T.M., 1982a Estimation of pH and Eh of ore-bearing hydrothermal solutions using data of inclusion compositions (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 217. Author at Inst. Geochem. & Anal. Chem., Moscow, USSR.
Efforts have been made to calculate the pH-values of ore-bearing solutions according to compositions of the inclusions, using different methods. Analytical limitations of these methods have been shown. The pH values of the inclusions have been estimated using a computer, taking into account the effects of dissociation and hydrolysis and formation of complexes of basic solution components at ore-formation temperatures of the deposits under study.
The data of salt and gaseous composition of gas-liquid inclusions have been tentatively used to estimate the oxidizing-reducing potential. Possible contribution of organic substances into concentration values of gaseous components has been estimated experimentally with a thermal release of the inclusions, and some ways to remove this effect have been discovered. Concentrations of CO_2, CH_4, H_2 for high-temperature hydrothermal deposits have been found by the method of gas chromatography to be close to the equilibrium. The values of Eh ranging from -0.6 to -0.9 B(V?)

for tin-bearing hydrothermal solutions have been estimated from the carbon-dioxide-methane equilibrium, using the data on the salt composition and pH of the inclusions solutions.

The estimation of acidity-alkalinity of hydrothermal solutions derived from the compositional analytical data of fluid inclusions has been used to reveal the chemical mechanism of precipitation of tin in the form of cassiterite from hydrothermal tin-bearing solutions. (Author's abstract)

SUSHCHEVSKAYA, T.M., 1982b, Use of highly-sensitive instrumental methods for analysis of inclusion composition in minerals, in Use of methods of thermobarogeochemistry during prospecting and studies of ore deposits, N.P. Laverov, ed.: Moscow, "Nedra" Publ. House, p. 6-14 (in Russian).

The author presents the use of the following analytical methods for inclusion studies, essentially on the basis of literature data: A. Reactions in solutions - volumetric and nephelometric methods; B. Radiation absorption - AAS and IR absorption; C. Electroanalytic methods - potentiometry and polarography; D. Radiation emission - flame photometry, emission spectroscopy, electron microprobe; E. Use of magnetic field - mass spectrometry. (A.K.)

SVEINBJORNSDOTTIR, A.E., 1982, Water-rock interaction in Krafla and Reykjanes geothermal systems, Iceland (abst.): Geol. Soc. Newsletter (London), v. 11, no. 4, p. 17-18. Author at Univ. East Anglia.

The hydrothermal alteration in the Krafla and Reykjanes geothermal systems is similar, in spite of contrasting hydrothermal fluids. Oxygen isotope measurements demonstrate that the hydrothermally altered rocks have undergone extensive oxygen isotope exchange with the thermal waters. The results are an average ^{18}O depletion of about 10% in the Krafla system and about 2.5% in the Reykjanes. The ^{18}O depletion of the rock samples in the Reykjanes drillhole show that the circulating fluid in the Reykjanes geothermal field has, at some earlier stage of the system, been lighter (i.e., more meteoric) than at present. Hydrothermally grown quartz at Reykjanes appears also to record a lighter fluid than now present in the system. However, calcite is found to be in equilibrium with the present fluid at the present temperature, but demonstrates that the hydrothermal water at Reykjanes is isotopically heterogeneous. Hydrothermally grown quartz and calcite indicate a higher "fossil" temperature in the Krafla geothermal field than is measured at present. The alteration mineral assemblages, both in Krafla and Reykjanes, appear to be in ionic equilibrium with the present hydrothermal fluids at present field temperatures, however, the extent to which this is true in detail will be discussed. (Author's abstract)

SVERJENSKY, D.A., 1982, Oil-field brines as ore-forming fluids (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 628.

SZEWCZYK, J., KARNIEWICZ, J. and KOLASINSKI, W., 1982, Growth kinetics of lithium formate crystals in normal and heavy water solutions: J. Crystal Growth, v. 60, p. 14-20. Authors at Instit. Physics, Tech. Univ. of Lodz, ul. Wolczanska 219, 93-005 Lodz, Poland.

Data on growth rates of hydrated lithium formate (LFM) and deuterated lithium formate (DLFM) crystal faces as a function of supersaturation at 307.65 K and observations of growth hillocks and liquid inclusions are presented and discussed. Following Bennema's modification of the BCF surface diffusion model as applied to crystal growth from solution, the values of growth parameters have been calculated and compared with the values reported for the growth of other substances. It was found that large liquid inclusions begin to appear at supersaturations $\sigma>0.0185$ for LFM and $\sigma>0.0192$ for DLFM, but tiny inclusions appear even at $\sigma = 0.0108$. (Authors' abstract)

TAGUCHI, Sachihiro, 1982, Underground thermal structure of geothermal fields revealed by the distribution of homogenization temperature of fluid inclusions: J. Geotherm. Res. Soc. of Japan, v. 3, no. 3, p. 165-177 (in Japanese; English abstract). Author at Res. Inst. Ind. Sci., Kyushu Univ.
See next abstract. (E.R.)

TAGUCHI, Sachihiro and HAYASHI, Masao, 1982, Application of the fluid inclusion thermometer to some geothermal fields in Japan: Geotherm. Res. Council, Transactions v. 6, p. 59-62. Authors at Res. Inst. Ind. Sci., Kyushu Univ. 86, Kasuga City, Fukuoka 816, Japan.

Th of fluid inclusions in hydrothermal quartz, anhydrite and calcite from some geothermal fields in Kyushu, Japan, has been measured. In the very active Hatchobaru geothermal field, it has revealed that Th is near the boiling point curve of water, and agrees well with the present reservoir temperatures. On the other hand, in the less active Kirishima geothermal field, inclusions have a wide range of Th, and their minimum values are quite close to the present underground temperatures. This may indicate that the geothermal field has cooled down to some extent, and also that the fluid inclusions have been formed at various stages of the cooling process. Some considerations suggest that not only the primary inclusions but also the secondary ones can be useful, when they contained only liquid at the time of trapping. (Authors' abstract)

TAKENOUCHI, Sukune, 1981, Fluid inclusion studies of several Philippine porphyry copper deposits, in Metallogeny of Asia 1980; Proc. of an Int'l. Symp. on Metallogeney of Asia, S. Ishihara and A. Sasaki, eds.: Report of Geol. Survey of Japan, No. 261, p. 149-167. Author at Univ. Tokyo, Dept. Miner. Dev. Engrg., Tokyo, Japan 113.

Fluid inclusions in porphyry copper deposits of the Philex, Marcopper, Sipalay, Basay and Atlas mines were studied. Polyphase, gaseous and liquid inclusions were found in these deposits, but the mode of occurrence of these fluid inclusions varied from deposit to deposit, and suggested a relationship between the hydrothermal activity and the pattern of mineralization and wall-rock alteration. A vertically extended pipe-shaped orebody was rich in high-salinity polyphase inclusions but poor in low-salinity liquid inclusions, suggesting a significant contribution of magmatic water to the formation of the ore deposit. Liquid inclusions were predominant in a laterally extended flat-lying orebody, indicating an intense activity of circulating meteoric water. Biotitization was pervasive in the former case and sericitization was overprinted on biotitization in the latter case. (Author's abstract)

TALANTSEV, A.S., 1982, Combined methods of thermobarogeochemistry -- principles and perspectives of improvement, p. 22-29, in Mineralogical studies of endogene deposits of the Urals: Sverdlovsk, Ural Sci. Center Publ. House, 700 copies printed, 152 pp., price 1 rbl. 05 kopecks (in Russian).

The combined method of thermobarogeochemistry is proposed, based on the complex use of results of studies of chemical composition of minerals with variable composition and P fluid inclusion investigations. The above methods support one another and result in the possibility of control. (Author's abstract, translated by A.K.)

TALBOT, C.J., TULLY, C.P. and WOODS, P.J.E., 1982, The structural geology of Boulby (potash) mine, Cleveland, United Kingdom: Tectonophysics, v. 85, p. 167-204. First author at Dept. Geol., The Univ. Dundee, DD1 4HN, Scotland, Great Britain.

Exceptional flowage of sylvinite is proposed to explain the structures. Involves a discussion of the effects of H_2O on weakening NaCl and KCl. (E.R.)

TALKINGTON, R., WATKINSON, D.H. and JONES, P., 1982, Platinum-group minerals and other solid inclusions in chromite of mafic-ultramafic complexes (abst.): Geol. Assoc. Canada/Min. Assoc. Canada Program with Abstracts, v. 7., p. 83. Authors at Dept. Geol., Carleton Univ., Ottawa, Ontario K1S 5B6, Canada.

In the present study of chromites, stratiform, ophiolitic and Alaskan-type from Canadian and other complexes, we have identified and analyzed platinum-group element minerals, alloys, native elements, anhydrous and hydrous silicates and oxides as inclusions in massive chromite and in disseminated chromite in a variety of lithologies.

The predominant platinum-group element phases are laurite-erlichmanite and Os-Ir-Ru alloys. Native Ag and Cu, and a Cu-Zn alloys are rare; Cu, Ni, Fe-bearing sulphides are common.

The silicate inclusions are olivine, enstatite, diopside, albite, Mg-amphiboles, Mg, Na-phyllosilicates, and "secondary" Mg-rich hydrous phases. All silicate minerals are Mg and Cr-rich and Fe-poor.

Oxide inclusions of magnetite, hematite, rutile and ilmenite are commonly rod-like or euhedral with their long axis parallel to a chromite crystallographic axis. These inclusions are abundant in the hydrated lithologies.

The common silicate minerals within chromites for all complex types are:

$$\left.\begin{array}{l}\text{olivine}\pm\text{pargasitic amphibole}\pm\text{sodic phyllosilicates}\\ \text{enstatite}\pm\text{Mg-amphibole}\pm\text{Mg-phyllosilicates}\\ \text{diopside}\pm\text{Mg-amphibole}\pm\text{Mg-phyllosilicates}\\ \text{Mg-amphibole}\pm\text{Mg-phyllosilicates}\pm\text{albite}\end{array}\right\}\pm\text{ metallic phase}$$

The intimate association of the platinum-group minerals, silicates and fluid inclusions with chromite suggests that the origin of these solid and fluid inclusions must be considered within a chromite crystallization model, whereby the chromite and its inclusions of metallic and other elements have been concentrated by fluids within crystallizing magma. (Authors' abstract)

TARASOV, A.V. and APLONOV, V.S., 1982, Temperature conditions of formation of sulfates associated with sulfides: Geologiya i Geofizika, no. 11, p. 51-56 (in Russian; English abstract). Authors at "Sevmorgeologiya," Noril'sk, USSR.

Sulfates (gypsum and anhydrite) associated with sulfide ores in the deposit Noril'sk-1 yield Td 900-500, 570-430, 410-210, 370-350, 200 and 150-90°C; pentlandite-chalcopyrite ores 430-210°C; these T ranges are attributed by authors to T of mineral formation(sic). (A.K.)

TAYLOR, B.E., 1982, Light stable isotope geochemistry of granitic gem- and non-gem-bearing pegmatites (abst.): Am. Mineral., v. 67, p. 185. Author at Dept. Geol., Univ. California, Davis, CA 95616.

The study of oxygen, carbon, and hydrogen isotope systematics of whole-rocks, mineral separates, and inclusion fluids from granitic pegmatites has elucidated many details regarding the magmatic crystallization history of certain pegmatites. Further, suggestion of the origins of many of the constituents of pegmatites (including gem minerals), comparison of isotopic variations in pegmatites of Precambrian to Late Cretaceous age, comparison of both deep- and shallow-seated environments, and distinction between magmatic and hydrothermal features in pegmatites and associated wall rocks are also possible. Isotopic compositions are generally similar for all granitic pegmatites examined, but differences in mineral fractionations for simple and complex pegmatites are found. Examples from more than ten major pegmatite districts in North America and Scandinavia are discussed.

The whole-rock oxygen isotope composition of pegmatites appears in most cases to reflect precrystallization isotopic exchange with wall rocks, while "closed-system" crystallization is indicated for the greater part of a pegmatite's crystallization history. Oxygen isotope fractionations indicate temperatures of formation (540-800°C) compatible with experimental data. Lower solidus temperatures of Li-bearing pegmatites are reflected by larger isotopic fractionations, and subsolidus crystallization of many minerals is indicated by both textural and isotopic evidence.

The hydrogen isotope variations of muscovite, biotite, and water released from fluid inclusions indicate that interaction with meteoric water is not typical of pegmatite emplacement and crystallization. The isotopic composition of micas falls within the range of "magmatic" water (δD = -40 to -80‰). The measured hydrogen isotope fractionations between inclusion fluid and hydrous minerals indicate temperatures of crystallization of magmatic to hydrothermal stages to be ~700 to 500°C.

The carbon isotope compositions of CO_2 released from fluid inclusions are typically in the range of -6.0 to -8.0‰ ($\delta^{13}C$). Some variation beyond this range (-2.2 to -15.6‰) may be due to late-stage contamination from wall rocks, loss of CO_2 from pegmatites during crystallization, or to analytical difficulties due to the very small sample size involved. (Author's abstract)

TERNOVOY, V.V., 1982, Criteria of relations of fluorite mineralization with granitic magmatism for the Chatkalo-Kuramin region (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 234-235.

THEODORE, T.G., BLAIR, W.N. and NASH, J.T., 1982, Preliminary report on the geology and gold mineralization of the Gold Basin-Lost Basin mining districts, Mohave county, Arizona: U.S. Geol Survey Open-File Report 82-1052, p. 1-

The Gold Basin-Lost Basin mining districts are associated with widespread quartz-cored pegmatite-vein systems. Some gold is found also in small episyenitic alteration pipes or in veins caught up tectonically.

Homogenization studies of fluid inclusions prominent in the veins and pipes yield temperatures mostly in the range 150 to 280°C. Early-stage trapping temperatures at the pipes probably were about 330°C and pressures in the range 500 to 700 bars can be inferred. Fluids were moderately saline, mostly 4 to 16 weight percent NaCl equivalent, nonboiling, and also contain appreciable amounts of carbon dioxide and, in places, fluorine. Such fluids associated with the deposition of gold in these districts largely bridge the fluid composition interval between many other epithermal precious-metal and porphyry copper deposits. (From the authors' abstract)

THEODORE, T.G., BLAKE, D.W. and KRETSCHMER, E.L., 1982, Geology of the Copper Canyon porphyry copper deposits: Lander County, Nevada, in S.R.

Titley, ed., Advances in Geology of the Porphyry Copper Deposits, Southeastern North America, p. 543-550.

Includes a discussion (p. 548-549) of fluid inclusion studies of the deposit, from the literature. (E.R.)

THEODORE, T.G. and MENZIE, W.D., 1982, Fluorine-deficient porphyry molybdenum deposits in the Cordillera of western North America (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 95-96. Authors at U.S. Geol. Survey, Menlo Park, CA, USA.

The primary and pseudosecondary fluid-inclusion signature of the deposits studied is diagnostic, and distinct from the fluid-inclusion signature of the Climax-type deposits. The quartz stockworks contain very abundant large inclusions that are moderately saline (possibly 4-12 equivalent weight percent NaCl) and that homogenize at moderate temperatures (250°-350°C). Fluid inclusions in many deposits contain significant but varying amounts of carbon dioxide (probably in the range 4-8 mol percent range). NaCl and KCl daughter minerals are sparse, and some trapped sulfides and iron oxide(s) have been identified. The $^{18}O/^{16}O$ and D/H isotopic ratios in the deposits studied to date suggest that the involved late magmatic fluids probably incorporated a minor meteoric component sometime during the systems' early stages. Deposition of the ores may reflect cooling and related changes in pH. (From the authors' abstract)

THOMPSON, A.B., 1982, Wet and dry metamorphism and melting (abst.): Geol. Soc. Newsletter (London), v. 11, no. 4, p. 14. Author at E.T.H., Zurich, Switzerland.

Many studies of metamorphic parageneses tacitly assume that a free fluid phase was always present during metamorphic equilibration (wet metamorphism) as opposed to the circumstance that while volatile species are released during metamorphism, these species may not saturate the grain-boundaries to produce free fluid (dry metamorphism). Water-activity has meaning for both wet and dry metamorphism and may be evaluated if a reaction may be written involving H_2O and pressure (rock) and temperature of equilibration are known. PH_2O only has a physical meaning for wet metamorphism. Although the effects of an impure aqueous fluid on the displacement of reactions in P-T space and on kinetics and deformation are well demonstated, there is actually little compelling evidence to suggest that the presence of an aqueous fluid is a necessity for metamorphism in the lower crust and upper mantle for the time duration of most dynamic processes including partial melting. (Author's abstract)

THURMOND, Valerie and MILLERO, F.J., 1982, Ionization of carbonic acid in sodium chloride solutions at 25°C: J. Solution Chem., v. 11, no. 7, p. 447-456.

TINSLEY, J.C., 1982, [Quaternary speleothem studies] (abst.): Geol. Survey Research 1981, U.S. Geol. Surv. Prof. Paper 1275, p. 177.

Experiments show that modern calcite in some caves is in isotopic equilibrium with the depositing ground water. Oxygen isotope ratios are being measured presently at different sites along the same growth lamination in individual speleothems to check for variations due to nonequilibrium conditions. This isotopic technique provides an independent way of testnig data on continental climates inferred from other sources. (Author's abstract)

Of pertinence to isotopic studies of fluid inclusions in speleothems. (E.R.)

TITLEY, S.R., ed., 1982, Advances in geology of the porphyry copper deposits, southwestern North America: The Univ. Arizona Press, Tucson, AZ, 560 pp.

TODOROV, T. and KRUSTEVA, M., 1982, Temperature conditions of formation of fluorite mineralization in Bulgaria (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 235-236. Authors at Geol. Inst., Sofia, Bulgaria.

The most important types of fluorite deposits and ore manifestations of Bulgaria are the quartz-fluorite vein (Palat), quartz-carbonate-fluorite metasomatic (Mihalkovo, Dospat), sulphide-baryte-fluorite vein (Ustrem, Yugovo) and metasomatic types (Chiprovtsi - the Staina chuka site and some ore bodies of the Yugovo deposit). In addition to fluorite, the deposits contain great amounts of quartz, baryte, calcite and iron, lead and zinc sulphides. In quartz-fluorite and quartz-carbonate-fluorite deposits sulphides had precipitated before fluorite and baryte, while in sulphide-baryte-fluorite deposits they are superimposed on them.

All the fluid inclusions are filled in a liquid phase. The deposits were formed at shallow depths, therefore the filling temperature is considered to be equal to mineralization temperature. The following Th results have been thus obtained [on a Koefler stage] for individual deposits: 267-70°C for Yugovo; 260-80°C for Mihalkovo; 250-120°C for Ustrem; 210-120°C for Palat; 160-90°C for Dospat; and 130-90°C for Chiprovtsi - Staina chuka. (From the authors' abstract)

TORGERSEN, T. and JENKINS, W.J., 1982, Helium isotopes in geothermal systems: Iceland, The Geysers, Raft River and Steamboat Springs: Geoch. Cosmo. Acta, v. 46, no. 5, p. 739-748.

TORGERSEN, T., LUPTON, J.E., SHEPPARD, D.S. and GIGGENBACH, W.F., 1982, Helium isotope variations in the thermal areas of New Zealand: J. Volcanol. Geotherm. Res., v. 12, p. 283-298. First author at Woods Hole Oceanogr. Inst., Woods Hole, MA 02543, USA.

Helium isotope ratios measured in the thermal areas of New Zealand range from R/R_A = 5-8($R = {}^3He/{}^4He$; $R_A = R_{air}$), in general agreement with earlier work on subduction zones. At Wairakei values up to $R/R_A \simeq 8.2$ were measured, which overlap with the range for typical mid-ocean ridge basalts ($R/R_A \simeq$ 8-10). The large $^3He/^4He$ variations observed throughout the Taupo Volcanic Zone and also within the Wairakei Geothermal Field are not correlated with gas chemistry, water chemistry, etc. However, $^3He/^4He$ ratios do correlate with absolute He concentration and with $^{40}Ar/^{36}Ar$ ratios, suggesting that the observed $^3He/^4He$ variations are due to mixing between a ^3He-rich mantle end-member and a radiogenic component added either at depth or near the surface. (Authors' abstract)

TOURAY, J.-C., 1982, Fluid inclusions as evidence for the metamorphism of evaporitic series: Sci. Terre, 1979, v. 23, no. 2, p. 99-103 (in French). Author at Inst. Rech. Ressour. Mater. Miner., Univ. Orleans 45046 Orleans, France.

A review with 19 references.

TOURET, J., 1982a Fluid inclusions in high-grade anatectic metamorphites (abst.): Geol. Soc. Newsletter (London), v. 11, no. 4, p. 15. Author at Free Univ., Amsterdam, The Netherlands.

Fluid inclusions have been studied (by microthermometry) in metapelites and metabasites which have undergone partial melting in the transition zone from amphibolite to granulite facies. Mobilisates contain far more abundant and larger inclusions than non-mobilized or restite layers, corresponding to several generations of well-defined and chemically contrasted fluids: CO_2, $CO_2 + CH_4$, $H_2O + NaCl$, and N_2. N_2 is much more widespread than formerly assumed and its common presence poses severe problems for the interpretation of low homogenization temperatures of carbonic inclusions in terms of high density fluids. From the very complicated pattern of observed fluid distribution, a two stage model of buffering mechanisms is proposed: a prograde stage, during which pore fluid composition is internally buffered by local mineral assemblages and dehydration reactions; and a retrograde stage, which corresponds to most fluid inclusions observed in the mobilisates. Fluid composition during this retrograde stage is mainly controlled by volatile solubility in anatectic melts at decreasing P and T. This model is based on few (less than 10) sufficiently well-studied cases, but its general applicability is difficult to reconcile with the concept of large scale migration of anatectic melts during granulite facies metamorphsm. (Author's abstract)

TOURET, Jacques, 1982b An empirical phase diagram for a part of the N_2-CO_2 system at low temperature, *in* R. Kreulen and J. Touret (guest eds.), Current Research on Fluid Inclusions Chem. Geol., v. 37 p. 49-58. Author at Inst. voor Aardwetenschappen, Vrije Univ., 1007 MC Amsterdam, The Netherlands.

Microthermometric and chemical (Raman analysis) data for 23 inclusions from Triassic dolomites and evaporites (northern Tunisia) are used to generate a T-X section of the N_2-CO_2 binary system. Most observed features, including some metastable homogenizations, are consistent with a simple topology well known in many binary and notably in the CO_2-CH_4 system. (Author's abstract)

TOURET, Jacques, SMITH D.C. and KECHID, S.-A., 1982, Fluid inclusions in some eclogites and gneisses from the western gneiss region, Norway (abst.): Terra Cognita, v. 2, p. 318. First author at Inst. Aardwetenschappen, Vrije Univ., Postbus 7161, 1007 MCM Amsterdam, Holland.

In the several eclogites examined, fluid inclusions containing pure, or almost pure, CO_2 are common in quartz and garnet but rare in clinopyroxene whilst H_2O is occasionally found in quartz. In the several gneisses examined, H_2O is more common in quartz whilst CO_2 (often impure) is less common in quartz and garnet but also occurs in plagioclase. However, in several other eclogites and gneisses there are no measurable fluid inclusions, or only CO_2 or only H_2O. The CO_2 and H_2O usually occur in different inclusions, thus indicating different fluid-trapping events. Unequivocal "primary" fluid inclusions have not been found in the eclogites, though some give the impression of being relict inclusions affected by recrystallization(s) of the host mineral.

The CO_2 inclusions homogenize at very variable Th, usually into the liquid phase, sometimes into the gas phase, and rarely at the critical Th = +31°C. Maximum CO_2 densities are distinctly *higher* in garnet (≈1.05 g/cm^3) in several country-rock gneisses, and in the Ulstein-Dimnöy "garnet-biotite-gneiss" (= "retrogressed quartz-phengite-eclogite," Smith, 1980, Nature 287, p. 366), and also in quartz in the "hjørundfjordite" massif (high-pressure acid charnockite, Smith, 1982, Reunion Ann. Sci. Terre, Paris, P. 582). The low and *similar* density CO_2 in garnet and in quartz in the gneisses is compatible with garnet recrystallization in the gneisses at lower pressure than in the eclogites. Some eclogites whether negligibly or strongly amphibolitized, indicate an exceptionally-wide range of CO_2 densities in garnet corresponding to $-37<Th<+31$°C. However another, the retrogressed dolomite-eclogite from Ulstein-Dimnöy (Lappin and Smith 1981, Trans. Roy. Soc. Edinburgh, in press), indicates an exceptionally-narrow range, -3<Th<+3°C, close to the lowest Th recorded in the adjacent "retrogressed quartz-phengite-eclogite" which again is compatible with garnet recrystallization. Th<0°C has not yet been recorded in the country-rock gneisses but is common in the eclogites, thus implying a deeper fluid-trapping event in the eclogites.

The maximum CO_2 densities (corresponding to Th ≈-50°C) recorded in these Norwegian eclogites are similar to those observed in certain Austrian eclogites from the Tauern Window which are contrarily regarded as of eclogite-facies age or of post-eclogite blueschist-facies overprinting age. Perhaps the maximum density of ≈1.15 g/cm^3 corresponds to the resistance limit of garnet such that higher density fluid inclusions in eclogites, if they existed, could not survive. (Authors' abstract)

TREIMAN, A.H. and ESSENE, E.J., 1982, Volatile phase composition of a carbonatite, Oka complex (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 633.

TREMBLY, J.A., 1982, Hydrothermally altered basalts from the Mariana Trough: MS thesis, Univ. Arizona, Tucson, Arizona, 42 pp.

Indexed under Fluid Inclusions. (E.R.)

TRENDAFELOV, D., MARKOV, L. and BALAREV, Kh., 1981, Studies of phase equilibria in systems $MgCO_3$-$MgSO_4$-H_2O, $MgCO_3$-$MgCl_2$-H_2O at 25°C in atmosphere of CO_2: Zhurn. Neorg. Khimii, v. 26, no. 6, p. 1681-1684 (in Russian).

TROFIMOV, V.S., 1981, New data on the formation of diamonds in kimberlites of the upper strata of the Earth's crust: Geol. Rudnykh Mestor., no. 3, p. 14-20 (in Russian; translated in Int'l. Geol. Review, v. 24, no. 8, p. 920-924, 1982). Author at Central Sci. Res. Inst. Prospecting for Nonferrous, Rare & Noble Metals (TsNIGRI), Moscow, USSR.

It is shown that diamonds in kimberlites crystallize not in the Earth's upper mantle, at depths on the order of 150-600 km, but in special magma chambers formed at depths of only several kilometers in the apical parts of "abyssoliths" - abyssal injections of mantle material into the upper levels of the Earth's crust. In these chambers, repeated supply of heat and fluids from the mantle produces continuously changing PT conditions sufficient to form diamonds and to cause the entire observed variety of kimberlites and diamonds contained in them. (Author's abstract)

TRUESDELL, A.H., NEHRING, N.L., DesMARAIS, D.J. and MAZOR, E., 1982, Geochemistry of gases in the hydrothermal system of Cerro Prieto, Mexico: Proc. Pacific Geothermal Conf. 1982 Part 1, Univ. Auckland Geothermal Inst., Auckland, NZ, p. 271.

TRUESDELL, A.H. and THOMPSON, J.M., 1982, The geochemistry of Shoshone Geyser Basin, Yellowstone National Park, in S.G. Reid and D.J. Foote, eds., 33rd Annual Field Conf., Wyoming Geol. Assoc. Guidebook 1982, Mammoth Hot Springs, WY, Sept. 15-18, 1982, p. 153-159.

TRUFANOV, V.N., KURSHEV, S.A., MAISKY, Y.G., USHAK, A.T., TRUFANOV, S.N., PROKOPOV, N.S. and TIMCHENKO, N.A., 1982, Throttling effect in hydrothermal systems and ore-forming processes (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 48-49.

TSAI, C.-L., CHEN, C.-H. and YANG, H.-Y., 1982, Calcite nodule and high-pressure megacrysts in the basaltic pyroclastics from Mafu, northern Taiwan: Acta Geol. Taiwanica, Sci. Rpts. of Nat'l. Taiwan Univ., no. 21, p. 81-91. First author at Dept. Earth Sci., Nat'l. Cheng Kung Univ., Tainan, Taiwan.

Calcite nodule and clinopyroxene, amphibole, phlogopite megacrysts occur in the basaltic pyroclastics from Mafu, northern Taiwan.

Calcite nodule is the product of replacement and alteration of ultramafic nodule of upper mantle origin. Clinopyroxene megacryst crystallized as near liquidus phase at pressure between 10-20 kb. Amphibole megacryst probably crystallized as near liquidus phase at pressure between 10-22 kb. During the crystallization of clinopyroxene and amphibole megacrysts, immiscible fluid rich in sulfide and iron occurred and was incorporated into the host crystals as spherical or oval inclusions. Unmixed vapor phase occurred during the later stage of amphibole crystallization before the pyroclastics were erupted to the surface. (Authors' abstract)

TSERTSVADZE, Z.Y., 1982, Ore forming hydrothermal systems of arsenic, mercury and antimony deposits of the Caucasus (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 49-50. Author at Geol. Survey of Georgian SSR, Tbilisi, USSR.

The formation temperature of the Caucasian As, Hg and Sb deposits varies from 300 to 70°C while the pressure varies from 1500 to 300 bar, as evidenced by the PVT data for CO_2 at medium crystallization temperatures of the ore minerals. Relatively higher temperatures (300-130°C) enhance generation of quartz-antimonite and quartz-antimonite-ferberite deposits; while at lower temperatures (250-100°C) quartz-dickite-cinnabar bodies are formed. The lowest temperature (180-70°C) provide quartz-calcite-realgar-orpiment deposits. Minerals of the quartz-antimonite stage are crystallized within similar temperature ranges in the complex arsenic-mercury-antimony and monomineral antimony deposits.

The analysis of the mineral aqueous extractions has shown that the ore-forming hydrothermal solutions contain Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, NO_2^-, CO_3^{2-}, HCO_3^-, SO_4^{2-}, while inclusions contain the following gases: N_2, CO_2, CH, NH_3, O_2, H_2S, Ar, He, H_2O, Cl, SO, T.Y. Especially high gas content was found in the realgar (73.85 vol.%) and orpiment (58.73 vol.%). The mercury and antimony sulphides of the Akhei, Zopkhito and other deposits contained CO_2 in 6-7 times lower amounts than the arsenic sulphides. CO_2 - content was low in ore quartz and calcite and even lower in gangue quartz and calcite. High values of the CO_2/H_2O, CO_2/CH_4, gas/water ratios were found in realgar, orpiment, quartz and calcite of the Lukhumi ore deposit. In ore and gangue minerals of the antimony and mercury deposits these values change but negligibly.

The quantitive analysis of the investigation results suggests a basically sulphur-hydrocarbonate and sulphur-chloride-hydrocarbonate composition of the hydrothermal solutions of antimony-mercury-arsenic ores. (From the author's abstract)

TUGOVIK, G.I., ZAYKIN, I.D. and KIRASIROVA, V.I., 1982, Composition of fluid inclusions in platinoids from granulite complex and certain problems of their origin: Akad. Nauk SSSR Doklady, v. 266, no. 3, p. 704-706 (in Russian). Author at Amur Complex Sci.-Res. Inst. of Far-East Sci. Center of Acad. Sci. of USSR, Blagoveshchensk.

Samples of platinum minerals were collected in the eluvial layer of Archean granulite complex (mafic and ultramafic schists, gneisses, quartzites, marbles, gabbroids and ultramafites). Volatiles were analyzed by gas chromatography in two T intervals: 150-600°C (first values in analysis results) and 600-800°C (second values, all in molar % of total volatiles). Sperrylite contains: CO_2 17.20; 7.75, H_2 11.68; 1.77, CO 5.51; 40.97, N_2 0.55; 4.10, CH_4 0.36; 0.00, H_2O 65.05; 45.40; total volatiles in cm^3 per kg of sample 178; 40.4; mixture of polyxene, Os-iridium, Cu-platinum and stannopalladinite: CO_2 10.08; 15.06, H_2 5.88; 0.97, CO 3.55; 32.07, N_2 0.34; 4.25, CH_4 0.30; 0.00, H_2O 79.83; 47.62; total volatiles in cm^3 per kg. (Abstract by A.K.)

TUPYAKOV, V.Ye., SHIROKIKH, I.N. and ROZOV, D.N., 1982, Model of the ore-metasomatic column at the Kari ore field (Eastern Transbaikalia): Geologiya i Geofizika, no. 11, p. 33-38 (in Russian; English abstract). First author at Inst. Geol. Geophys. of Siberian Branch of Acad. Sci. USSR, Novosibirsk.

The paper bears Th for gold-ore-bearing metasomatites quoted from earlier published papers. (A.K.)

TVALCHRELIDZE, A.G., 1982, Ore-bearing hydrothermal systems of stratiform pyrite deposits (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 50-51.

TVALCHRELIDZE, A.G., ROZHDESTVENSKAYA, V.A., YAROSHEVICH, V.Z. and NAROZAULI, I.G., 1979, A genetic model for the Urup copper massive sulfide deposit: Geol. Rudnykh Mestor., v. 21, no. 6, p. 44-58 (in Russian; translated in Int'l. Geol. Review, v. 24, no. 1, p. 11-23, 1982).

Abstract in Fluid Inclusion Research--Proceedings of COFFI, v. 12, p. 194, 1979. (E.R.)

TYAGI, A., ROONWAL, G.S. and JAIRATH S.K., 1982 Fluid inclusions in quartz crystals of kaolinized pegmatite of Mehrauli area, south Delhi (abst.): [Proceedings & Abstracts], National Workshop on Fluid Inclusion Studies, 22-23 March, 1982, Indian Inst. Tech., Bombay, p. 38 (unpaginated). Authors at Dept. Geol., Univ. Delhi, Delhi 110007.

The primary fluid inclusions present in quartz crystals from the kaolinized pegmatite of Mehrauli area of south Delhi have Th L-V(V) at 415°C. However, the temperature of homogenization of primary inclusions present in smoky quartz is higher, (~500°C). It suggests that smoky quartz possibly started crystallizing earlier. The pneumatolytic phase of quartz formation was followed by hydrothermal phase, which is registered as secondary inclusions in quartz. These secondary liquid inclusions homogenize into aqueous phase at a temperature around 230-370°C. (Authors' abstract)

UCHAMEISHVILI, N.E., 1982, Physico-chemical conditions of formation of neogranitic intrusions of the Great Caucasus (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1;982, Collected Abstracts, p. 218. Author at Inst. Geochem. & Analy. Chem., Moscow, USSR.

The presumed existence of a common primary magmatic source is proved by similar Th (1250-1050°C) of melt inclusions in accessory apatite and intratelluric impregnations of feldspars and quartz of neogranitic rocks. Unlike the feldspars in which homogenization of the inclusions occurs within narrow temperature ranges, quartz contains melt inclusions which become homogeneous under rather different temperatures, from 1250 to 720°C. This feature speaks for crystallization of quartz during the whole long history of the intrusive formation. The melt inclusions in the quartz of granitic rocks reflect the granitic magma evolution. H_2O content and pressure are shown to be growing in the process of the granitic melt evolution.

Besides the melt inclusions, the quartz of neogranitic rocks of a number of massifs contain fluid inclusions, both gaseous and gas-liquid (two-phase and multiphase), evidencing that the formation of the intrusion (which began at the magmatic stage) occurred in postmagmatic time as well. It is with these neogranitic intrusions which were formed under the fluid effects, that the endogenous deposits and ore manifestations are associated (Tyrnyauz, Karoby, Tsurungal etc.). The Th range of fluid inclusions is 950-130°C. The melt and fluid inclusions were found to be syngenetic. The temperature field from 950 to 720°C of coexistence of a silicate melt and a gas-liquid fluid is defined by the presence of low-dense fluid inclusions which contain daughter minerals, ore-minerals included. The temperature of the end of magmatic stage is somewhere around 700°C. The postmagmatic fluids at temperature of solidus were presented by a concentrated chloride melt and an essentially water vapor. They were mixed during temperature decrease , resulting in formation of a single less concentrated fluid. (From the author's abstract)

URUSOVA, M.A., RAKOVA, N.N., VALYASHKO, V.M., ZELIKMAN, A.N. and BELOUS, Ye.D., 1982, The system Na_2CO_3-NaF-H_2O at 225°C: Zhurn. Neorg. Khimii, v. 27, no. 5, p. 1331-1333 (in Russian). First author at Inst. of General and Inorg. Chem. of Acad. Sci. USSR, Moscow, USSR.

The paper presents solubility isotherms 25, 50, and 225°C and the authors conclude that the system belongs to the simple eutectic type.(A.K.)

VAKIN, E.A. and KUTYEV, F.Sh., 1982, Results of analyses of gas microinclusions in the minerals of abyssal xenoliths and composition of magmatic gases: Bull. Volcanol., v. 45, no. 3, p. 273-276. Authors at Inst. Volcanol., Acad. Sci. USSR, Piip Avenue 9, Petropavlovsk-Kamchatsky, USSR.

Gas compositions (acid gases, CO_2, CO, H_2 and N_2), and Th, were determined for inclusions in nodules in 10 different volcanoes, and compared with analyses of gases evolved from erupting craters. (E.R.)

VALLEY, J.W., 1982, Fluid heterogeneity in the lower crust (abst.): EOS, Trans. Am. Geophys. Union, v. 63, p. 448. Author at Dept. Geol., Rice Univ., Houston, TX 77251.

Stable isotope analysis combined with phase equilibria provides a powerful tool for studying deep crustal fluids. If P, T, experimental equilibria, thermochemical data and activity models are known, then fluid-buffering assemblages allow estimation of fluid compositions at the peak of metamorphism, but taken alone cannot yield fluid quantities. Isotope mass-balance allows quantification of fluid flow if premetamorphic isotopic compositions, metamorphic volatilization effects, isotope fractionations and T are known. In the granulite facies of the Adirondack Mts., N.Y., mass-balance is frequently imprecise because of uncertainty in premetamorphic composition due to ambiguities in igneous vs. sedimentary parentage and metamorphic recrystallization with high temperature exchange. Similar problems beset all regional metamorphics where equivalent unmetamorphosed rock units cannot be sampled. Interpretation is possible in instances of large isotopic gradients, high $\delta^{18}O$ calcite (>25) and low $\delta^{18}O$ wollastonite (3 to -1.3). While low $\delta^{18}O$ wollastonites indicate massive, but localized, metasomatism and meteoric water exchange, high $\delta^{18}O$ calcites and gradients (up to :16‰ (sic) in 15 m between marble and anorthosite; 8‰ in 20 m between layered, non-carbonate metasediments; and 6‰ in 1 m in skarn) indicate restricted fluid flow and heterogeneous conditions.

Complex fluid heterogeneity in the Adirondacks is supported by the absence of volatilization isograds in marbles and variations in calculated fluid fugacities. When normalized to a common buffer, fH_2O varies by $>10^{0.5}$, fCO_2 by $>10^{2.5}$, fO_2 by $>10^{1.2}$, fF_2 by $>10^{2.5}$, indicating that buffering capacities have not been exhausted. The sharpest gradient is in fCO_2 by a factor of $>10^{2.5}$ in 15 m. The results suggest that fluid activities and flow paths in the lower crust are highly variable and that caution should be exercised in assuming homogeneous fluid conditions for all rock types. (Author's abstract)

VALLEY, J.W. PETERSEN, E.U., ESSENE, E.J. and BOWMAN, J.R., 1982, Fluorphlogopite and fluortremolite in Adirondack marbles and calculated C-O-H-F fluid compositions: Am. Min., v. 67, p. 545-557. First author at Dept. Geol., Rice Univ., Houston, TX 77001.

Fluorphlogopites (up to $XF = 0.96$) and fluortremolites (up to $XF = 0.82$) have been found in Grenville marbles near Balmat, New York. In these minerals high fluorine contents correlate inversely with iron solid solution, but do not appear to affect the stable isotope fractionation of hydrogen.

The substitution of fluorine for hydroxyl in micas and amphiboles is partly responsible for stabilizing hydrous minerals in the granulite facies marbles of the Adirondacks. The importance of this effect can be calculated from thermochemical data and a knowledge of F/OH distribution in natural assemblages. Phlogopite concentrates fluorine relative to tremolite. The F/OH distribution coefficient does not vary with metamorphic grade but differs significantly in the most F-rich sample from the other samples. Application of volatilization equilibria in marbles without consideration of possible fluorine substitution can lead to large errors in estimated pressures, temperatures and fluid compositions.

The fugacities of eight C-O-H-F fluid components are restricted by (and are estimated for) the assemblage fluorphlogopite + calcite + quartz + graphite. H_2O and CO_2 were the dominant fluid components in these graphitic marbles and CH_4 was minor. Calculations of many oxidation-fluoridation equilibria (fF_2 vs fO_2) for common calcsilicate minerals support these values of fF_2 and fO_2. The inferred fO_2 is within 0.5 log unit of the QFM buffer, near that commonly inferred for other Adirondacks marbles. Minimum values of log fF_2 are -35.0 for end-member fluorphlogopite, -34.4 for end-member fluortremolite and -34.1 for norbergite plus fluortremolite in calcite marbles at these P and T. Such values of fF_2 may not be unusual, suggesting that fluorphlogopite and fluortremolite could be relatively common rock-forming minerals in iron-poor marbles. (From the authors' abstract)

VALYASHKO, V.M., 1981, Regularities of construction of phase diagrams of water-salt systems in wide interval of temperatures and pressures: Zhurn. Neorg. Khimii, v. 26, no. 11, p. 3044-3054 (in Russian). Author at Inst. of General and Inorg. Chem. of Acad. Sci. USSR, Moscow.

The paper presents the principles of systematics of phase diagrams of binary systems and the systematics and peculiarities of ternary phase diagrams and discusses the system Na_2O-SiO_2-H_2O on the basis of experimental data. (A.K.)

VAN ELDIK, R. and PALMER, D.A., 1982, Effects of pressure on the kinetics of the dehydration of carbonic acid and the hydrolysis of CO_2 in aqueous solution: J. Solution Chem., v. 11, no. 5, p. 339-346.

VAN ENCKEVORT, W.J.P. and JETTEN, L.A.M.J., 1982, Surface morphology of the {010} faces of potassium hydrogen phthalate crystals: J. Crys. Growth, v. 60, p. 275-285. Authors at RIM Lab. Solid State Chem., Faculty of Sci., Catholic Univ., Toernooiveld, 6525 ED Nijmegen, The Netherlands.

A detailed surface microtopographic study with the aid of highly sensitive differential interference and phase contrast microscopy has been carried out for the {010} faces of potassium hydrogen phthalate single crystals. Two types of growth hillocks could be identified: (i) macroscopic hillocks, emitting steps of considerable height (100-2500 A) from their centers, and (ii) shallow hillocks, being sources of growth steps of 14 A, which corresponds to one unit lattice translation. From a relationship between hillock centers and dislocation etchpits, the macroscopic hillocks were identified as a group of cooperating spirals, whereas the shallow hillocks are single spirals originating from single dislocations of unit height. Several properties of both spiral types are described, among which [are] a relation between inclusion strings and the occurrence of some of the macroscopic hillocks, the phenomenon of bunching of lower steps to higher steps, the formation of liquid inclusions via macrostep overhangs and the equivalence in advancement rates of steps of different heights. (Authors' abstract)

VAN ENCKEVORT, W.J.P., VAN ROSMALEN, R.J., KLAPPER, H. and VAN DER LINDEN, W.H., 1982, Growth phenomena of KDP crystals in relation to the internal structure: J. Crystal Growth, v. 60, p. 67-68. First author at RIM Lab. Solid State Chem., Catholic Univ., Toernooiveld, 6525 ED Nijmegen, The Netherlands.

The influence of the hydrodynamic environment on the perfection of large, single KDP (potassium dihydrogen phosphate) crystals has been studied by means of X-ray diffraction topographic techniques. The crystals were grown from solutions under carefully defined conditions. One of the phenomena caused by the hydrodynamics is the occurrence of quasi-periodic veils of liquid inclusions. This quasi-periodicity can be explained by conflicting growth mechanisms, depending on dislocation density. A strong dependence of growth rate on dislocation density has clearly been observed, also for crystals without liquid inclusions. In addition, the patterns of the growth bands in KDP could also be related to the hydrodynamic environment. A major change in the well-known minimum-energy directions of dislocation lines is visible in the growth bands. (Authors' abstract)

VANKO, D.A. and BATIZA, Rodney, 1982, Gabbroic rocks from the Mathematician Ridge failed rift: Nature, v. 300, n. 5894, p. 742-744. Authors at Dept. Earth & Planet. Sci., Washington Univ., St. Louis MO 63120, USA.

Quartz veins in retrograded amphibolitized gabbros contain polyphase fluid inclusions which sometimes contain a salt crystal. These inclusions and the Cl content of amphiboles indicate that late hydrothermal fluids were quite saline. (E.R.)

VANKO, D.A. and BISHOP, F.C., 1982, Occurrence and origin of marialitic scapolite in the Humboldt lopolith, N.W. Nevada: Contrib. Mineral. Petrol., v. 81, p. 277-289. First author at Dept. Earth & Planet. Sci., Washington Univ., Box 1169, St. Louis, MO 63130, USA.

Very high NaCl contents (~77 wt.%) are needed to form scapolite unless CO_2 is present. (E.R.)

VARČEK, C., 1982, Character and sources of hydrothermal systems of the siderite formation in the west Carpathian Mts. (ČSSR) (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 52-

53. Author at Comenius Univ., Bratislava, Czechoslovakia.

Study of fluid inclusions in minerals of ore deposits brought valuable data about the character of hydrothermal systems. The regime of temperature of the hydrothermal mineralization was mainly from 350 to 100°C, with expearing(sic) rejuvenation (increasing temperature of the mineral crystallization by 100 to 200°C) at the beginning of each stage of this polyascendent mineralization.

Data were obtained of the concentration of hydrothermal solutions and variability of amount of at least some components. At some paragenetic types a very high content of CO_2, at others NaCl, and oscillating contents of alkaline cations, carbonatic, sulphatic and chloride anions, which also helps to solve the problem of sources of the hydrothermal solutions. (From the author's abstract)

VARMA, O.P., 1982, Fluid inclusion studies as an effective tool to mineral exploration - some suggestions in the Indian context (abst.): [Proceedings & Abstracts], National Workshop on Fluid Inclusion Studies 22-23 March, 1982, Indian Inst. Tech., Bombay, p. 55-56 (unpaginated). Author at Dept. Applied Geol., Indian Sch. Mines Dhanbad - 826 004, Bihar.

A review of possible uses of inclusions in Indian economic geology. (E.R.)

VAR'YASH, L.N. and REKHARSKIY, V.I., 1981, Behavior of Cu(I) in chloride solutions: Geokhimiya, 1981, no. 7, p. 1003-1008 (in Russian; translated in Geochem. Int'l., v. 18, no. 4, p. 61-67, 1982).

VASILENKO, V.B., KUZNETSOA, L.G., KHOLODOVA, L.D., EGIN, V.I., ENTIN, A.R., SUCHKOV, V.I. and BELOUSOV, V.M., 1982, Apatite rocks of Seligdar: Siberian Branch of "Nauka" Publ. House, Novosibirsk, 216 pp., 1000 copies printed, price 3 rbls. 40 kopecks (in Russian).

The apatite deposit Seligdar consists of carbonate and greenstone varieties, the latter comparable with peridotites and missourites, probably of magmatic-metasomatic origin. Apatite bears the following inclusions: solid (hematite and unidentified transparent mineral), G/L P with Th 190-370°C, S 165-420°C, three-phase with silicate that did not dissolve on heating. (A.K.)

VAUGHAN, P.J., 1982, An experimental study of the role of CO_2 in physical processes in the mantle (abst.): Terra Cognita, v. 2, p. 228-229. Author at Lab. de Géophy. et Géodynamique interne, Univ. Paris-Sud, 91405, Orsay, France.

Kimberlite magma generation in the mantle is linked to physical processes involving a fluid phase which is likely to be CO_2-rich. In peridotite xenoliths bubbles frequently occur within olivine grains in association with spinel crystals suggesting exsolution of a dissolved fluid phase during ascent of the xenolith. Experiments designed to clarify the role of CO_2 in bubble development have been conducted in a Griggs apparatus modified for high pressure. Hot-pressed olivine samples were sealed in Pt capsules with small amounts of silver oxalate, a material which breaks down to CO_2 and silver at relatively low temperature. The samples were held at p,T conditions appropriate to the lower lithosphere for periods of about a day. As expected from petrologic studies, a uniformly distributed carbonate phase occurs along grain boundaries and as inclusions within olivine. This is presumably magnesite generated during: Forsterite + $CO_2 \rightleftharpoons$ Magnesite + Enstatite. By varying the p,T path followed during quenching one can study either the degree of incorporation of CO_2 into olivine under conditions stabilizing the carbonate or the development of features related to the generation of free CO_2. Analysis of these samples is in progress. In addition, several samples have been deformed and have developed shear zones containing mylonitic material. Thus application of pressure up to 3.0 GPa has not precluded shear zone formation. (Author's abstract)

VDOVYKIN, G.P., VISHNEVSKIY, S.A., ZHUYKOVA, T.L. and ZYKOVA, P.D., 1981, Gas-liquid inclusions, gas composition and carbon concentration in deep-lying traprock sills of the western part of the Tunguska syneclise and the Nepa-Botuobuya anteclise of the Siberian platform: Dokl. Akad. Nauk SSSR, v. 256, no. 2, p. 452-456 (in Russian; translated in Dokl. Acad. Sci. USSR, v. 256, p. 165-169, 1982).

Abstract in Fluid Inclusion Research--Proceedings of COFFI, v. 14, p. 217. (E.R.)

VENTSLOVAYTE, E.I., 1982, Acid-basic conditions of formation of near-ore metasomatites at the pyrite-polymetal deposit Korbalikha in the Rudnyi Altai, p. 128-136 in Acid-basic properties of chemical elements, minerals, rocks and natural solutions: "Nauka," Moscow, 216 pp., 1100 copies printed, price 2 rbls 50 kopecks (in Russian).

The deposit Korbalikha occurs in sedimentary-volcanic rocks of Upper Devonian. Wall chlorite-quartz metasomatites formed at 350-400°C (Th), calcite-talc 210-310°C; barite crystallized at 140-278°C, ore minerals (pyrite, chalcopyrite, sphalerite, galena) 225-300°C, quartz-calcite veinlets 160°C. (A.K.)

VERKHOVSKIY, A.B., KHOREV, A.N. and LEVSKIY, L.K., 1981, Cosmochemical and geochemical consequences of sorption of argon and xenon by minerals: Geokhimiya, 1981, no. 11, p. 1627-1636 (in Russian; translated in Geochem. Int'l., v. 18, no. 4, p. 23-32, 1982).

VETO, E., 1982, On the relationships between mineralization and gas-liquid inclusion zoning in the central Börzsöny Mts. (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 219-220. Author at Hungaria State Geol. Inst., Budapest, Hungary.

Investigations have been carried out on the Early Badenian andesite-dacite series in the central part of the Börzsöny Mts. using the methods of petrography, ore microscopy, geochemistry, thermometry, and cryoscopy. It is concluded that:

- mineralization on the Kuruzpatak, Banyapusta and Rozhahed area is a result of the same hydrothermal process;
- high-temperature (>360°C) mineralization is possible on the Kuruzpatak area;
- mineralization phases on the Banyapusta and Rozhahed areas occurred in the range 260-160°C for various parageneses.

NaCl concentration appears to be 7-12% in two-phase inclusions and 30-38% in three-phase inclusions. The latter data provide general characteristics of porphyry copper mineralization, however, they do not prove existence of economically significant deposit. In the Rozhahed district Th of inclusions in quartz and calcite increases with the Cu/Pb+Zn ratio. Crystallization of quartz and calcite seems to proceed only under hydrostatic pressure below 10 MPa. Cooling of the solutions was obviously accelerated due to their mixing with meteoric waters. (From the author's abstract)

VETONE AKOS, Eva, 1982, Relationship between fluid inclusions in hydrothermal calcite quartz veins and ore mineralizations in the central

Borzsony Mountains, northern Hungary: Magy. All. Foldt. Intez. Evi Jel., 1980, p. 59-75 (in Hungarian).

On the basis of fluid inclusion data, a cogenetic post-volcanic origin is hypothesized for the vein-type base metal sulfide ores hosted by Badenian andesitic-dacitic rocks at Kuruc-patak, Banya-puszta, and Rozsa-hegy. From all three deposits, the NaCl contents of 2- and 3-phase inclusions range 7-12 and 30-38, respectively, and are not inconsistent with associated porphyry Cu mineralization at depth. Fluid-inclusion Th indicate high-temperature (300 to >360°), katathermal or pneumatolytic mineralization at Kuruc-patak and a lower-temperature, 3-stage (>260, 190-235, and <160°) mineralization (pyrite + calcopyrite + sphalerite ± pyrrhotite ± galena ± arsenopyrite ± marcasite) at Banya-puszta and Rozsa-hegy. At the Rozsa-hegy deposit, Th increase with the Cu/(Pb + Zn) ratio of the ores and decrease progressively across alteration sequence biotite → biotite-K feldspar → hydromuscovite-carbonate → hydromuscovite-illite-carbonate. (CA 98: 146855c)

VIL'DENBERG, Ye.V., 1982, Gases of the Iren salt-bearing beds as index of oil capacity of the Northern frame of the Prikaspiyskaya Depression: Izvestiya Vyssh. Uchebn. Zaved.-Geologiya i Razvedka, no. 9, p. 77-83 (in Russian). Author at Volgouralnipigaz, USSR.

Samples (250) from 93 drilling cores were investigated for N_2, CO_2, H_2, CH_4, C_2H_6, C_3H_6 and C_3H_8 contents; part of these gases came from fluid inclusions in salts. (A.K.)

VINEY, P.R., 1982, Geology and mineralization in the Upper Scamander area, (eastern Tasmania). Unpubl. hons. thesis, Univ. Tasmania, 165 pp.

The study of the Scamander area includes a review of local geology, and sections on petrography, mineragraphy and S-isotopes, as well as fluid inclusions. The mineral field consists of quartz veins containing W, Sn, Cu and Ag-Pb-Zn mineralization zoned (in that order) outward from granite. Fluid inclusions from specimens scanning most of the zoning include aqueous L+V and CO_2-bearing aqueous L+V types. Some pure CO_2 inclusions were noted. Fluid compositions vary irregularly across the field: salinity 0 to 4 eq.wt.% NaCl; CO_2 content in CO_2-bearing inclusions 21-42%. Tm CO_2 mode is -56.3°C. Density of CO_2 increases from 0.62 to 0.79 g/cm^{-3} with distance from granite. Th of CO_2-bearing inclusions falls in range 220-380°C, and suggests a T gradient, 300°C to 250°C, between W and Cu zones. (Abstract by C.J. Eastoe)

VISSER, Wiekert, 1982, Maximum diagenetic temperature in a petroleum source-rock from Venezuela by fluid inclusion geothermometry, in R. Kreulen and J. Touret (guest eds.), Current Research on Fluid Inclusions: Chem. Geol., v. 37, p. 95-101. Author at Koninklijke/Shell Explor. en Prod. Lab., 2288 GD Rijswijk (Z.H.), The Netherlands.

Abstract in Fluid Inclusion Research--Proceedings of COFFI, v. 14, p. 219, 1981. (E.R.)

VITVITSKII, V.V., EVSTAFIEV, V.P. and FODKUSHOV, Yu.I., 1982, Gypsum formation in sodium chloride brines of the Moscow artesian basin: Akad. Nauk SSSR, Dokl., v. 264, no. 2, p. 470-473 (in Russian).

VOIGT, D.E., BODNAR, R.J. and BLENCOE, J.G., 1982, Water solubility in melts of alkali feldspar composition at 5 kbar, 950°C (abst.): EOS, Trans. Am. Geophys. Union, v. 63, p. 428. Authors at Dept. Geosci., The Pennsylvania State Univ., University Park, PA 16802.

The water-saturation curve for melts of alkali feldspar composition at 5 kbar, 950°C has been bracketed using various experimental techniques and starting materials. The most sensitive and reliable method of identifying oversaturation proved to be the occurrence of vapor pits at the top of the quenched-glass charge along with trapped vapor bubbles within the charge that were significantly larger than accompanying uniformly-sized bubbles which represent vapor exsolved during quenching. The weight-loss method for determining the maximum solubility of water in melts was found to be a reliable indicator of oversaturation, but the amount of water lost could not be used to calculate the saturation curve because of residual water trapped in the charge. By applying all of these various criteria, the maximum water solubility could be determined to better than ±0.3 wt.% water.

Results of our experiments indicate that the maximum solubility of water decreases from 9.1 wt.% (59 mole %) for a melt of Na-feldspar composition to 5.1 wt.% (45 mole %) for a melt of K-feldspar composition. These values are consistent with those of other workers and imply that water solubilities in aluminosilicate melts are very significantly dependent on anhydrous bulk composition. Furthermore, it is now evident that variable limits of water solubility in aluminosilicate melts must be accounted for in models of pegmatite formation and generation of magmatic hydrothermal fluids from granitic magmas, as well as in calculations of the amounts of energy released upon exsolution of water from a magma during explosive volcanism. (Authors' abstract)

VOLOSOV, A.G., BORISOV, M.V., SUSHCHEVSKAYA, T.M. and KNYAZEVA, S.N., 1981, Deposition of cassiterite during formation of hydrothermal tin-ore deposits, according to the results of physicochemical modeling: Geokhimiya, no. 1, p. 71-89 (in Russian; translated in Geochem. Int'l., v. 18, no. 1, p. 49-66, 1982).

Abstract in Fluid Inclusion Research--Proceedings of COFFI, v. 14, p. 221. (E.R.)

VOROB'YEV, Ye.I. and MATONIN, V.N., 1982, Conditions of lazurite formation in Pribaykal'ye from results of studies of fluid inclusions, in N.P. Ermakov, ed., Thermobarogeochemistry in Geology - Materials of the Sixth All-Union Symposium on Thermobarogeochemistry: Vladivostok, Far East Sci. Center, Acad. Sci. USSR Pub. House, p. 114-117 (in Russian).

Metasomatic calcite, syngenetic with lazurite mineralization, bears P and S fluid inclusions. S inclusions are rare, they have tubular habit and G/L filling. P inclusions are very numerous, they have small size (usually ≤10 μm) and peculiar filling. They occur randomly or in growth zones of calcite, their habit is round or hexagonal, and they bear almost always the "screening" particle of trapped mineral - anhydrite. Moreover, inclusions contain dm (~60%), L and small G bubble. The dm is native sulfur, at ~120-150°C it melts. Further heating causes change of inclusion color and at ~650°C the inclusion becomes uniformly black. The obtained data prove that lazurite formed under high activity of sulfur, as is confirmed by S present in lazurite, plus pyrite and anhydrite occurring with lazurite. Optimum T of lazurite formation was evaluated as 650°C, as is confirmed by high Mg content in calcite syngenetic with lazurite (Goldschmidt-Newton geothermometer). (Authors' abstract, translated by A.K.)

VOVK, I.F., 1981, Radiolytic model of formation of brine compositions in the crystalline basements of shields: Geokhimiya, no. 4, p. 467-480 (in Russian; translated in Geochem. Int'l., v. 18, no. 2, p. 80-93, 1982).

Abstract in Fluid Inclusion Research--Proceedings of COFFI, v. 14, p. 221-222. (E.R.)

VOZNYAK, D.K. and GALABURDA, Yu.A., 1982, Improved stage for cryometric studies of inclusions in minerals: Mineralog. Sbornik, v. 36, no. 2, p. 89-91 (in Russian; English abstract). Authors at Inst. Geochem. and Physics of Minerals, Kiev, Ukrainian SSR.

The stage may be used at T -192 to +80°C; preparation is immersed in alcohol cooled by gas or liquid nitrogen. The improvement consists of two copper plates with illumination holes lying under and above preparation for better and more uniform heat conduction. The holes in the copper plates are filled by sapphire plates. Scheme of measurement of temperature is also given; the precision of the T measurements is ± 0.2°C. (Abstract by A.K.)

VYNAR, O.N., KALYUZHNYI, V.A. and KADURIN, V.N., 1982, Fluid regime of ore-bearing quartz veins in the zone of tectonic-magmatic activization of the Ukrainian Shield: Mineralog. Sbornik, v. 36, no. 2, p. 60-75 (in Russian; English abstract). First author at Inst. Geol. Geochem. of Mineral Fuels of Acad. Sci. of Ukrainian SSR, L'vov, Ukrainian SSR.

The studied region, Akhtovo vein field, occurs in the Kinovograd block and consists of massive and brecciated veins 0.1-0.5 m thick and 1-30 m long. Mineral associations are formed by quartz (gray, white, rock crystal and amethyst), calcite, siderite, cerussite, Pd-gold, Bi-gold, Ag-gold, cassiterite, pyrite, chalcopyrite, arsenopyrite, tennantite, bismuthinite, aikinite, pyrargyrite, tetrahedrite, sphalerite. Quartz of coarse-grained porphyry granite bears essentially S inclusions with Th 200-230 and 370-390°C (boiling solutions); probably P one have Th 280-325°C. Quartz from fine-grained alaskite granite bears inclusions with Th 460°C (in G), 370-375°C, 270-280°C, 195-200°C and 160-170°C. Vein quartz yielded following Th: metasomatic 360-370, 270-275, 200-220, 160-170°C; ore-bearing 300-320, 290-205, 195-200, 100-120°C; post-ore 260-270, 220-230, 180-200, 120-140°C. Inclusions of 100% LCO_2, LH_2O 20-30 + LCO_2 50-60 + G 10-20 vol.% and LH_2O 50-60 + LCO_2 20-30 + G 10-20 vol.% were also found, from heterogeneous trapping. Ternary plot CO_2-N_2-CH_4 groups the fluids of the studied inclusions along N_2-CO_2 side with maximum extent toward CH_4 corner equal 25%; Na-Ca+Mg-K plot - along Na-K side with extent toward CA+Mg corner essentially up to 30%; however the data are widely spread over a plot SO_4-HCO_3+CO_3-Cl+F. Total salt content varies from 16 to 86 mg per kg. The values of pH for water leachates were 7.5 to 9.5. Widely occurring refilling of fluid inclusions was used for establishing the sequence of changes of ore-forming fluids. Probably heterogenization of fluids causes crystallization of quartz and ores. (Abstract by A.K.)

WALTHER, J., 1982, Fluid inclusions in apatites from the Kaiserstuhl carbonatite, an example of fluid trapping by volume controlled conditions (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 220-221. Author at Univ. Karlsruhe, Karlsruhe, West Germany.

Apatites from the Kaiserstuhl-Carbonatite in the southern part of the Rhine Graben, W.-Germany, bear an extraordinarily curious diversity of fluid inclusions. About 1/3 of cavities is of one-phase gas type, 2/3 are two- to multiphase inclusions with various, mostly high degrees of filling and very wide spread of salinities.

Solid phases mainly are chlorides, carbonates, sulphates of Na, K, (with) NaCl absolutely dominant. Bituminous material occasionally occurs in separate cavities, mainly accompanies other fluids and can be detected by fluorescence microscopy. Small spots of solid calcite in apatite, often in identical optical orientation and partly connected with surrounding calcite, clearly show operation of a displacement reaction of calcite by apatite.

Abundance and arrangement of different types of inclusions do not show any regularity or relation to growth zones and therefore cannot have originated in different environments or depth levels. After all structural criteria they prove to be simultaneous, primary and syngenetic with apatite growth.

Corresponding to various cavity fillings, we observe wide spread of homogenization temperatures and dissolution of daughter crystals, ranging from somewhat below 200°C up to 450°C. A great many of inclusions however decrepitate, especially around 200°C and at higher temperature.

A critical fact is that there are no separate cavities, filled by two-phase CO_2, although apparently empty gas cavities contain pressurized CO_2. Two-phase CO_2 only occurs in small amounts (10-20 % wt) in water-rich inclusions and surprisingly in nearly same amounts, whether salinity is low or extremely high. This, because of the strong salting-out effects in highly ionic strength solutions, cannot be explained, regarding CO_2 as dissolved species and is hard to reconcile with certain given conditions of temperature and pressure.

These in short are the facts, which must be explained. It is evident that this cannot be done successfully by any straightforward strategy. Therefore behaviors of model-fluids in different environments and P, T conditions were studied and PVTX graphs constructed.

It is shown that [the] process is controlled by small volume increase, due to opening cracks and fissures. Increase in solution concentration, due to loss of solvent by evaporation, can be linked to volume change, combining balance equations to lever rule.

Calculations demonstrate that crystallization sequence of solids is crowded in a small range of evaporation (75 to 82%). This means small changes in L/V-equilibria will cause large effects in L/S-equilibria.

Regarding the small volume of apatite clusters in carbonatite (about 0.1 cm^3), only a few centimeters of fissure opening will suffice, to completely evaporate its water filling and dry up its salt content.

In the course of evaporation solution is accompanied by vapor, solid NaCl and finally solid KCl. Because in heterogeneous fluid systems all phases coexisting with solution can be trapped simultaneously in various portions by the growing host crystal, a great variety of phase anomalies will arise in the cavities. This is true especially with solids, suspended in solution in intimate contact with the growing apatite. In this way inclusions with high degree of oversaturation can form [at] relatively low temperatures. High temperatures beyond 200° to 250°C however must be excluded, otherwise we need very high pressure to obtain observed densities in the CO_2 subsystem of the cavities.

Textural criteria clearly demonstrate that calcite is displaced by apatite. This process must have operated by release of CO_2. CO_2 as will be shown in a model system H_2O - CO_2 - NaCl, can bring about the same effect as volume increase due to fissure opening. The process however does not operate isobarically. It is shown that pressure increase causes the rather random distribution of CO_2 in cavities and the lack of separate CO_2 inclusions which, because of subsolvus conditions prevailing, is hard to explain by any other process.

Because fluid pressure can fluctuate, even at constant depth level, volume controlled inclusions do not deliver direct information about depth of apatite growth.

Cavity fillings are stages of evolution of evaporating and crystallizing solutions, modified by local and temporal gradients in formation parameters.

Inclusions, due to anomalous phase ratios, will not react reversibly in heating stage experiments. They explode at various temperatures and their cavity fillings do not show any consistent trend. (Author's abstract)

WANAMAKER, B.J., BERGMAN, S.C. and EVANS, Brian, 1982, Crack healing in silicates: observations on natural lherzolite nodules (abst.): EOS, Trans. Am. Geophys. Union, v. 63, p. 437. First author at Dept. Geol. & Geophys. Sci., Princeton Univ., Princeton, NJ 08544.

Crack healing is a process by which the connectivity of crack networks in rocks may be modified and is expected to strongly affect many physical properties such as permeability, acoustic velocity, and resistivity. In an attempt to understand more about the mechanisms and kinetics of crack healing we have been studying a suite of samples of Type 1 harzburgite and lherzolite nodules from the Marcath flow, a late Cenozoic alkali basalt from the Lunar Volcanic Crater Field, Nevada. The porosity in the healing cracks evolves from planar cracks to tubular voids and finally to unconnected spherical porosity; all stages of healing can be observed in the Lunar Crater samples. The final unconnected voids may be slightly elliptical in shape (aspect ratios ~1.1 to 1) or nearly spherical depending perhaps on the contents of the inclusions, the temperature and pressure.

Both CO_2 fluid inclusions and two-phase CO_2 fluid/silica melt inclusions are present, sometimes within the same healed crack. We have observed that the healing process is more advanced where melt is present, probably because of increased diffusion rates. In some cases fluid densitites vary as a function of distance from the former crack tip; but in other cases densities are constant within a given healed crack. Work is in progress to place limits on ascent histories of xenoliths using the information obtained from healed cracks. (Authors' abstract)

WANG, Yurong, LI, Jiatian, LU, Jialan and FAN, Wenling, 1982, Geochemical mechanism of Nb-, Ta-mineralization during the late stage of granite crystallization: Geochemistry v. 1, no. 2, p. 175-185. Authors at Inst. Geochem., Academia Sinica.

The mechanism of Nb-, Ta-mineralization is discussed in the light of the properties of Nb-, Ta-complexes in different phases. Experiments show that Nb and Ta are essentially enriched in the melts when Nb-, Ta-bearing albite granites are completely melted (800-850°C) and in equilibrium with a HF-bearing vapor phases. It is also demonstrated from the experiments that the hydrolysis of Nb-, Ta-fluorine complexes in aqueous solutions takes place with increasing temperature, reaching a maximum value in the vicinity of critical temperature and becoming stable under super-critical conditions. Under this circumstance, Nb-, Ta-complexes can be transported in the vapor phase. Ta exhibits a great ability of transport in the vapor phase as compared with Nb, while Nb is more soluble than Ta under hydrothermal conditions. (Authors' abstract)

WASS, S.Y. and POOLEY, G.D., 1982, Fluid activity in the mantle-evidence from large lherzolite xenoliths (abst.): Terra Cognita, v. 2, p. 229.

WATSON, E.B., SNEERINGER, M.A. and ROSS, Alan, 1982, Diffusion of dissolved carbonate in magmas: experimental results and applications: Earth & Planet. Sci. Letters, v. 61, p. 346-358. First author at Dept. Geol., Rensselaer Polytechnic Inst., Troy, NY 12181, USA.

The diffusivity of dissolved carbonate in sodium aluminosilicate (60% SiO_2, 30% Na_2O, 10% Al_2O_3) and iron-free "basalt" melts was measured by a

^{14}C thin-source tracer technique at conditions of combined high temperature and high pressure, ranging from 800°C to 1350°C and 0.5 to 18 kbar for the simple melt and 1350° to 1500°C at 15 kbar for the haplobasalt melt. Carbonate diffusion is markedly different from previously determined systematics of water, being 1-2 orders of magnitude slower in granitic magmas and considerably faster in basalts. This difference can result in diffusional fractionation of CO_2 and H_2O in magmas, which may be most significant in small-scale processes such as growth of vapor bubbles and formation of some types of glass inclusions in phenocrysts. The new data also place constraints on the rate at which CO_2-dominated fluid bubbles can actually grow. Under more or less isothermal conditions at ~10 kbar, the growth rate is on the order of 1 mm/day, depending upon the degree of supersaturation in CO_2. When combined with knowledge of initial CO_2 contents of magmas and observed characteristics of dispersed bubbles (e.g., in ocean-floor basalt glasses), the diffusivity data may expedite the reconstruction of magma decompression paths. (From the authors' abstract)

WEARE, J.H., HARVIE, C.E. and MØLLER-WEARE, Nancy, 1982, Toward an accurate and efficient chemical model for hydrothermal brines: Soc. Petro. Eng. J., v. 22, p. 699-708. Authors at Univ. California-San Diego CA.

In this paper, we describe the development of a chemical equilibrium model for hydrothermal waters based on the semiempirical equations of aqueous electrolyte solutions recently introduced by Pitzer et al. We discuss application of this model to the system, $Na/K/Ca/Mg/Cl/SO_4/H_2O$, at 25°C. Accurate solubility predictions (usually within 5% of experimental results) can be made for ionic strengths of 0 to 20 m.

We are extending our chemical equilibrium programs to include high temperature ($T \approx 200°C$). We have assessed the availability of data for modeling hydrothermal waters. In this paper, we discuss the accuracy of existing high temperature data in terms of the binary HCl/H_2O system. (From the authors' abstract)

WEEKS, W.F. and ACKLEY, S.F., 1982, The growth, structure, and properties of sea ice: U.S. Army Corps of Engineers, Cold Regions Research & Engrg. Laboratory, CRREL Monograph 82-1, 136 pp.

This monograph describes in some detail the current state of knowledge of the observed variations in the structural characteristics (grain size, crystal orientation, brine layer spacing) and composition (brine, gas and solid salts) of sea ice as well as the presumed causes of these variations. The importance of these variations in controlling the large observed changes in the mechanical, thermal and electrical properties of sea ice is also discussed. (Authors's abstract)

The sub-zero phase relations for seawater are also given, plus data on the individual crystal phases formed on cooling. (E.R.)

WENDLANDT, R.F., 1982a, An experimental and theoretical analysis of partial melting in the system $KAlSiO_4$-CaO-MgO-SiO_2-CO_2: a model for alkalic magma, carbonatite and kimberlite genesis (abst.): Terra Cognita, v. 2, p. 227.

WENDLANDT, R.F., 1982b, Sulfide saturation of basalt and andesite melts at high pressures and temperatures: Am. Min., v. 67, p. 877-885. Author at Lunar & Planetary Inst., 3303 NASA Road 1, Houston, TX 77058.

The solubility of sulfur in silicate melt coexisting with iron sulfide melt has been determined as a function of temperature and pressure for three silicate compositions: Mt. Hood andesite, Grande Ronde basalt and Goose Island basalt (FeO_t = 5.4, 11.1 and 17.0%, respectively). Experimental temperatures vary from 1300-1460°C and pressures vary from 12.5-30 kbar. The oxygen fugacity in the experiments is near that of the C-CO-CO_2-O_2 buffer (10^{-9} bar at Pt = 20 kbar) and the sulfur fugacity is buffered internally at a value above the iron-troilite equilibrium ($fS_2 \approx 1$ bar at Pt = 20 kbar).

Sulfur solubility decreases with increasing pressure and increases with increasing temperature and FeO_t content of the silicate melt; observed solubilities range from a low value of 0.05 wt.% at 30 kbar and 1420°C (andesite) to a high value of 0.26% at 12.5 kbar and 1420°C (Goose Island basalt). The FeO_t content of the coexisting sulfide melt decreases with increasing pressure (from a maximum of 5.5% at 12.5 kbar and 1420°C - Goose Island basalt), increases with FeO_t content of the silicate melt and does not appear to be dependent on temperature. With increasing pressure, the miscibility gap between natural silicate melts and sulfide metals expands and the ratio of FeO_t in silicate melt to FeO_t in sulfide melt increases.

The sulfur solubility measurements establish a basis for evaluating the appearance of immiscible sulfide in erupted magmas, core segregation processes, and subsequent transition metal partitioning studies. Because of the strong negative pressure dependence of sulfur solubility in silicate melts, a magma may be sulfide-saturated in the source region but not on eruption until the late stages of crystallization. (Author's abstract)

WESOLOWSKI, D., DRUMMOND, S.E., MESMER, R.E. and OHMOTO, H., 1982, Tungsten speciation in NaCl solutions to 300°C (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 645.

WEST, R.J. and AIKEN, D.M., 1982, Geology of the Sierrita-Esperanza deposit: Pima mining district, Pima County, Arizona, in S.R. Titley, ed., Advances in Geology of the Porphyry Copper Deposits, Southeastern North America, p. 433-465.

Includes some reference (p. 461-462) to fluid inclusion studies from the literature. (E.R.)

WHITE, W.B., 1981, Reflectance spectra and color in speleothems: The NSS (Nat'l. Speleological Soc.) Bull, v. 43, p. 20-26. Author at Dept. Geosci. & Materials Res. Lab., The Pennsylvania State Univ., University Park, PA 16802.

Calcite in its pure form is colorless. White speleothems are rare; most are colored shades of yellow, tan, gray and brown. Gascoyne has challenged the long-held (but unsupported) view that the common yellow to brown colors are due to iron oxides and advances organic stains as the dominant colorant. This hypothesis is tested by the use of diffuse reflectance spectroscopy, which permits one to extend his "color vision" into the near-infrared.

Pure calcite exhibits a complex spectrum in the 1.4 to 2.5 μm region due to incorporated water either as water-filled voids within the calcite crystals or adsorbed on grain boundaries. Characteristic d-electron spectra of the iron-group elements were found in a few cases.

The spectra of hematite, goethite, and other iron oxide hydrates all contain a characteristic band in the 850 to 950 nm region. The band also appears in the spectra of some speleothems. The spectra of most yellow and brown speleothems are featureless in the 700 to 1400 nm region. The characteristic 900 nm band of the iron oxides is systematically absent. The conclusion is that the almost universal yellow to brown colors of most speleothems are not due to iron oxides. The spectra suggest that a single colorant is responsible and the leading possibility is humic substances extracted from the overlying soils. (From the author's abstract)

WHITNEY, J.A. and STORMER, J.C., Jr., 1982, Primary sulfide inclusions within the Fish Canyon ash-flow tuff and their implications for the paragenesis of calc-alkaline silicic magmas and related ore deposits (abst.): EOS, Trans. Am. Geophys. Union, v. 63, p. 451. Authors at Dept. Geol., Univ. Georgia, Athens, GA 30602.

The Fish Canyon ash-flow tuff is an extremely voluminous (>3000 km^3), homogeneous extrusion erupted from the central San Juan field. It apparently came from the lower crust with rather short residence times in the upper crust. It can therefore give us information on the chemical conditions present in calc-alkaline batholiths prior to solidification. Pyrrhotite is a common inclusion within several phenocrystal phases from the Fish Canyon Tuff. The source area was therefore apparently saturated with respect to iron sulfide. Combined with data on the iron-titanium oxides, biotite, and phase assemblage, the fugacity of various gaseous species can be calculated. Chemical and physical variables of interest include: $T = 790°C \pm 20$; $fH_2O = 2000 \pm 1000$ bars; $\text{Log } fO_2 = -11.9 \pm 0.4$; $\text{Log } fS_2 = 0.0 \pm 0.5$ (~1 bar); $\text{Log } fSO_2 = 2.0 \pm 0.6$ (~100 bars); $\text{Log } fH_2S = 1.8 \pm 0.45$ (~70 bars).

The sulfur and oxygen fugacity values fall very near the sulfur condensation curve, implying that liquid sulfur may have been present in the source area. The pyrrhotite blebs may have formed from such material, with the fugacities buffered by the assemblage Po-Mg-S(L). High sulfur fugacities during melt formation may explain the apparently high oxygen fugacity in calc-alkaline silicic magmas, and thus the differences in fractionation trend between calc-alkaline and tholeiitic associations. During cooling of such magmas, separation of sulfurous gases will control the path followed with respect to oxygen fugacity. In addition, if the Fish Canyon is typical of such magmas, large volumes of sulfur are available during cooling, and may represent a major source of sulfur for related ore deposits. Other ash-flows should be carefully examined for similar sulfide phases. (Authors' abstract)

WHITTAKER, P.J. and WATKINSON, D.H., 1982, Chromite in Cache Creek Group ultramafic rocks, British Columbia (abst.): Geol. Assoc. Canada/Min. Assoc. Canada Program with Abstracts, v. 7, p. 87. Authors at Dept. Geol., Carleton Univ., Ottawa, Ontario K1S 5B6, Canada.

Subeconomic chromite concentrations occur in Alpine-type serpentinized ultramafic rocks within the Permian Cache Creek Group. Peridotite, and to a lesser extent dunite, host the chromite. Chromite occurrences mapped include; Anarchist, Bridon, Cameo L., and Scottie Creek. Murray Ridge and the Mitchell Range were mapped in detail. Chromite from these areas displays disseminated, layered and nodular cumulate texture, and layered and massive texture. The host rocks are sheared with a strongly developed foliation and chromite is consequently fractured to various degrees. Partial oxidation has generated ferrit-chromite and magnetite rims. Chromite core analyses reflect a mixed distribution of high iron and high chromium chromite. Chromite contains inclusions of olivine and orthopyroxene, most of which are serpentinized but with some that remain fresh. Fluid inclusions range from spherical to tubular and are sometimes necked. Bright cores and dark rims and extremities indicate a contrast between two phases occupying fluid inclusions. Negative crystal cavities also occur in chromite. Sulphide inclusions are Ni-Fe and precious metal minerals. EDS analyses have indicated Ru, Os, and Ir to be the common PCE. The ultramafic host rocks to the chromite occurrences are dismembered segments of deformed ultramafic part of an ophiolite succession. The scattered distribution of silicate, sulphide, and fluid inclusions in chromite suggests that localized zones of solid and fluid mobilization existed in upper mantle refractory and cumulate rocks. (Authors' abstract)

WILKINS, R.W.T. and EWALD, A., 1982, Ore-forming fluids of the Aberfoyle tin-tungsten deposit, Tasmania (abst.): J. Geol. Soc. London, v. 139, part 1, p. 96-97.

Aberfoyle is the largest mine within a small but significant tin and tungsten mineral field associated with the Ben Lomond Granite in NE Tasmania. The veins developed within a hydrothermal system in fractured quartzites and shales of the Mathinna Group, above a cupola of the granite. The paragenetic sequence of minerals in the veins can be broadly summarized in three major overlapping stages. In the early stage, within which most ore deposition occurred, cassiterite and wolframite were accompanied by halide-bearing minerals such as fluorite, apatite, topaz and triplite. In the intermediate stage sulphides, chiefly arsenopyrite, pyrite, pyrrhotite, chalcopyrite, sphalerite and stannite were accompanied by quartz. In a late stage of alteration and secondary remobilization of earlier-formed minerals, minor sulphides, chiefly galena, were deposited with scheelite, carbonates and some fluorite.

A preliminary study of fluid inclusions in cassiterite and transparent gangue minerals enables the evolution of the hydrothermal system to be loosely reconstructed. Three types of fluid can be distinguished: (a) CO_2-rich, (b) H_2O-rich with high salinity, and (c) H_2O-rich with low salinity. All three fluid types were present from time to time during the primary depositional stages. Only the low salinity aqueous fluid pervaded the system during the late stage.

Fluid inclusion data indicates that cassiterite-wolframite deposition took place at c. 500-530°C and 700-750 bars total pressure. Late stage alteration of primary ore minerals took place between 150 and 225°C. Lithostatic pressure conditions appear to have prevailed from the earliest stage of ore disposition. However, the presence of naturally decrepitated inclusions in quartz shows that significant fluctuations occurred in P-T conditions.

It is postulated that the CO_2-rich and high salinity aqueous fluids, derived from crystallization of the granite, carried metals, sulphur and carbon into the fracture system. These magmatic fluids became entrained in a meteoric water-dominated convection cell and deposited their metals as the fluids cooled and mixed. The existence of such a system at depth may be inferred from the characteristic fluid inclusions even in barren veins well above the level of economic mineralization. (Authors' abstract)

WILKINSON, W.H., Jr., VEGA, L.A. and TITLEY, S.R., 1982, Geology and ore deposits at Mineral Park: Mohave County, Arizona, in S.R. Titley, ed., Advances in Geology of the Porphyry Copper Deposits, Southeastern North America, p. 523-541.

Includes a discussion (p. 535-537) of the several fluid inclusion studies of the deposit, and the significant differences reported between them. (E.R.)

WILLAN, R.C.R., 1982, Stratabound baryte and sulphide mineralization in the Dalradian supergroup of the Grampian highlands, Scotland (abst.): IAGOD Sixth Symp., Tbilisi, USSR, Sept. 6-12, 1982, Collected Abstracts, p. 236-237.

WINOGRAD, I.J. and ROBERTSON, F.N., 1982, Deep oxygenated ground water:

anomaly or common occurrence?: Science, v. 216, p. 1227-1229. First author at U.S. Geol. Survey, Reston, VA 22092.

Contrary to the prevailing notion that oxygen-depleting reactions in the soil zone and in the aquifer rapidly reduce the dissolved oxygen content of recharge water to detection limits, 2 to 8 milligrams per liter of dissolved oxygen is present in water from a variety of deep (100 to 1000 meters) aquifers in Nevada, Arizona, and the hot springs of the folded Appalachians and Arkansas. Most of the waters sampled are several thousand to more than 10,000 years old, and some are 80 kilometers from their point of recharge. (Authors' abstract)

WOERMANN, E. and ROSENHAUER, M., 1982, Oxygen fugacity and the fluid C-H-O phase in the Earth's mantle (abst.): Terra Cognita, v. 2, p. 227-228. First author at Inst. Kristallogr., Rehinisch Westfaiische Tech. Hochschule.

From experimental work it is deduced that CO_2 reacts with mantle silicates above 26 kb to form carbonates. With pressures increasing still further dolomite or magnesite are buffering mixed fluid phases to continuously lower CO_2-activities (Wyllie, 1978; Eggler, 1978). In a similar way H_2O reacts to form hydrous phases - e.g. brucite- above about 90 kb, buffering the fluid phase to lower H_2O activities with increasing pressure. As a consequence a binary CO_2-H_2O phase will disappear as soon as a hydrous and a carbonate phase coexist with mantle silicates (Ellis and Wyllie, 1979,1980).

The absence of carbonates from typical mantle peridotites and the stable occurrence of diamond indicate that oxygen fugacities must be sufficiently low in the Earth's mantle to reduce the CO_2 activity to a level below the stability of carbonates (Rosenhauer et al., 1977). Intrinsic oxygen fugacity measurements of mantle derived samples indicate that fO_2 may be as low as the wüstite-iron level (Ulmer, 1980; Arculus and Delano, 1980).

Thermodynamic calculations indicate that CH_4 is a stable species in a C-H-O fluid phase under 90 kb and the corresponding temperature of the mantle and fO_2 of the WI-buffer. It follows that:

1. It is possible that a fluid phase with high CH_4 concentrations is stable in the Earth's mantle, and

2. The ultimate limit for the existence of a fluid phase in a peridotitc mantle will be extended to greater depths by the formation of methane. (Authors' abstract)

WOLF, K.H., ed., 1981a, Handbook of Strata-Bound and Stratiform Ore Deposits, Part III, Vol. 10, Bibliography and ore occurrence data: Amsterdam, Elsevier Sci. Pub. Co., 576 pp.

WOLF, K.H., ed., 1981b, Handbook of Strata-Bound and Stratiform Ore Deposits, Part III, Vol. 9, Regional studies and specific deposits: Amsterdam, Elsevier Sci. Pub. Co., 771 pp.

Includes stratiform, oolitic iron, deep-sea sediments, lake sediments, Precambrian Ni-Fe-Cu sulfide, pyritic black shales, Meggen, Rammelsberg, Pine Point, and strata-bound Sn deposits. (E.R.)

WOLF, K.H., ed., 1981c, Handbook of Strata-Bound and Stratiform Ore Deposits, Part III, Vol. 8, General studies: Amsterdam, Elsevier Sci. Pub. Co., 592 pp.

A series of reviews of classification, metallogeny, models, etc.(E.R.)

WOOD, J.A. and MOTYLEWSKI, Karen, 1979, Meteorite research: Reviews of Geophy. & Space Phy., v. 17, no. 4, p. 912-925. Authors at Harvard-

Smithsonian Center for Astrophy., Cambridge, MA 02139.

An extensive review of pertinence to studies of inclusions in meteorites. (E.R.)

WOODS, T.L., ROEDDER, Edwin and BETHKE, P.M., 1982, Fluid-inclusion data on samples from Creede, Colorado, in relation to mineral paragenesis: Geological Survey Open-File Report 82-313, 77 pp.

Published and unpublished data on 2575 fluid inclusions in ore and gangue minerals from the Creede, Colorado, Ag-Pb-Zn-Cu vein deposit collected in our laboratories from 1959 to 1981 have shown that the average salinity (wt. % NaCl equivalent, hereinafter termed wt.% eq.) and homogenization temperature (Th), and the ranges of these two parameters for fluid inclusions in sphalerite, quartz, fluorite, and rhodochrosite, respectively, are 8.1 (4.6 - 13.4), 239°C (195-274°C); 6.1 (1.1 - 10.0), 260°C (190->400°C); 10.7 (6.1 - 11.1), 217°C (213-229°C) and 260°C (247-268°C) (bimodal distribution of Th); and 9.9 (9.3 - 10.6), 214°C (185-249°C). Inclusions have been measured in minerals from four of the five stages of mineralization previously recognized at Creede. The few inclusions of fluids depositing rhodochrosite (A-stage, earliest in the paragenesis) yield Th and salinity values more similar to those of the low-temperature (average Th 217°C) fluids forming some of the much later fluorite (C-stage) than to any of the other fluids. Th measurements on A-stage quartz range from 192°C to 263°C and average 237°C. The early, fine-grained, B-stage sphalerites yielded Th of 214 to 241°C and salinities of 6.1 to 10.2 wt.% eq.

D-stage sphalerite (late in the paragenesis) has been studied in detail (growth-zone by growth-zone) for several localities along the OH vein and reveals a generally positive correlation among Th, salinity and iron content of the host sphalerite. The deposition of D-stage sphalerite was characterized by repeated cycling through different regions of salinity/Th space, as Th and salinity generally decreased with time. Seventeen salinity-Th measurements were made on D-stage sphalerite from one locality on the Bulldog Mountain vein system, which, like the OH vein, is one of four major ore-producing vein systems at Creede. These data suggest a lower Th for a given salinity fluid from sphalerite on the Bulldog Mountain vein than on the OH vein. The very high values of Th for some quartz samples (mostly D-stage) are believed to be a result of the trapping of both gas and liquid from a boiling fluid in the upper levels of the vein system. Boiling of fluids depositing D-stage quartz is indicated by the presence of steam inclusions in quartz and the extreme variability of Th values measured on quartz. The pressure was low ($\leq$125 kg/cm^2) throughout ore deposition.

Three major growth zones in D-stage sphalerite are recognized throughout the OH vein. Deposition of the first major zone began from fluids having intermediate salinities and temperatures (7.8 - 9.2 wt.% eq., 240°C) but the characteristics of the fluids oscillated after that, ranging from 7.2 to 10.1 wt.% eq. and from 225°C to 270°C. Deposition of the second major, most Fe-rich zone began with the hottest, most saline fluids present during D-stage mineralization (270°C, 10.5 - 12.5 wt.% eq., 3 mole % FeS in sphalerite). The fluid then oscillated with respect to Th and salinity (213-274°C, 5.2 - 12.5 wt.% eq.) but showed a general decrease in both with time. Deposition of the youngest major zone began with a very Fe-poor sphalerite (0.25 - 0.75 mole % FeS), from the least saline, coolest fluids (5 - 6.5 wt.% eq., 200-212°C) and ended with a trend of increasing temperature at approximately constant salinity.

The fluid-inclusion data can best be explained by a mixing model involving at least two fluids--one hot and saline, the other cool and fresher. Sudden changes in the mixing ratio, presumably from changes in the plumbing, punctuated long periods of remarkably uniform conditions of ore fluid flow and deposition. The effects of other processes such as convection and heat exchange with wall rocks must have been superimposed on this simple mixing model, however. In contrast to an earlier interpretation, several aspects of the inclusion data may be interpreted to suggest exceedingly slow ore deposition. Work in progress may resolve some of these ambiguities and refine the model. (Authors' abstract)

WYLLIE, P.J. and SEKINE, Toshimori, 1982, Aqueous solutions and magmas in subduction zones (abst.): EOS, Trans. Am. Geophys. Union, v. 63, p. 449. First author at Dept. Geophys. Sci., Univ. Chicago, Chicago, IL 60637.

The thermal structure and history of subducted lithosphere exerts the major influence on the paths followed by volatile components stored initially in the oceanic crust. The variety of possibilities can be illustrated in four permutations for combinations of relatively warm or cool (endothermic dehydration) subducted crust, and cool or warm (induced convection) mantle wedge, conbined with known phase boundaries for dehydration, decarbonation, and melting. For a moderately cool crust and warm mantle wedge, dehydration of crust produces metasomatic amphibole in mantle wedge, and H_2O-undersaturated siliceous melt in crust. The cool melt rises into hotter mantle, and solidifies by hybridization. Phase equilibria from model system $KAlSiO_4$-Mg_2SiO_4-SiO_2-H_2O confirm that hybridization is not simple mixing. According to results extrapolated deeper than 100 km, hybridism produces a series of discrete masses composed largely of phlogopite, orthopyroxene, and jadeitic clinopyroxene. The heterogeneous layer produced just above the oceanic crust provides (1) expelled aqueous fluids which rise to generate in overlying mantle H_2O-undersaturated basic magma, the parent of the calc-alkalic series erupted at the volcanic front, (2) phlogopite-pyroxenites which melt when they cross the deeper, high-temperature solidus, yielding parents of alkalic magmas erupted behind the volcanic front, and (3) exotic blocks which rise diapirically for long-term residence in lithosphere, contributing later to mantle metasomatic processes. Diffusing peridotite components during hybridization cause precipitation of phlogopite and then pyroxenes, with little change in melt composition. All potassium is separated as phlogopite. (Authors' abstract)

XIA, Hongyuan, LIANG, Shuyi, XIE, Weixin and SHUAI, Dequan, 1982, Primary zoning of Huangsha tungsten deposit and its genesis, in United Nations Econ. and Social Commission for Asia and the Pacific (RMRDC) Symp: Tungsten Geology, Jiangxi, China, held in Bandung, Indonesia, 1982: Geol. Pub. House, Beijing, China, p. 553-566. Authors at Chengdu College of Geol.

An attempt is made to elucidate the relationship between granite evolution and associated tungsten mineralization, through the application of mineral association, typomorphic minerals, typomorphic elements, petrochemical parameters and fluid inclusion thermometric study. It is believed that vertical zoning was caused by magmatic crystallization-differentiation-metasomatism, coupled with pulsative zoning at different mineralization stages as well as vertical deposition zoning in the same mineralization stage. In the same petrogenic and metallogenic process, there is a regular variation in mineral association, and the typomorphic minerals, such as wolframite and fluorite, display transitional characteristics which reflect the changes in the physicochemical environment of mineralization. It is suggested that the mica stringers at the top of the vein could be used as a guide for exploration of Sn and W mineralization in the upper and middle part of the vein, and that the reverse vertical deposition zoning might be used in the search for silver-rich sulphide ores in the middle and lower portion of the vein system. This is applicable in the exploration of tungsten deposits not only in Jiangxi, but may also elucidate the wolframite-quartz vein deposits in northern Guangdong, southern Hunan and Guangxi provinces (within the limits of Nanling Range). (Authors' abstract)

XU, Yongchang, WANG, Xianbin, WU, Renming, SHEN, Ping, WANG, Youxiao and HE, Yongping, 1982, Rare gas isotopic composition of natural gases: Geochem., v. 1, no. 2, p. 218-232. Authors at Lanzhou Inst. Geol., Acad. Sinica.

One hundred natural gas samples of different geological periods collected from various localities were determined for their nitrogen, helium and argon contents as well as the isotopic composition of argon. The ratio Ar^{40}/Ar^{36} was found to be from 305 to 9,255. A current helium-argon chronological formula for calculating natural gas ages was corrected. Instead, based upon the chronological accumulating effect of radiogenic Ar^{40}, an Ar^{40}-Ar^{39} empirical formula for calculating natural gas ages has been proposed.

It can be seen from the ratio of nitrogen to atmospheric argon that most of the nitrogen in these natural gases could not be derived from atmospheric nitrogen.

The range of radiogenic He/Ar^{40} is from 5.19 to 23.18, and that for most samples from 7 to 14. The He/Ar^{40} ratios of Sinian samples are from 5.39 to 6.14, indicating their derivation from the deep interior of the earth.

It should be noted that the Ar^{40}/Ar^{36} ratio shows a general trend of approaching the atmospheric value from the Sinian to the Tertiary period, or from old to young in geological age, mirroring, to a great extent, the evolutionary tendency of the rare gas isotopic composition of natural gases with continuous degassing of the earth. (Authors' abstract)

YAGNIK, S.K., 1982 Thermal-gradient migration of brine inclusions in salt: Univ. Calif. Berkeley Dept. Nuclear Eng. Contract AC03-76SF00098, NTIS DE 82013007, 10 p.

YARDLEY, B.W.D., 1982, How do fluids move through metamorphosing rock? (abst.): Geol. Soc. Newsletter (London), v. 11, no. 4, p. 16-17. Author at Univ. East Anglia.

There are at least two very different approaches to the study of metamorphic fluids, and the fact that they often give conflicting results probably means that fluids can move through metamorphosing rock in different ways.

Fluid released by devolatilization reactions must, at least initially, move pervasively through the rock along grain boundaries. Its composition can be calculated from thermodynamic considerations assuming it is in equilibrium with the host rock. Similar pervasive flow can also occur during retrogression and it will be shown that here too the solid phase assemblage can successfully buffer fluid composition.

On the other hand, fluid inclusion studies on vein samples often reveal a wide range of fluid types in individual veins, and it will be argued that this is the result of fluids derived from different layers moving rapidly along fractures so that they do not equilibrate with wall rocks.

Pervasive fluid flow must sometimes be very important, and can cause oxygen metasomatism for example. However, fluid movement also becomes concentrated in veins (hydrofractures) and shear zones, where it is much more rapid. Evaluation of the relative significance of the different types of fluid movement must be an important objective. (Author's abstract)

YAROSHEVICH, V.Z. and AREVADZE, D.V., 1982, Accuracy of results of isotope studies of components of gas-liquid inclusions in minerals, in Use of methods of thermobarogeochemistry during prospecting and studies of ore deposits, N.P. Laverov, ed.: Moscow, "Nedra" Publ. House, p. 94-102 (in Russian).

The problem of release of fluids from inclusions in minerals and possibility of contamination of their isotope composition during preparation of samples for mass-spectrometric isotope measurements, is discussed critically. On the example of the published data on isotope composition of argon, water and CO_2, the sources of experimental errors are shown, leading to decrease of accuracy of results and inadequate genetic interpretations. (Authors' abstract translated by A.K.)

YEFREMOVA, V.P., KUZNETSOV, V.A. and SHUKINA, N.D., 1982, The solubility of α-HgS in hydrosulfide solutions at elevated temperatures: Geokhimiya, no. 1, p. 71-98 (in Russian).

YOCK, D., 1982, Petrographic study of cores and cuttings from drillholes 410 and MB60, Tongonan geothermal field, Philippines (abst.): Proc. Pacific Geothermal Conf. 1982 Part 1, Univ. Auckland Geothermal Inst., Auckland, NZ, p. 416.

Petrographic techniques were used to analyze cuttings and cores from two drillholes, MB6D and 410 in Tongonan, Leyte, Philippines. Identification of the mineralogy was through examination of hand specimens and thirty-five thin sections of cores and cuttings. X-ray diffraction was used to identify clays and actinolite. Microprobe analyses of epidote were made of samples from drillhole 410. Fluid inclusion temperatures were measured from MB6D core at 2647.4 - 2649.8m. Information gained from these techniques has been correlated and used to interpret lithology, mineralogy, hydrothermal alteration, and temperatures encountered in wells MB6D and 410. Evidence shows well 410 is permeable with a high temperature mineral assemblage in equilibrium from depths between 600m - 2346m. The measured bottom hole temperature is 317°C. MB6D has measured temperature less than 250°C throughout the well, superimposed on a fossil hydrothermal system. The well is now generally impermeable due to extensive silicification. The reservoir rocks in both holes are propylitic diorites with extensive epidote veining. It is speculated that fracturing in the pluton (diorite) has increased permeability in the surrounding rocks, causing lateral dissipation of thermal energy. (Author's abstract)

YOSHIDA, Tetsuo, HASBULLAH, Chairullah and OHTAAKI, Tohru, 1982, Kuroko-type deposits in Sangkaropi area, Sulawesi, Indonesia: Mining Geol., v 32, no. 5, p. 369-377. First author at Dept. Mining Kyushu Univ., Fukuoka 812, Japan.

Several kuroko-type ore deposits occur in the central part of western Sulawesi, Indonesia.

The filling temperatures of fluid inclusions in sphalerite and quartz from druse and vein range from 160° to 346°C. This is almost the same as that of the kuroko-type deposits in Japan. (From the authors' abstract)

YOSHIDA, Tetsuo and MUKAIYAMA, Hiromu, 1982, Fluid inclusion study on the Fukazawa Kuroko deposit in the Hokuroku basin, Akita, Japan: J. Mining & Metal. Inst. Japan, v. 98, p. 477-482 (in Japanese; English abstract). First author at Research Associate, Faculty of Engrg., Kyushu Univ.

The Fukazawa Kuroko deposit is situated in the almost central part of the Hokuroku basin. The Tsunokakezawa ore body dealt [with] in this paper is the largest in the Fukazawa deposit and consists mainly of typical stratiform Kuroko ore body with several outlets of ore fluids forming siliceous ore bodies. The stratiform Kuroko ores are composed largely of sphalerite, galena and barite with pyrite, chalcopyrite, tetrahedrite, bornite, chalcocite and covellite. Chalcopyrite and pyrite are commonly found in the coarse grained stratiform Kuroko ores which are distributed mainly in the western part of the Tsunokakezawa ore body. On the other hand, tetrahedrite, bornite, chalcocite and covellite are found in the fine grained ores with barite, and are commonly in the eastern part of the ore body. Colloform and framboidal textures are frequently observed in the fine grained ores.

Filling temperatures have been measured for 104 fluid inclusions in sphalerite, barite and calcite. They range from 209° to 370°C. Most of them are ranged between 250° and 340°C. The higher temperature values are obtained largely from the western part of the ore body and the lower values from the eastern. Inclusions in the Kuroko ores formed near the outlets of ore fluids yield higher filling temperatures than those in the outskirts of them.

From these temperature data, the depth of sea in the central part of the Hokuroku basin at the formation of the Fukazawa deposit is estimated to have been about 1440 meters at least. It is deeper than that proposed by Sato (1968). However, it is shallower than that supposed from the foraminiferal assemblage by Guber and Ohmoto (1978). (Authors' abstract)

YOSHIDA, Yutaka, 1982, Study on the hydrothermal system in the Nigorikawa Basin, Hokkaido: J. Balneological Soc. of Japan, v. 33, no. 1, p. 24-36. Author at Geotherm. Dev. Div., Japan Metals & Chem. Co., Ltd.

Thermal waters discharged from the Nigorikawa Basin are characterized by various contents of Cl^-, high contents of CO_2 and HCO_3^- and by the constant water temperature. These are considered to be due to the characteristic hydrothermal system in this area. According to the results of chemical analyses, it is suggested that the origin of the thermal water is related to the deep hot water ascending through the fractured zone along the caldera wall. The underground water which is heated by conductive heat is reserved in the two types of the reservoirs after being mixed with the steam and/or deep hot water. Because of incomplete mixing of such waters, Cl^- concentrations of thermal waters are varied in a wide range. On the other hand, as the movement of CO_2 gas is independent of water thermal waters become uniform both in the total dissolved carbonate concentration and enthalpy. These two kinds of waters come up to the surface, without mixing with the cold underground water near the surface. (Author's abstract)

YOUNG, L.M., 1982, Fluid-inclusion temperatures of diagenesis in the Lake Valley Formation (Mississippian) near Silver City, New Mexico (abst.): Geol. Soc. Am. Abstracts with Programs, v. 14, p. 651. Author at Dept. Geosci., Northeast Louisiana Univ., Monroe, LA 71209.

Fluid-inclusion thermometry was used to determine temperatures of crystallization/recrystallization in the Lake Valley Formation at Chloride Flat, Lone Mountain, and Georgetown. In general, there is a crude correlation between temperature and stratigraphic proximity to nearby Late Cretaceous-Early Tertiary intrusions. Temperatures of 335-380°C (mode 1) occur closest to large intrusions, whereas most other temperatures show a range of 165-260°C (mode 2).

However, some Lone Mountain samples show a bimodal temperature distribution, with a mode within a range of 75-130°C (mode 3). This mode might be either (1) a relic of sedimentary (non-igneous) diagenesis or (2) produced by secondary or pseudo-secondary inclusions related to igneous diagenesis.

A few samples of Ordovician Cutter Dolomite were examined in the hope of establishing a "baseline" temperature of sedimentary diagenesis. These samples yielded values from 135-150°C, which would appear to constitute yet another mode. These data thus fail to help resolve the distinction between sedimentary and igneous diagenesis in the Lake Valley, possibly because the Cutter was affected by the same episode of hydrothermal mineralization that affected the overlying Fusselman Dolomite.

From the data at hand, one can conclude that mode 1 and at least the upper range of mode 2 of temperatures are igneous-related; the remaining data are ambiguous. (Author's abstract)

YU, Changtao, 1982, The nature of fluid inclusions in quartz crystals from the gold-bearing quartz veins and ore-forming temperature at Linglong gold mine, Zhaoyuan County, Shandong Province: Scientia Geolo. Sinica, 1982, no. 3, p. 309-314 (in Chinese; English abst.). Author at Shenyang Instit. Geol. & Mineral Resources, Ministry of Geol.

The gold-bearing quartz veins in the Linglong gold mine were formed in three different ore-forming stages: (1) early quartz-pyrite stage, consisting of quartz, sericite and pyrite; (2) quartz-gold-metallic sulfide stage, consisting of quartz, pyrite, chalcopyrite, galenite, sphalerite, bornite, cosalite, kroebrite, native gold, electrum and minor sericite; (3) carbonate stage, consisting of calcite, siderite and minor quartz.

Stages (1) and (2) contain the following types of inclusions:

1) Two-phase inclusions (liquid solution and vapor; see photographs 3, 5).

2) Polyphase inclusions (liquid solution, liquid CO_2, vapor and fibrous daughter crystals of unknown mineral; see photograph 6).

The fluid inclusions in the quartz formed in stage (1) homogenize at the critical point at 360° to 480°C. However, those in quartz of stage (2) homogenize to liquid and their homogenization temperature ranges from 120° to 360°C. Decrepitation temperature of pyrite ranges from 255° to 320°C and that of sphalerite ranges from 190° to 205°C. Hence, the writer supposes that the ore-forming medium in the quartz-pyrite stage was a high temperature fluid under critical (or supercritical) condition, and that the ore-forming medium in the quartz-gold-metallic sulfide stage was a low temperature thermal solution. Pressure under which the mineral was formed is 420 bar.

The release of red-brown NO_2 from the inclusions during their decrepitation (see photograph 4) shows that the ore-bearing fluid contains nitrate or nitrite. Hence we think that the gold exists and was transported as $HAuCl_4$ into the ore-bearing fluid. (Author's abstract, edited by E.R. but sic)

YU, Fuji and LIU, Deping, 1982, Continuous isotopic measurement of oxygen and hydrogen in water of the order of microlitre and its application to fluid inclusion study: Geochimica (Diqiu Huaxue), no 3, p 291-295 (in Chinese; English abstract).

A combination of the high temperature CO_2-H_2O equilibrium method and hot uranium or zinc method has been established for simultaneous determination of oxygen and hydrogen isotopes extracted from water samples on the order of microliters. The analytical accuracy of this method is ±0.1% for oxygen and ±1.0% for hydrogen. As an additional merit of this instrument it is easy to operate and only 3 hours are needed to complete a run. Preliminary results of its application to determining isotopic composition of fluid inclusions are satisfactory. (Authors' abstract)

YURKOVA, R.M., SLONIMSKAYA, M.V., DAYNYAK, B.A. and DRITS, V.A., 1982, Hydrogen and methane in serpentines of various genetic types (on the example of Skhalin and Koryak Upland): Akad. Nauk SSSR Doklady, v. 263, no. 2, p. 420-425 (in Russian). Authors at Geol. Inst. of Acad. Sci. USSR, Moscow.

Serpentine samples of grain size 0.03-0.1 mm were analyzed by DTA device up to 600°C (below T of serpentine decomposition) and gas analyser "Setaram." The highest H_2 and CH_4 contents are typical of post-olivine early antigorite. Replacement of antigorite by lizardite causes decrease of H_2 and CH_4 contents. Solid-stage recrystallization of serpentines causes loss of the above gases. (Abstract by A.K.)

ZAREMBO, V.I. and L'VOV, S.N., 1982, Limiting partial volumes of individual ions in aqueous solution: Geokhimiya, no. 3, p. 388-399 (in Russian).

ZAYKIN, I.D. and MOISEENKO, V.G., 1982, A new method for the determination of true mineral crystallization temperatures: Akad. Nauk SSSR, Dokl., v. 265, no. 6, p. 1486-1488 (in Russian).

The method is based on thermokinetics of gas liberation from inclusions. (E.R.)

ZEMSKOV, V.S., BELOKUROVA, I.N., BABARENKO, A.A., SAVYTCHEV, V.V. and BOGDANOVA, N.F., 1982, Solidification of copper and silver under microgravity conditions: J. Crystal Growth, v. 60, p. 86-90. Authors at Baikov Instit. Metall., Acad. Sci. USSR, Leninskii prospekt 49, 117334, Moscow, USSR.

The external and internal structures of copper and silver samples have been studied, which were obtained by containerless solidification in microgravity experiments of short duration. The investigation of the structures by light and electron microscopy, as well as by X-ray methods, allowed us to reveal a texture of single-crystal type and a clearly pronounced dendritic structure. In copper samples, pores have been found whose occurrence could be due to the formation of shrinkage cavities or to the evolution of gases which the starting samples contained. Lack of contact with container walls and lack of convection have caused the solidification to occur under the conditions of high supercooling with the formation of a few dendrites (from 1 to 3). (Authors' abstract)

ZHANG, Ligang, ZHUANG, Longchi, QIAN, Yaqian, GUO, Yingshun and QU, Ping, 1982, Stable isotope geochemistry of granites and tungsten-tin deposits in Xihuashan - Piaotang area, Jiangxi Province, in United Nations Econ. and Social Commission for Asia and the Pacific (RMRDC) Symp: Tungsten Geology, Jiangxi, China, held in Bandung, Indonesia, 1982: Geol. Pub. House, Beijing, China, p. 553-566. Authors at Yichang Inst. Geol. and Min. Resources, Ministry of Geol., PRC.

The $^{18}O/^{16}O$ ratios were determined for 10 whole-rock samples and 4 quartz-phenocryst samples from the Yanshanian granitic rocks in the Xihuashan-Piaotang area, Dayu county, Jiangxi Province. The $\delta^{18}O$ values range from +9.5 to +11.30‰ and from +10.1 to +10.8‰ respectively. The $\delta^{18}O$ values of the whole-rock and the quartz samples show that they are enriched in ^{18}O and the granites are presumably derived from the anatexis of crustal argillo-arenaceous sedimentary rocks. The $^{18}O/^{16}O$ ratios of the ore fluids of quartz for the pegmatoid shells show a strong correlation with the values (from +8.5 to -10.5‰) of the regional juvenile water.

The first two stages of mineralization have $\delta^{18}O(H_2O)$ values which are nearly constant from +4.7 to +8.0‰ and the $\delta^{18}O(H_2O)$ values of stages 3 and 4 range from +3.0 to -8.7‰ in Xihuashan tungsten-tin veins, and the δD values of fluid inclusions in quartz of different stages range from -43 to -60‰. Synthesizing the relevant data indicates that the ore-forming fluids of the first two stages are related to reequilibrated magmatic water and that mineralization of the later two stages was brought about by a hydrothermal solution with a dominant meteoric water content.

The $\delta^{18}O$ and δD values of ore fluids of the stages 1, 2, 3, and 4 are from +9.1 to +4.8 and -54 to 55‰ respectively in Piaotang tungsten-tin veins. This may be from a reequilibrated magmatic water source. The $\delta^{18}O$ and δD values of the major stage (5) of economic tungsten mineralization are from +6.0 to 1.1‰ and -59 to -63‰, respectively. This it might be a mixture of juvenile and meteoric water. The later stage (6) hydrothermal solution also shows a composition of meteoric water.

The 36 various sulfides show a very narrow range of $\delta^{34}S$ values from +0.6 to -3.4‰ in the ore zone. (Authors' abstract)

ZHANG, Shulin, 1982, Ore-forming solution and genesis of a rock crystal deposit in south Hunan, indicated by fluid inclusion studies: Geochem., v. 1, no. 4, p. 387-408. Author at Geol. Team No. 654 Hunan Geol. Bureau.

Si, Al, Ca, Mg, Fe, Na, K, CO_3^{-2}, F, etc. are detected from the fluid inclusion leachates. Among these constituents, Si, Na, and CO_3^{-2} are predominant, amounting to more than 80 percent. This indicates that the ore-forming solution must be alkaline with Si, Na, and CO_3^{-2} as its dominant components. Th for the solution range from 80 to 360°C. Although rock quartz can crystallize at the above temperature interval, perfect crystals of economic importance are largely formed below 260°C. The temperature of formation increases toward the granite intrusives at a rate of about one degree per meter. It is estimated from the lithostatic load that the salinity of rock quartz is 17-23 (NaCl wt%), while that of vein quartz is relatively high as compared with the former. There is a tendency for the salinity of the ore-forming solution to increase with depth. (Author's abstract)

ZHANG, Zhengen and LI, Xilin, 1982, Studies on mineralization and composition of DC ore field, Guangxi, China: Geochemistry, v. 1, no. 4, p. 355-368. Authors at Inst. Geochem., Acad. Sinica (in English).

Th of inclusions: granite (707 and 685°C); Cu-Zn skarn (423°C), Zn skarn (418°C); W-quartz vein (307°C); cassiterite-sulfide (273°C); Pb-Zn-Sb (131°C); Hg (120°C). Gas-rich inclusions are higher near the "magma" [i.e., intrusive?]. (E.R.)

ZHARIKOV, V.A., 1982, Criteria of acidity of mineral-forming processes, p. 63-91 in Acid-basic properties of chemical elements, minerals, rocks and natural solutions: "Nauka," Moscow, 216 pp., 1100 copies printed, price 2 rbls 50 kopecks (in Russian).

The paper presents essential definitions, modes of evaluation of acidity of minerals and their paragenesis and modes of evaluation of mineral forming medium-melt or solution. (A.K.)

ZHILINSKIY, G.B., KISLITSYNA, V.P., KOPYATKEVICH, I.R., LAVRINENKO, L.I. and NOVITSKIY, Yu.V., 1981, Synthetic monocrystals of cassiterite: "Nauka," Moscow, 140 pp., 850 copies printed, price 1 rbl. 50 kopecks (in Russian).

The book bears some Th of inclusions in cassiterite, quoted from various publications (p. 10), results of studies of conditions of hydrothermal crystallization, description of dissolution kinetics, mass transport and cassiterite crystallization. (A.K.)

ZHIRNOV, A.M., 1982, Geological-structural factors of formation of ore stocks in subsurface vein gold deposits: Izvestiya Akad. Nauk SSSR Ser. Geol., no. 9, p. 107-119 (in Russian). Author at "Severovostokzoloto," Magadan, USSR.

The main part of the gold in the discussed deposits (names not given) of subsurface type, precipitated at 390-300°C (Th of inclusions in quartz), only rarely at T decreasing to 200°C, although initial solutions penetrating fissures might be ≥420°C. (A.K.)

ZHU, Gu, FAN, Qinxuan, WU, Jiaquan and LEI, Kerun, 1982, The extraction and the determination of micro-amount sulfate ions in the liquid phase of fluid inclusion: J. Central-South Inst. Mining & Metallurgy, no. 1, p. 21- (in Chinese; English abstract).

High temperature extraction in a closed system after decrepitation and the improvement of the determination by the indirect barium iodate method are reported in this paper. It is proved by experiments that the composition extracted is equal to that of the liquid phase of the inclusion and that the amount extracted is basically complete. The sensitivity is 0.25 ppm. Determination error of the method is about ±15%. (Authors' abstract)

ZHUKOV, F.I. RYABOKON, A.S. and DEMIKHOV, Yu.N., 1982, Formation of gold-ore zones determined from variations in carbon, sulfur, hydrogen, and oxygen isotopes in rocks and gas-liquid inclusions: 9 Vses. Simpoz. po Stabil. Izotopam Geokhimii, Moskva, 16-19 Noyab., 1982, M. 1982, no. 1, p. 94-96 (in Russian).

Title only translated. (CA 99: 25654y)

ZIAN, Xiaozeng and LIU, Jinquan, 1982, The granitic rocks of Fujian Province and their evolution, in Proceedings of Symp. on Geology of Granites and their Metallogenetic Relations, Abstracts, Nanjing, China, Oct. 26-Nov. 9, 1982, p. 9-11. Authors at Bureau Geol., Fujian Province.

There are two genetic series of granitic rocks. One is the crust derivation type (metamorphism-metasomatism granites and remelting granites). The other is the mantle derivation type (mix-fusion granites and differentiation type granites).

Gas-liquid inclusions (Th ~400°C) are only seen in quartz of the metamorphism-metasomatism type granite. In the remelting type, gas-liquid inclusions are more than the melt inclusions in the quartz(sic). The homogenization temperature is about 800°-860°C. The inclusions in quartz of the mix-fusion type are mainly melt inclusions with Th ~900°-1030°C. In quartz of granites of the differentiation type, there exist abundant melt inclusions, with Th ~980°-1140°C. (From the authors' abstract)

ZIEGENBEIN, Dieter and JOHANNES, Wilhelm, 1982, Activities of CO_2 in supercritical CO_2-H_2O mixtures, derived from high-pressure mineral equilibrium data, in High-Pressure Researches in Geoscience, W. Schreyer, ed.: E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart, p. 493-500. Authors at Min. Inst. Univ. Hannover, Welfengarten 1, 3000 Hannover, FRG.

Equilibrium temperatures and pressures of the reaction calcite + quartz = wollastonite + CO_2 have been determined in pure CO_2 gas (1-5 kbars, 600-850°C) and CO_2-H_2O mixtures (2, 3, 4 kbars, 520-850°C). Activities and activity coefficients of CO_2 are derived from these data. Considerable non-ideal mixing behavior of CO_2 with activity coefficients $\gamma CO_2 > 1$ at all investiated P, T, X conditions is revealed. The activities disagree with calculated data of Flowers (1979) but are in accord with CO_2 activities derived from other mineral equilibrium studies (Zharikov et al., 1977). (Authors' abstract)

ZOLENSKY, M.E. and BODNAR, R.J., 1982, Identification of fluid inclusion daughter minerals using Gandolfi X-ray techniques: Am. Mineralogist, v. 67, p. 137-141. Authors at Dept. Geosci., The Pennsylvania State Univ., University Park, PA 16802.

Abstract in Fluid Inclusion Research--Proceedings of COFFI, v. 13, p. 280-281, 1980. (E.R.)

ZUMBRUNN, R., NEFTEL, A. and OESCHGER, H., 1982, CO_2 measurements on 1-cm^3 ice samples with an IR laserspectrometer (IRLS) combined with a new dry extraction device: Earth & Planet. Sci. Letters, v. 60, p. 318-324. Authors at Physics Inst., Univ. Bern, Switzerland.

A new dry gas extraction and analysis method for small (1 cm^3) ice samples is presented. The extraction device, cooled to -20°C, contains two movable steel needle matrices for crushing the ice. During the crushing process the gas escaping from the ice sample is continuously analyzed for CO_2 with an infrared laserspectrometer. This method enables a fast measurement (few minutes) of the CO_2 concentration in the air bubbles with high spatial resolution in the ice core and a minimum potential contamination. An important CO_2 contamination source due to an interaction of water vapor with surfaces is shortly discussed.

The reproducibility of extraction and analysis is ±2%. We analyzed CO_2 concentrations in the trapped air from different ice cores originating from the Greenland ice sheet and from Antarctica. (Authors' abstract)

ZYRYANOV, V.N., 1981, Phase relations in the Lc_{ss}-Ne_{ss}-Fsp-$(K,Na)Cl^m$ system and the pseudoleucite problem: Geokhimiya, 1981, no. 5, p. 662-670 (in Russian; translated in Geochem. Int'l., v. 18, no. 3, p. 23-31, 1982). Author at Inst. Exper. Min., Acad. Sci. USSR, Chernogolovka, USSR.

Measurements have been made on the distribution of K and Na between Lc_{ss} and a $(K,Na)Cl^m$ melt at 800-1000°C; it is shown that Lc_{ss} can coexist with 95% $NaAlSi_2O_5$. Measurements have been made on the temperature of Lc_{ss}-Ne_{ss} and Lc_{ss}-Fsp equilibria for natural objects in the range 800-900°C, which correspond to the crystallization conditions for nepheline syenites. The leucite crystals from the liquidus stage in such rocks are enriched in sodium by ion exchange with the fluid. When these attain the composition corresponding to the Ne-Fsp eutectic, they melt and then crystallize as pseudoleucite (Ne+Fsp). Pseudoleucite consisting of Ks and Fsp is formed in potash-rich intrusions by the decomposition of leucite in the solid state. It is shown that analcime, which occurs in typical magmatic structures in the groundmass in volcanites, crystallizes from the melt in the form NaLc, which acquires the structure of analcime after quenching by hydration under subsolidus conditions. (Author's abstract)

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. 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.

BERDNIKOV, N.V. and KARSAKOV, L.P., 1982, Fluid inclusions in minerals of the rocks of the Belomorian complex: Akad. Nauk SSSR Doklady, v. 266, no. 6, p. 1440-1443 (in Russian).

The Belomorian complex is one of the oldest on the Baltic shield. It consists of granite gneisses, amphibolites, amphibole-, mica- and high-alumina gneisses and schists of the Belomorian series of the Archean, intruded by Archean and Early Proterozoic gabbroids and granites. In the structure of the Belomorian shield, the complex constitutes the Belomorides, which underwent polycyclic development: two stages of deformation, metamorphism and magmatism are observed in the Archean (2850 and 2700 Ma) and two in the Early Proterozoic (2400 and 1900-1800 Ma) [1, 2]. The distinguishing feature of the Belomorian complex is low-gradient metamorphism in all periods of the geologic evolution. In the early stages, rocks of high-pressure granulite facies were developed ($P = 9 \cdot 10^8$ Pa, $T = 800°C$). All later periods of evolution also began with the manifestation of high-pressure metamorphism, to which the formation of a complex of eclogitized basic rocks and kyanite gneisses is related ($P = 9\text{-}10 \cdot 10^8$ Pa, $T = 650\text{-}750°C$ [1-3]. It is very interesting to trace the evolution of the low-gradient metamorphism of the Belomorian complex on the basis of fluid inclusions.

We studied the garnet-kyanite-biotite gneisses on the left bank of the Ryabina stream (Kanda River basin, Yena segment of the Belomorian megablock), which are interbedded here with amphibole gneisses, migmatites and amphibolites. They enter into the structure of the Rybnogorsk synformal fold [4]. In this segment, the rocks are metamorphosed to amphibolite facies, the metamorphic processes of the Svecofennian epoch of activation being more intensively manifested. The temperature of the metamorphism, from the biotite-garnet geothermometry, was 60°C,**and the pressure $6.5 \cdot 10^8$ Pa [1]. No high-temperature parageneses of the granulite facies are known [1441*]. According to [1], the kyanite gneisses of the Yena segment were formed at lower pressures than the rocks of the Chupa segment.

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*Beginning of new page in the Russian text. **Sic. Probably 600°C meant.

Carbon dioxide inclusions in quartz and from samples of garnet-amphibole and garent-biotite-kyanite gneisses were studied by cryometric methods. Primary carbon dioxide inclusions in quartz are well faceted, are oriented strictly along the elongation of the crystal (fig. 1a), and are from 5 to 15 μm in size. The carbon dioxide filling them is mainly pure; only in rare cases does its triple point drop to -58 to -60°C. Homogenization of the carbon dioxide occurs in a broad interval, from -34 to +15°C (spec. vol. of CO_2 0.92-1.22 cm^3/g).

In three partially faceted, flat primary inclusions, superdense carbon dioxide was found (fig. 1c). When such inclusions were chilled, no heterogenization set in, but at temperatures of about -70°C the carbon dioxide froze, with the formation of a shrinkage cavity, which gradually decreased in size as the temperature rose and disappeared completely the moment the carbon dioxide melted. Melting occurred at -56.6°C, with readily visible movement of the phase boundary of melting.

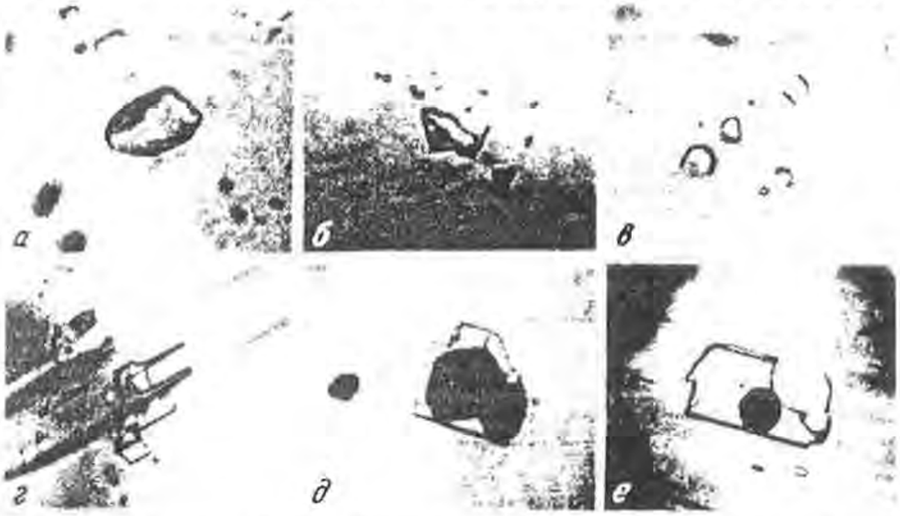

Fig. 1. Carbon dioxide inclusions in quartz (a-c) and kyanite (d-f) from kyanite gneisses of the Yena segment of the Belomorian megablock, x800; a, d = primary, b = secondary, c = superdense, e = inclusion enveloping a crystal of graphite (?), f = healing of primary inclusion; dark = graphite (?).

Pseudosecondary carbon dioxide inclusions differ from primary ones in that they have a zonal arrangement in the crystal, less perfect faces and narrow range of homogenization temperatures, from -11.5 to -15°C (spec. vol. of CO_2 1.02-1.22 cm^3/g)(sic).

Secondary carbon dioxide inclusions form zones along healed cracks cutting across mineral boundaries and associations of primary and pseudosecondary inclusions. They usually are small and have crooked, amoeboid boundaries (fig. 1b). The practically pure carbon dioxide filling them (Tm = -56.6°C) homogenizes in the interval -23 to +7.5°C (spec. vol. of CO_2 0.96-1.14 cm^3/g), although zones of very dense secondary inclusions are found (Th from -44.5 to -25.3°C, spec. vol. of CO_2 0.88-0.95 cm^3/g).

[1442] The Th of carbon dioxide inclusions in quartz are given in the histogram in fig. 2a. Superdense inclusions are arbitrarily given Th = -60°C.

Kyanite contains a large number of carbon dioxide inclusions. The primary inclusions are usually three-dimensional (fig. 1d), tubular; sometimes they have faces in the form of a prismatic crystal. Their long axes coincide with the elongation of the mineral. They form groups, chiefly in the inner parts of the crystal. Their Th varies from -57 to

+4°C (spec. vol. of CO_2 0.84-1.11 cm^3/g). Superdense ones are common among them. Primary inclusions often contain a solid phase in the form of a black opaque lump, which in isolated cases is pseudohexagonal in shape, and the frequency of occurrence of a solid phase in the inclusions increases in proportion to their density. The black solid phase also occurs outside the inclusions. Sometimes its size reaches 50-60 μm. In this case the carbon dioxide inclusions "stick" to it (fig. 1e), which indicates their primary nature. The black solid phase was identified as graphite. In some primary inclusions, healing of the vacuole by material of the host mineral is observed (fig. 1f). Apparently that process could have taken place when pressure increased in the progressive stage of metamorphism and contributed to equalization of the external pressure and fluid pressure within the inclusion.

Pseudosecondary inclusions in kyanite are usually flat, rarely tubular to acicular, with good faces, and form thick zones along the cleavage of the mineral. The pseudosecondary inclusions homogenized in the range of -22 to +12°C (spec. vol. of CO_2 0.96-1.18 cm^3/g). No solid phases were noted in them.

Very rarely secondary inclusions are encountered in kyanite, following healed cracks across the elongation of the crystal. They have an angular corrugated shape and contain low-density carbon dioxide (Th >+22°C). The cryometric data on CO_2 inclusions in kyanite are given in fig. 2b; a composite histogram of Th is given in fig. 2c.

Detailed cryometric investigations of especially large (up to 20 μm) three-dimensional primary inclusions in kyanite made it possible to find the separation of fluid in them in the course of freezing. At $T = -62°C$ a transparent solid phase Ts_1 freezes out. Complete freezing of the inclusion occurs at -68°C with the "explosion" typical of carbon dioxide. Partial melting of Ts_1 occurs at -60°C, and the inclusion thaws out completely at -56.6°C. After [1443] thawing the content of the inclusion in one case immediately went to the fluid state (superdense CO_2), in another bubbles appeared which disappeared at -52°C. It was not possible to ascertain the composition of the impurity causing the appearance of Ts_1 by the cryometric method.

The absence of visually identifiable water was typical of all the carbon dioxide inclusions.

Using the data on specific volumes of practically pure carbon dioxide inclusions in the minerals and the P-T-V diagram for pure CO_2 [5], it is possible to calculate the pressure of metamorphism of the rocks investigated. In primary and pseudosecondary inclusions at 650°C it ranges from 3.2 to $8.1 \cdot 10^8$ Pa. If it is taken into account that the specific volume of carbon dioxide in superdense inclusions is not determined by the cryometric method, the maximum pressures of progressive metamorphism probably exceeded $8.1 \cdot 10^8$ Pa.

Seconary carbon dioxide inclusions characterize the conditions of the regressive state of metamorphism. At 600°C the pressure in them varies from 6.9 to $2.4 \cdot 10^8$ Pa or lower, as secondary carbon dioxide inclusions in kyanite remain heterogeneous at +22°C. In fig. 2d and e, the scatter of Th is presented in the form of horizontal lines, for inclusions from individual zones and groups in quartz and kyanite, respectively. The larger scatter of values is caused by the extensive development of processes of anomalization of the inclusions by microcracks at different stages of metamorphism. Apparently the metamorphism of the rocks studied was accompanied by intensive tectonic movements.

Thus cryometric investigations on carbon dioxide inclusions in the minerals of the Yena segment of the Belomorian megablock support the con-

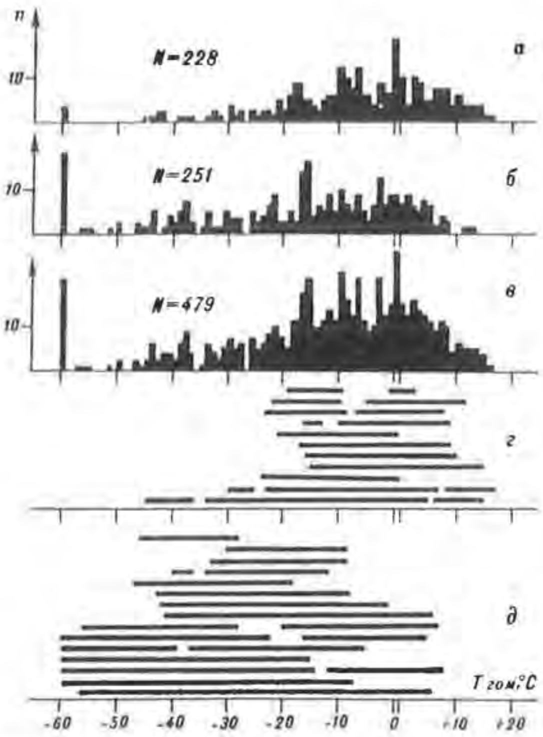

Fig. 2. Results of cryometry of carbon dioxide inclusions in minerals of the kyanite gneisses of the Yena segment of the Belomorian megablock: a - in quartz, b - in kyanite, c - composite histogram; d, e - spread of Th of carbon dioxide inclusions in individual zones and groups in quartz (d) and kyanite (e).

clusion that the rocks constituting it were formed at pressures above $8.1 \cdot 10^8$ Pa in the course of low-gradient metamorphism.

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1. The Earth's crust in the eastern part of the Baltic shield: Moscow, Nauka, 1978, 228 p.
2. Cyclicity and directionality of metamorphic processes: Leningrad, Nauka, 1978, 280 p.
3. Volodichev, O.I. Facies metamorphism of kyanite gneisses: Leningrad, 1975, 190 p.
4. Ez, V.V. Structural geology of metamorphic complexes: Moscow, Nedra, 1978, 191 p.
5. Mel'nik, Yu.P. Thermodynamic properties of gases under the conditions of deep petrogenesis: Kiev, Naukova dumka, 1978, 250 p.

CHKHARTISHVILI, T.A. and NAUMOV, V.B., 1982, Thermometric investigation of granitoid rocks of the Kelasursky intrusive (Abkhazia): Bull. Acad. Sci. Georgian SSR, v. 107, no. 3, p. 549-552 (in Russian with Georgian and English abstracts; translation courtesy of Paul R. Bannes).

The Kelasursky granitoid intrusive is situated in the Gagra-Javsky tectonic zone of the Greater Caucasus. The main mass of the rocks composing it is represented by biotite granite. The youngest appear to be dikes of granite-aplites, aplite-orthotectites and granite-porphyries(1).

The genesis of the Kelasursky massif continues to be the subject of controversy. In any case, a substantial resolution of this question may have purely applied significance inasmuch as it determines the degree of its ore content. With this object in mind the authors undertook thermometric investigation of the massif rocks. Previous research in this direction has shown that complete homogenization for the majority of melt inclusions in blocky quartz of aplite-orthotectites begins at 740-780°C, and, for a few, at 800°C(2). Here we present the results of thermometric investigation of melt inclusions in quartz of thin (20-50 cm) granite-aplites and granite-porphyries.

In determining Th, the results used were obtained from groups of inclusions (no less than 3-5). As a rule, homogenization was carried out repeatedly, since the first homogenization will give somewhat elevated results.

As in preceding research(2), thermometry of melt inclusions was carried out in a heating stage with a platinum heater(3) and by use of the quenching method. This method permits observation of a large amount of inclusions over an extended interval of time. The accuracy of the measuring instrument is ±10°C.

Granite-aplites are spread throughout the entire intrusive, and dip to the northwest and southwest at an angle of 10-80°; to a lesser extent, northern (0-20°) and southern (150-145°) dip (∢ 10-40°) is observed; and still less often, an eastern (75-110°) dip at an angle of 75-85°.

In mineralogical composition these rocks correspond to potassium-feldspar granites, alaskites and quartz alaskites, which, along with petrochemical peculiarities (table), points to their genetic relationship with a granitic magma.

They are characterized by aplitic, less often by porphyritic and micropegmatitic structures. Occasionally one observes transitions to granitic structure.

Plagioclase (oligoclase) is polysynthetically twinned, and sometimes forms phenocrysts, and contains myrmeketic intergrowths of quartz. Potassium/sodium feldspar (anorthoclase, untwinned microcline, sodium orthoclase, orthoclase) is usually perthitic. Quartz is widely distributed in the form of fine, and occasionally coarse grains (phenocrysts). Biotite and hornblende are observed in insignificant amounts. Accessories are represented by orthite, zircon, magnetite, apatite, and sphene. The rocks are characterized by sharp contacts (with thin quench zones) with the country rocks and by homogeneity which points to their intrusive nature(4).

Primary crystallized inclusions were observed by us in quartz. They are very fine, usually 1-5 μm, sometimes 6 μm. The identification of solid phases in inclusions seemed impossible in view of their small size; however, anisotropy of the majority of phases was observed in crossed Nicols. In investigating approximately 100 inclusions it was established that at a temperature of 640°C for 6 hours, homogenization of the inclusions was not observed. Complete homogenization commenced for the majority of the inclusions at 680-700°C (for 2 hours).

Granite-porphyries are connected to the edge or apical parts of the intrusive and constitute a structural part of biotite granites. Their mineralogical composition and petrochemical peculiarities are analogous to biotite granites (table). They are characterized by glomeroporphyritic, granitic-porphyritic, wholly crystalline-porphyritic, sometimes eutectophiric structures. Phenocrysts are represented by oligoclase, potassium-sodium feldspar, quartz, and biotite.

Plagioclase is usually coarsely crystalline, idiomorphic, zoned, poly-

Average chemical composition of biotite granites, granite-aplites, biotitic granite-porphyries (edge facies and crosscutting bodies)

Rocks	Oxides (weight %)													Sum	Avg.*
	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	BaO	P_2O_5	P.P.P.		
Biotite granite	69.60	0.20	15.00	1.70	2.00	0.10	0.95	2.30	3.30	3.15	0.51	0.18	0.85	99.84	18
Granite-aplite	75.25	0.10	12.84	0.66	1.05	0.03	0.04	1.04	2.68	4.31	0.33	0.21	0.98	99.52	6
Biotitic granite-porphyry (edge facies)	69.91	0.21	15.13	0.88	2.71	0.10	1.27	2.54	2.92	3.12	0.42	0.11	0.67	99.99	6
Biotitic granite-porphyry (crosscutting bodies)	69.57	0.25	14.94	0.89	2.69	0.10	1.08	2.48	3.38	3.54	0.40	0.19	0.60	100.04	4

*Number of analyses averaged

synthetically twinned, and forms three varieties: two as phenocrysts and one in the ground mass. Phenocrysts of potassium-sodium feldspar (sodium orthoclase) are usually perthitic; occasionally they form micropegmatitic intergrowths with quartz.

The phenocrysts of quartz are usually coarse, xenomorphic, sometimes subidiomorphic. They often form poikilitic intergrowths in biotite, potassium spar and plagioclase. Biotite is represented by idiomorphic, tabular crystals, corroded by the ground mass. The latter is characterized by microaplitic, microgranitic, micropegmatitic, micrographic, eutectophiric, blastogranitic, granular, panxenomorphic-granular structures. In the groundmass, just as in the phenocrysts, one often observes grains of apatite, zircon, orthite, pyrite, attached to biotite and plagioclase, occasionally to other minerals.

For these rocks complete homogenization of melt inclusions occurs at 820°C. Exposures of 30 minutes were quite satisfactory. The maximum size of the inclusions was ≤7 μm; they amounted to 300.

The authors also analyzed melt inclusions in granite-porphyries, developed in the form of small stocklike and vein-like bodies in individual sites of the intrusive. The petrographic composition and structure of these is identical to granite-porphyries of the edge portion yet they belong to the granitic group according to the classification of P. Niggli(5), while the granite-porphyries belong to the granodioritic group. This is to be explained by the weak phenomenon of hybridism (the presence of inclusions of labradorite, hornblende, and the transition in places of granite-porphyries to granodiorite-porphyries)(6).

The majority of inclusions (with a size up to 10 μm) out of the 100 studied homogenize at 800-880°C, but in one plate 6 inclusions homogenized together at 750°C. Exposures of 1-2 hours here were sufficient for homogenization.

Thus, complete homogenization of melt inclusions in aplite-orthotectites occurs at 740-780°C, occasionally at 800°C; in thin granite-aplites, at 680-700°C; in crosscutting bodies of granite-porphyries of the edge facies, at 820°C.

The presence of melt inclusions, as well a glass within these inclusions, points to crystallization of the Kelasursky granites from true melts. Th values obtained are to be considered the crystallization temperatures of the corresponding rocks and consequently of the entire Kelasursky intrusive.

REFERENCES

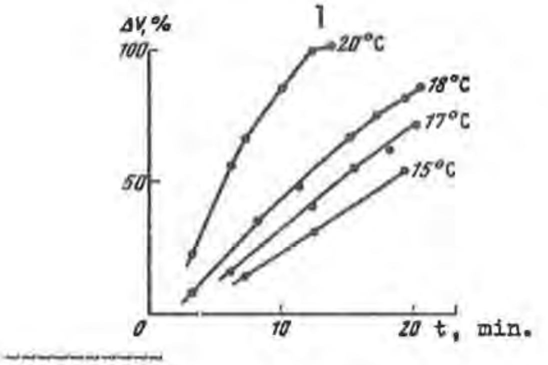
1. G.M. Zaridze. The petrography of magmatic and metamorphic rocks of Georgia. Moscow, 1961
2. T.A. Chkhartishvili, V.B. Naumov. Dokl. Akad. Nauk GSSR, 85, no. 1, 1977.
3. V.B. Naumov. Geochemistry, no. 4, 1969.
4. N.A. Solodov. Symposium, "Rare elements in pegmatites," Moscow, 1962.
5. S.D. Chetverikov. Textbook on petrochemical calculations. Moscow, 1956.
6. T.A. Chkhartishvili. Dokl. Akad. Nauk GSSR, 78, no. 1, 1975.

GRISHINA, S.N., 1982b Ranges of use of individual volumetric gas analysis of inclusions, _in_ Use of methods of thermobarogeochemistry during prospecting and studies of ore deposits, N.P. Laverov, ed.: Moscow, "Nedra" Publ. House, p. 108-111 (in Russian).

Method of analysis of G bubbles after opening of inclusions in inert liquid (...) has been widely used for over ten years (...) for bubbles of sufficiently large dimension interval, from 3 μm to 1 mm [1]. Until now the errors of the method have not been discussed sufficiently. The only stated error is caused by uncertainty of measurement, not exceeding 15% of even smallest bubbles [1]. However, other factors exist, influencing the accuracy of analysis. Below there is shown that consideration of these factors in a number of cases decreases the possible amount of analyzed components and essentially diminishes the range of dimensions of analyzed bubbles.

The scheme of the analysis is a sequence of selective sorptions of gases. The amount of a component is evaluated by the change of bubble volume, supposing that bubble decrease in each reagent is caused only by chemical reaction of a determined component. However, the bubble change may be also caused by interaction with "inert" liquid and by internal P of G due to forces of surface tension. On the basis of the above listed factors, E. Roedder [5] expressed doubts on the correctness of the method, without, however, numerical evaluation. The calculation of change of surface tension made by the author showed that influence of this factor is small. The evaluation of bubble interaction with "inert" liquid is more complicated, because it is different at various stages of analysis. Inclusion opening is made in a highly inert solution of LiCl in glycerine. During the time necessary for opening in inert liquid only the "acid gases" dissolve, which is always taken into account during calculation of their amount. Next the bubble of released gas is put in solutions of specific sorbents (reagents), prepared in pure glycerine. Use of glycerine solutions of LiCl as solvents [at this stage] is impossible, because Li forms complexes with sorbents. In sorbents, together with selective reactions, also other gases may dissolve; this is erroneously interpreted as the result of chemosorption. Amount of dissolved substance will be different, depending on the composition of the analyzed gas and conditions of the performed analysis. For evaluation of the minimum value of this factor, there were performed experimental studies of kinetics of nitrogen sorption in glycerine, with analysis time averaging one hour. The selection of nitrogen was made because of its lowest solubility and its determination in the analytical scheme from the nonsorbed remnant.

Experiments revealed a significant change of bubble sorption velocity in the working temperature interval, that is explained by the major (two fold and more) change of viscosity of the inert liquid (fig. 1).



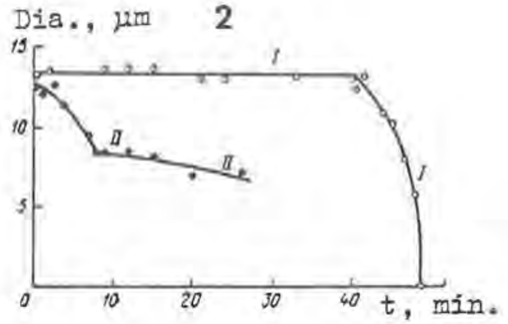


Fig. 1. Change of nitrogen bubble volume with initial diameter 9 μm during dissolution in glycerine at various T.
Fig. 2. Influence of light filter in the microscope illuminator on dissolution of nitrogen bubbles in glycerine: I-first 40 minutes bubble was illuminated with green filter, next the filter was removed, II-first 8 minutes the bubble was illuminated without filter and next the green filter was put in.

Besides the change of the surrounding air T, a large influence was revealed from local T change caused by light focussing on the bubble (fig. 2). This heating occurs due to use of additional long-focus condenser applied for better quality of image through the thick windows of the crushing stage [3]. Taking into account the essential influence of heating on the velocity of bubble dissolution, it is necessary to perform the further analysis with use of cuvettes with thin walls without additional condenser and with minimum illumination.

From theoretical analysis of bubble dissolution process in viscous liquid [4] the relation between the square root of time of bubble dissolution and its initial diameter is known and it was confirmed by the author's experiments with good coincidence. Whether the bubble dissolves in the time of analysis or remains stable depends much more on the diameter of the bubble than on the solubility of the gas in the bubble. At T <25°C N_2 bubbles of dia. >50 μm practically are not absorbed. Time of existence of N_2 bubbles with dia. <50 μm is comparable to the analysis time. In this case the bubble dissolution is erroneously regarded as the result of chemical reaction. To decrease the determination error caused by dissolution of small bubbles, the analysis should be performed at low T. Optimum T (15-16°C) is determined by the appropriate viscosity for analysis. The acceptable time of analysis depends on the bubble size and varies from 10 minutes for bubbles of dia. ~20 μm to 60 minutes for bubbles of dia. >50 μm. Hence, the time of remaining of bubbles in specific sorbents should be as short as possible, or the number of determined components should be reduced, if it is impossible to move the bubble quickly from one reagent to another. Taking into account the relation between dissolution rate and bubble size, at the present state of method development it is impossible to separate CO_2 from the group of acid gases on the basis of the proposed separation curve [2].

LITERATURE

1. Dolgov, Yu.A., Shugurova, N.A. Contributions to history of development and use of volumetric method of determination of gases in inclusions - in: Genetic mineralogy (from inclusions in minerals). Novosibirsk, 1978, p. 8-19.

2. Shugurova, N.A. Chemical basis of method of gas analysis in individual inclusions in minerals - in: Mineralogical thermometry and barometry, v. 2, Moscow, 1968, p. 18-23.

3. Shugurova, N.A., Shokhonova, L.A., Grishina, S.N. Contribution to the method of determination of gas phase composition in individual inclusions - in: Theory and practice of thermobarogeochemistry, Moscow, 1978, p. 237-240.

4. Epstein, P.S., Plesset, M.S. On the stability of gas bubbles in liquid-gas solutions. J. Chem. Phys., 1950, v. 18, no. 11, p. 1505-1509.

5. Roedder, E. Origin and significance of magmatic inclusions. Bull. Mineral., 1979, v. 102, no. 5-6, p. 487-510.

(Translated by A. Kozlowski, Warsawa, Jan. 13, 1985)

KALYUZHNYI, V.A., 1982a Principles of knowledge about mineral-forming fluids: "Naukova Dumka" Publ. House, Kiev, 240 pp., 1000 copies printed, price 2 rbls. 20 kopecks (in Russian). Author at Inst. Geol. and Geochem. of Mineral Fuels of Acad. Sci. of Ukr. SSR, L'vov, Naukova Str. 3A, Ukrainian SSR. Translation by A. Kozlowski.

Note: In translating this book I take into account that it represents in some sense a unique and probably most critical approach to fluid inclusion studies performed in the Soviet Union, where those studies have become presently a routine--and sometimes too routine--method of mineralogical, petrological and other geological studies. This places the author in a special and difficult position. On the other hand, this translation may give Western inclusion students something of a key to understanding and evaluating of the very extensive Soviet literature on fluid inclusions. In some places I omitted small parts of the original text that I supposed to be of minor interest to the Western reader; these places are marked by [...]. (A.K.)

Further caveats: This translation of the first four chapters of this book may give a false impression of the total contents, since these are in part a rather dense mixture of the basic principles, the scientific politics, and the involved semantics of fluid inclusion study. In large part they provide a documentation of the considerable disagreements between the two giants of Soviet inclusion study, N.P. Ermakov, and his former student, V.A. Kalyuzhnyi, that have been reflected in much of the Soviet inclusion literature of the last few decades. The remaining 158 pages of the book provide a good insight into the technical state of research on fluid inclusions in the Soviet Union, as may be gained from the Table of Contents below. The polemics here have resulted in a text that should have been heavily edited (and greatly shortened), but must be given here essentially verbatim (E.R.).

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(Forward) [...]

Introduction

Inclusions - they are portions of mineral-forming medium or foreign (xenogenic) substances trapped in a crystal (mineral) during its growth (regeneration, recrystallization). Inclusions are formed in the host mineral by trapping of "surface dividing" substances. This surface, a phase boundary between phases in dynamic equilibrium, is not stable and depends on the degree of indifference of the mineral host to the filling of the trapped inclusion. Experiments reconstructing T and P of usual postmagmatic processes prove the relatively insignificant interaction of fluids of inclusions and rock-forming minerals (silicates, sulfides, carbonates, etc.).† But under other thermodynamic conditions and in case of more soluble compounds such interaction appears very visible. Thus, inclusions may be evaluated as individuals that are independent of the host mineral physico-chemical systems only conditionally and within

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†Presumably reaction of inclusion fluids with the cavity walls is meant. (E.R.)

certain determined limits of the parameters of composition, temperature and pressure.

Thus, inclusions may be called any part in the crystal volume isolated during the crystallization process from all sides, and having a phase boundary. The well-known statement of N.P. Ermakow [63] was taken as the basis of this conclusion. In the structural sense the inclusion in a mineral is a space of internal defect of crystal lattice (vacancy or cluster of vacancies) filled in the process of crystallization by mineral-forming fluid* or other substance.

The first publication about experimental studies of inclusions in minerals came in the beginning of 19th century [172]. At that time and during several following decades a significant step was made in the recognition of the nature of inclusions. Due to the work of H. Davy, D. Brewster, H.C. Sorby, F. Zirkel and other scientists, the essential components and phase composition of inclusions were determined, the principles of use of inclusions for reconstruction of crystallization conditions were outlined and the descriptive-analytical material was systematized. Important also were theoretical and practical studies of the home (i.e., Russian) scientists: D. Sokolov, A. Auerbach, M. Krendovskiy, A.P. Karpinskiy, Ya.V. Samoylov, V.I. Vernadskiy and others [120]. Results of studies of inclusions of that period were the basis of the main principles of knowledge about mineral-forming fluids; the latter knowledge developed in the USSR especially from 30's-40's of the 20th century**.

The present state of knowledge about the essential composition of the Earth's crust is characterized by the recognition of details of the complicated changes of mineral individuals and their associations in a genetic, historical aspect. "The complete recognition of the whole history of a given mineral complex as a geological object," according to V.S. Sobolev [174] is the target of such studies. (...)"All features of minerals - their chemical composition, structure, physical and chemical properties, habit, associations and distribution in Nature are caused by their genesis...the genesis of each studied mineral is "noted" in the studied object" [40, p. 5,6].

Fluid inclusions in minerals are remnants, relics of mineral-forming medium. They "note" and preserve information about the history of changes of chemical composition and thermodynamic parameters of the [fluid] medium [basic to] the origin of minerals and their alterations. This is the main peculiarity of inclusions as indicators of mineral genesis. Under endogene conditions inclusions at the moment of sealing (trapping) reflect the composition and physico-chemical parameters of the fluid medium at the point of trapping. But during the long time of their existence they undergo changes, coming to us altered in various degrees. For this reason the consideration of inclusions as "preserved mineral-forming solutions," "portions of mineral-forming solution" or "inclusions of samples of mineral-forming media" is not founded satisfactorily.

Spatially and genetically, inclusions are immediately connected with minerals. But if minerals and their complexes, studied by methods of genetic mineralogy, may be the basis for reconstruction of sequence of alterations, evolution of "products of chemical process," the inclusions, by their nature, are suitable to recover the dynamics of the conditions of existence of the mineral-forming medium. Rational combination of genetic studies of mineral individuals (ontogeny) and relics of mineral-forming

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*The term "fluid" is used here for the most mobile, flowing substance of the Earth's crust - G or water solutions, or magmatic melt.

**The detailed historical reviews of development of studies of mineral-forming fluids are given in the works of N.P. Ermakov [63], F.G. Smith [172], G.G. Lemmlein [120].

medium is able to elucidate the details of mineral-forming process in general, i.e. to study "the alteration of products and processes in time in various natural areas of the Earth's crust" [15].

Thus, the targets of the discussed direction are wide enough and they are connected first of all with the problems of mineralogy, but also with petrology, geochemistry, crystallography and other sciences. Several features make fluid inclusion studies interdisciplinary: the specific properties of fluid inclusions (microscopic size and sealing of substance inside vacuole, the disordered, fluid phase state that requires other methods and rules of exact science than do solid, crystalline substances, permitting the extrapolation of the parameters of the process), as well as the target of the studies - to recognize the nature of the parent solution, usually not submittable to the immediate observation. Presently, the most frequently used name is "thermobarogeochemistry," replacing the earlier terms "geological thermometry of inclusions in minerals," mineralogical thermobarometry," "knowledge about mineral-forming media" etc. Unfortunately, this term is very inappropriate and it does not reflect the essential meaning of the new mineralogical direction for the following reasons:

a) by its sense the word "thermobarogeochemistry" means geochemistry including PT-parameters; but in geochemistry generally the distribution and migration of elements are not considered without taking into account thermobaric and other conditions;

b) during studies of inclusions the methods and laws of not only geochemistry, but also in the same degree - mineralogy, crystallography, physical chemistry, thermodynamics and other sciences - are used. Moreover, geochemistry of elements in inclusions may be studied in a limited range, only in the area of distribution of fluid medium of crystallization and without studies of minerals;

c) the main feature is not reflected in the name, i.e., that fluids of mineral-formation environment are studied; the lack of linking of semantics of the word and sense of the discussed subject occurs distinctly even in determination of this name by its author [67, p. 11], in which the geochemical content of the discussed branch is not reflected.

Thus, since we have a specific object and special problems in such studies, this branch cannot be called geochemistry, neither in part nor in the whole, as it appears from the name as now used. The discussed branch of science occupies an intermediate and independent position between mineralogy and geochemistry and most probably, the appropriate name of it, discussed many times by the L'vov investigators in the beginning of the 1960's, should be "knowledge about mineral-forming media (fluids)" or in abbreviation mineralfluidology; the latter was proposed during the meetings in Suktyvkar and in L'vov in 1975-78 [93,94].

[...]

The investigator of genesis of natural objects reconstructs the process of mineral genesis in a chronological sequence. Frequently in such cases the deciding role is played not by characteristic features but by deviations from them. Thus, nothing should be ignored by the investigator: the composition of only one (seemingly anomalous) inclusion among other, syngenetic inclusions, [one with] peculiar shape, [or one that is] surrounded by haloes of daughter inclusions.

Hence, for studies and reconstruction of the process of mineral-genesis it is necessary to know:

1. Features connecting in time and space the studied inclusions and the host crystal, i.e. are the relics-inclusions genetically identical with crystal material as the whole or with its determined growth zones. This problem is solved by the studies of genetic type of inclusions.

2. Degree of preservation of inclusion from the moment of its appear-

ance to the present time.

3. Direction and results of changes that influenced the inclusions and possibilities of use of those phenomena for this historical reconstruction of mineral genesis.

4. Possibility and methods of use of highly sensitive and exact studies of composition, phase alterations and physical properties of inclusions as specific microobjects.

5. The possible ranges of use of inclusions as indicators of parameters of mineral genesis on the basis of theoretical analysis, constructed on the basis of exact sciences or sufficiently verified experiments.

THE FIRST PART

CRYSTALLOGENESIS OF INCLUSIONS

Chapter 1

Problems of systematics of inclusions

The world of inclusions, like minerals, is very differentiated. Substances forming inclusion filling may occur in any phase state: solid, liquid or gaseous. Their combination in inclusions may be relatively simple or very complicated, depending on number of autigenic or xenogenic phases. Due to this fact there are large problems, difficult to solve, on the way of forming a natural classification of inclusions on the basis of their composition, state and genesis. Probably, descriptive and analytical-experimental data on static inclusions (i.e. under normal conditions), collected up to now, are not sufficent for distinguishing the clear taxonomic features of the determined genetic types of inclusions. Probably such features cannot be unique. Unambiguous solution of genesis is possible only during complex use of many features, not only determinable from inclusion studies, but also from substantial mineralogical and general-geological investigation.

In the past inclusions were systematized on the basis of their descriptive characteristics, mainly the phase state of filling [172]. The way of distinguishing the genetic features of inclusions was quite complicated. The final conclusion on genetic-information possibilities of inclusions was made by G.G. Lemmlein [122, p. 211 & 232]. He thought that on the knowledge level of his time it was possible to systematize inclusions only in limited ranges, using two features: 1) how and under what conditions the closed void in crystal appears (genesis of the inclusion vacuole with respect to crystal); 2) how are the conditions of formation of the inclusion filling and its relation to the parent environment (genesis of inclusion filling with respect to mineral-forming medium). Inclusion filling, after G.G. Lemmlein, a classification feature, may be applied in future after detailed studies of all possible forms and their compositions.

N.P. Ermakov in his early general works changed in some degree the ideas of G.G. Lemmlein and presented two classifications: 1) based on composition and state of inclusions; 2) based on their genesis. The first classification was made contrary to idea of G.G. Lemmlein (in it the phenomenological division of inclusions on the basis of aggregate [i.e. phase] state was joined with the supposed genesis), and the second, in reverse, in principle agreed with his essential ideas (some change of main taxonomic units was made). In 1960, the author, evaluating the ideas of G.G. Lemmlein as correct, proposed, following N.P. Ermakov, two classifications. The following ideas were their basis.

Systematics of inclusions derived from composition and phase state should be initiated by the usual visual observation at room conditions. Genetic classification should take into account the signs of origin of inclusions (fig. 1). The first systematics reflects a somewhat static picture of inclusions, that which is observed by the investigator immediately. The second one generalizes all information at the level of knowledge about inclusion genesis achieved, including also elements of a subjective character, because, linking inclusions with one or another genetic type, the investigator, on the basis of interpretation of numerous data, expresses in certain degree his understanding of the mode of formation of inclusions. For this reason it was proposed to distinguish sharply systematics on the basis of principle of their construction. But our tendency to take into account the existing traditions in names and to produce a more exact scheme of classification caused the introduction of many not well founded conditional statements (quantitative excess of groups of L inclusions etc.). Hence:

1. It is necessary to agree with the opinion of G.G. Lemmlein that our knowledge is not sufficient for construction of a complete natural classification of inclusions of a genetic nature.

2. Phenomenological, descriptive classifications without elements of genetic nature [are useful] but only as the complete characteristics of each of the inclusion types, with an exact basis for all available data about their composition, habit, distribution in crystal etc. are developed. This information, together with facts and thoroughly checked data about genesis should be given in the beginning of the general genetic classification, just as it was in biology and other natural sciences. The passion for terminological novelty cannot be approved, because it may cause nebulous understanding of the actual truth about phenomena; short, objective and exact descriptions of the observed subjects and phenomena is more rational; exact description of facts is the basis of the whole knowledge.

Fig. 1. Classification scheme of fluid inclusions in minerals [88]
(Fig. 1 not translated)

The above is caused not only by the great differentiation of inclusions and insufficient knowledge about them, but also by their convergency. The latter means that the same habit and composition of inclusions may be yielded by different modes of origin. Omitting the accidentally trapped and not always easily recognizable solid substances (xenogenic), all other components of mineral forming medium occurring in solid, liquid or gas state, may be trapped from melt, aqueous solution or gas solution. Thus, in the scheme of classification itself, the possibility to show the dividing of inclusions between the determined types and classes due to their composition and state, as it is presented by N.P. Ermakov [70, p. 22], simply does not exist. Combinations of substances typical of inclusions "crystals + gas" or "crystals + liquid + gas" (in N.P. Ermakov's: $K_t>G$, $G_x>>K$, $K_t>G+L$, $G>>K+L$, $K_t>K_1>G$ etc., where K-crystals) should be related not only to crystallized (magmatic), gaseous (pneumatolytic) or crystal-fluid types, but simultaneously to several types (from 2 to 8) of all three classes. The exceptions are only inclusions bearing magmatic glass. Its presence unambiguously proves the trapping of silicate melt in vacuole.

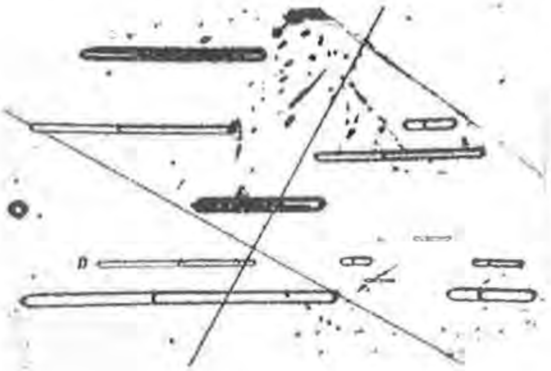
This is proved by the combinations of substances presented in the scheme [70] as well as those in which magmatic glass volume is less than total of the other phases ($A_s<G$, $A_s+K_t<G$, $A_s+K_1<G$ etc.); the listed compositions of inclusions, real for natural processes, are completely lacking in the discussed classification.

It is important to underline that classification cannot be the key for determination of inclusions; it only helps to systematize inclusions on the basis of data of the detailed and exact studies of the objects. The presented schemes, however, frequently are used just for the diagnostics of inclusions. For instance, Ermakov's classification, without special changes, is proposed as "The key for recognition of genesis of minerals by means of studies of inclusions of mineral-forming media [62, 64], or, as "Code for genetic microdiagnostics of endogene deposits [65], or in the same sense the "combination of inclusions with mineral-formation processes" [63,70]. This leads to [over-] simplification of studies of the inclusion genesis, almost a negation of the thorough analysis of facts, and results in the misunderstanding of the results of studies of the complicated processes of crystallization of minerals and discreditation of this branch of geological science.

The attempt to protect this scheme by separating from the other facts those not agreeing with the scheme caused the formation of the whole complex of so-called anomalous inclusions [67]. Evolution of meaning and genetic significance linked with this term is characteristic. Initially, the anomalous inclusions were called only those accidentally opened by mechanical fractures under laboratory conditions (during overheating, grinding, or breaking of specimens) and adhesion air bubbles trapped during crystal growth under [boiling or effervescing] conditions. Later, among anomalous inclusions, which are to be "necessarily recognized and excluded from the objects investigated" [66], the classes of syngenetic, subsyngenetic and epigenetic inclusions were distinguished. Especially are mentioned here "adhesion bubbles" of gases from a heterogeneous medium or vapor of boiling solutions, necked-down, refilled, decrepitated, etc. inclusions. Later, however, taking into account the important genetic significance of inclusions that formed due to trapping of gas bubbles and drops of water solution from boiling aqueous or magmatic fluid, the term "pseudoanomalous" (normal by their nature) inclusions was introduced [67]. However, new data on successful use of inclusions that seemed to be anomalous, for reconstruction of the deposit origin, forced a different evaluation of the group of inclusions, earlier qualified as not useful. That resulted in the distinguishing of the special "information sequences of inclusions" and among them the new, third information sequence, where in addition to the "normal, representative" inclusions, the coexisting or accompanying (earlier called pseudoanomalous) and inhomogeneous (heterogeneous by their nature) ones occurred as anomalous, non-representative inclusions [67]. Thorough study of the last two classes of inclusions (accompanying and inhomogeneous) shows that their essential representatives are inclusions trapped from heterogeneous solution and melt, being both in the first and in the second class, and there exist no genetic features distinguishing them. It is evident that introduction of such numerous poorly founded and contradictory terms cannot help the formation of the correct systematics of inclusions.

3. The procedure of selective dividing of all inclusions into "representative" and "non-representative" ones, "normal" and "anomalous," by its very nature is not useful for reconstruction of the details of history of mineral world; these microobjects, each of them, individually or together with the others, bears the determined information. The inclusions studies, nevertheless, should be accompanied by comparative analysis of their composition and state with other inclusions in close or distant genetic connection. This way the correct identification of filling and type of distribution of inclusion with respect to the growth forms of the host mineral may be obtained. The problems of inclusion genesis are discussed in a more detailed way in chapters about genetic classification of inclusions and phase state of mineral-forming fluids.

Let us now show two examples of the erroneous evaluation of information obtained from inclusion studies. The first describes the idea about pneumatolytic genesis of topaz from the Volyn' pegmatites [63], accepted after insufficiently thorough studies. A relatively common phase relation of L<G inclusions (L 40-50, G 50-60 vol.%), found in the central parts of the crystals and in the families of the secondary inclusions in healed fractures, and homogenization of those inclusions in G phase, were the basis for such a conclusion. But much later between very numerous such inclusions, occurring in the same healed fracture, there were found inclusions homogenizing at T typical of the usual L<G inclusions, but in L phase. Fig. 2 shows one of such inclusions. One may suggest that such inclusions should be called "non-representative" (anomalous), and all others called "normal" and so it was initially. However, if one takes into account the experimental data about the possibility of trapping the gas phase solely, without admixture of L phase, the problem about representative inclusions does not exist any more. All inclusions, with L<G and G<L fillings are normal and completely informative. They show that in the moment of fracture healing (and topaz crystallization), liquid parent fluid was boiling.



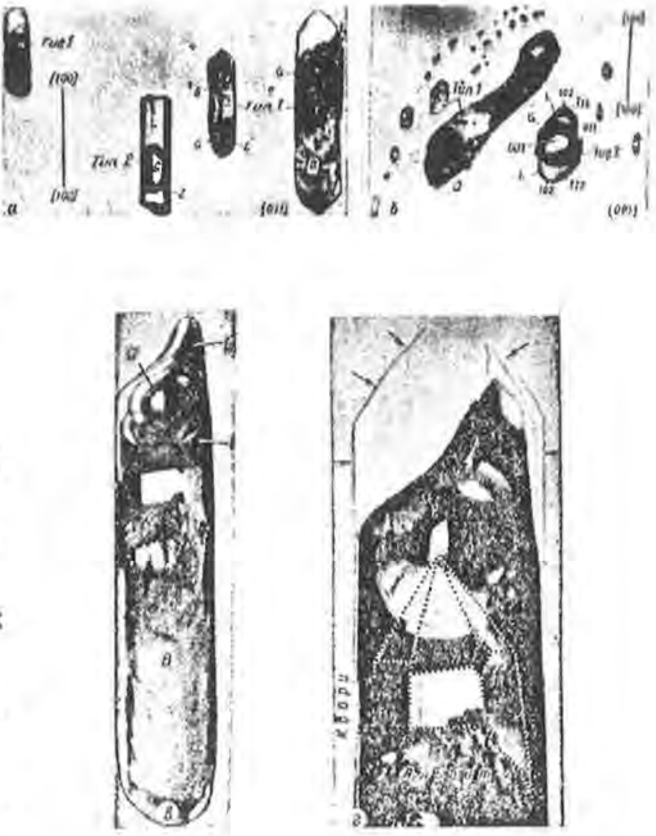


Fig. 2. Family of the early-secondary inclusions in topaz (Volyn): a - the only G<L inclusion among lots of L<G ones, magn. 350

Fig. 3. Primary inclusions in topaz occurring in one growth zone of the crystal (taken by D.K. Voznyak): a,b - magn. 50, c - magn. 100, d - close-up view of the part of the previous inclusion, magn. 200

Fig. 4. Fractures in topaz crystals, healed from solution being in the state of two-phase equilibrium (boiling), magn. 210

The second example of the erroneous use of genetic information from inclusions also is connected with the Volyn' topazes. Primary inclusions of complicated composition were found: solid substances ~70% + LH_2O ~20% + G ~10%. They were interpreted as crystallized relics of melt saturated with water [128]. Conclusion about the magmatic genesis of topaz was then refuted by numerous new data proving the xenogenic character of the solid phases in the same P inclusions in topaz [18]. Heterogeneous state of mineral-forming solution was also confirmed by extensive studies of natural material. Fig. 3 shows families of syngenetic inclusions with various degrees of fill and composition of solids. Inclusions have variable volume and composition of solid phases, proving the xenogenic character of the latter; inclusions without solid phases homogenize mainly in G phase; those with trapped minerals - in L phase, if the remaining solid phase is ignored. As in the first example, if one uses selective inclusion studies, various conclusions may appear about the phase state of the mineral-forming medium depending on what inclusions were called anomalous and what ones normal.

Finally it should be mentioned that heterogeneous G/L state of fluid during crystallization of topaz is confirmed by later gas-liquid inclusions with salt crystal daughter minerals. Families of S inclusions filled by various phases prove this (fig. 4). The inclusions are filled by various phase combinations: gaseous, liquid<gaseous, gaseous<liquid and polyphase.

Chapter 2

Nucleation and formation of inclusions. Genetic classification

Growth of a real crystal is accompanied by trapping in newly-formed layers portions of the parent medium or foreign admixtures - inclusions. Inclusions, like minerals, in their development, pass three main stages: nucleation, formation and alteration. The general cause of inclusion nucleation is the difference in the degree of supersaturation of the neighboring portions of parent solution touching the surface of a given crystal, that appears during its crystallization. Inclusion formation finishes by isolation from the surrounding medium. The latter is possible only in those layers of crystal where new portions of mineral precipitate, i.e. in the places of growth or regeneration. Under the action of various factors, influencing through the material of the crystal, inclusions may alter according to various conditions. Inclusions in minerals usually have microscopic dimensions. They appear in places of volume defects of mineral lattice. Discrete character of growth under the detemined physicochemical conditions causes the repeating of situations, which cause the appearance of defects and inclusions connected with them. For this reason inclusions are characterized usually by formation and distribution in groups in the crystal body. Groups or families unify the same or genetically close inclusions. Individual genetic types of inclusions in crystals are met in crystals rarely and thorough search almost always leads to finding of other similar vacuoles. Taking into account the possible complex combination of phase and substantial composition of primary filling of the vacuoles and their following alterations, for the exact establishing of conditions of genesis it is necessary to study groups of inclusions in detail. It is not sensible to consider individual inclusions out of connection with their syngenetic or almost syngenetic analogues in the studied groups.

The main rule of use of inclusions as indicators of mineral genesis is the solution of two most important problems: 1) what specific mineral individuals and growth or regeneration zones are coeval with the given inclusion or inclusion group, i.e. what is the spatial and temporaneous connection of defects-vacuoles formed in crystal with the determined elements of the crystal growth; 2) in what degree does the inclusion filling substance reflect the parent medium of the studied mineral, i.e. what is the genetic connection of inclusion filling and syngenetically precipitated mineral substance. Solution of each of those problems separately does not lead to the discovery of the genesis conditions. The joint solution of them is necessary, and the first problem usually is solved before the second one.

The main problem to be solved during studies of mineral genesis on the basis of fluid inclusions is to choose the alternative possibilities: 1) whether the studied inclusions are primary or secondary with respect to the determined parts of the crystal, and 2) is the inclusion filling authigenic or xenogenic with respect to the host mineral substance.

Primary inclusions. Crystal growth occurs from precipitation of new layers of substance on the faces always parallel to the previous ones, independent of the mode of precipitation - flat layers or spiral. The Cossel theory says that nucleation of layers starts in the most energetically appropriate points of the mineral surface, i.e. on its tops or edges. From those generating points, after D.P. Grigor'ev [39], by growing of new rows the layer extends over the surface. Each such layer or their assemblage forming a step of growth may be considered a zone of crystal growth. The material forming a growth zone precipitated almost contemporaneously on the whole surface of crystal and under the same conditions (in properly chosen intervals). Zones in crystal are well defined by color change, solid "dust" or inclusions of parent solution.

An inclusion trapped by a crystal is sealed in at a determined moment in the crystallization process, by a thin layer of crystal growth. Inclusions, to whose sealing moment a determined crystal growth zone may be attributed, and what touches this zone or occurs inside this zone, is called primary [88]. Thus, the necessary condition for an inclusion to be primary is the coeval formation in time and space with a determined zone of crystal growth. Thermodynamic and chemical conditions of existence of mineral-forming medium during sealing of P inclusions are the same as conditions of formation of a determined zone of mineral.

All P inclusions, from the point of view of activity of their material in the process of crystal growth may be divided into authigenic and xenogenic [232].

Authigenic inclusions - are those trapped by a mineral of the medium from which that very mineral grew. Their properties immediately reflect conditions of mineral origin.

Inclusions of material that might fall on the faces of the growing crystal accidentally and whose origin has no immediate relation to the formation of the given mineral individual, are xenogenic. They may be other minerals, "dust," droplets of oil etc.

Xenogenic inclusions give little data for reconstruction of formation conditions of these or other minerals. Essentially, they are used for construction of paragenetic schemes, spatial orientation of mineral individuals (from "dust" covering the upper faces of crystals), and recognition of crystal zones. Moreover, such inclusions represent minerals that are earlier or coeval with the host mineral, and may be preserved and not altered. Such minerals not immersed in the host mineral may be submitted to significant alterations or disappear completely.

Secondary inclusions. The parent solution or foreign substances may be trapped during healing of defect voids or fissures in crystals. Inclusions formed during this process are called secondary(s). Like primary inclusions, they may be either authigenic or xenogenic.

Authigenic inclusions may have (early secondary) or not have (late secondary) a syngenetic growth zone of the crystal. However, the necessary condition for a secondary nature is the spatial distance between inclusion itself and respective growth zone of the crystal. Such inclusions form later than those zones of the crystal, in which they occur, i.e. they are epigenetic with respect to the [host] zones [88].

Hence, P inclusions alwalys are connected with a determined zone of crystal growth and occur in contact with this zone. Early secondary inclusions have no contact with such zone. Late secondary inclusions form during fissure healing due to reprecipitation of material, essentially without transport from outside. A syngenetic zone of crystal growth is absent here. During studies of formation conditions of minerals the early secondary inclusions have the same importance as P inclusions [114,115]. Also N.P. Ermakov pointed out this fact, classifying such inclusions as primary-secondary (PS) or seemingly (pseudo) secondary [62,63]. The present author believes that they cannot be either intermediate between P and S ones, or pseudosecondary, but they are in fact secondary due to the absence of the spatial connection with the respective growth zones of the crystal.

Xenogenic inclusions are those foreign crystal, liquid or gas substances that came by various ways into fissures and during their healing were trapped in the mineral. One of the ways of penetration of foreign material into fissures is sucking it together with solution under action of vacuum produced in the space of fissure during its opening. Chips or small crystals of host mineral, occurring in the fracture plane, well visible in polarized light, evidently formed this way or by trapping of very small grains chipped out from the fissure walls and remaining in the fissure. In fissures in some places, small crystals or collomorphic clusters may form immediately from parent solution. Next they also may be trapped by the crystal as secondary xenogenic inclusions.

Primary and secondary authigenic inclusions form from G or L water solution or magmatic melt, sealed under mineral-forming conditions. For this reason it is necessary to distinguish inclusions of pneumatolytic, hydrothermal and magmatic origin (or pneumatolytic, hydrothermal and magmatic inclusions).

The mineral-forming environment is not always homogeneous. Often in LH_2O or in magmatic melt, separated gas bubbles or other liquids occur. The latter may or may not be trapped in inclusions. Of course, this causes the distinction in the genealogy of inclusions between their homogeneous or heterogeneous origin, which indicates only the state of the mineral-forming medium as a whole. The phase state of an inclusion at the moment of sealing may be reflected by expressions: inclusions from homogeneous trapping, inclusions from heterogeneous trapping. This extends and changes a little the names earlier introduced by the author for determination of the initial state of mineral-forming medium and of the inclusion itself [183].

More exact determination of the formation time of inclusions has a peculiar meaning for genetic studies of minerals. However, it is not sufficient to determine the syngenetic or epigenetic nature of an inclusion with respect to whole crystal, because in fact an inclusion is syngenetic only with certain part of the crystal. The same concerns S inclusions: they are not S at all, but S with respect to these or other growth zones of the crystal; they always have a syngenetic part of the crystal material and with respect to it they may be considered P inclusions. In other words, S inclusions are synchronous with the material of the healed fissure (during polycenter healing of relatively wide ones) and thus they are, sensu N.P. Ermakov, PS inclusions, because they carry traces of both primary and secondary nature. For more detailed understanding of the terms, the author said in the definition that early secondary inclusions have syngenetic growth zone in a given crystal, but late secondary have no such zone. This is needed for the correct answer for the question: to what exact zones of the given crystal (i.e., to what material) are the given inclusions P or S? If one does not put such a limit, thus in any case to all S inclusions sensu N.P. Ermakov, the synchronous growth zones may be found either in the given mineral (crystal) or in another one of quite other composition. According to N.P. Ermakov such inclusions are e.g. synchronous to metacolloid aggregates in the Volyn' pegmatites [67, p. 189] and inclusions in metacrysts of fluorite after quartz in pegmatites of the Karib pluton [67, p. 201]. But this is incorrect, because in this case all sense of distinguishing of inclusions is lost. Thus all inclusions (in healed fissures inclusively) should be called P and the term "PS" becomes not needed. Also on the other hand, all inclusions might be called "PS" ones.

Let us now consider in detail the problems of the meaning of certain other terminology.

1. One may suppose that the essential difference between the classifications: G.G. Lemmlein's and the author's - and N.P. Ermakov's on the other hand, is only in semantic, because their two main genetic classes are adequate. On genetic features these two inclusion types are called by G.G. Lemmlein, the author and N.P. Ermakov, respectively: 1) secondary syngenetic - early secondary - primary-secondary; 2) secondary postgenetic - late secondary - secondary. But in fact the difference in N.P. Ermakov's classification is essential. N.P. Ermakov does not accept the priority of G.G. Lemmlein in the distinguishing of inclusion types as well as in terminology, as was said above. In N.P. Ermakov's classification, in fact instead of one of the essential taxonomic units of the G.G. Lemmlein's classification ("secondary inclusions"), its derivatives are given (syngenetic "primary-secondary" and postgenetic "secondary" inclusions). This change results in disappearance of the second essential taxonomic unit ("secondary inclusions") equivalent to the first one ("primary inclusions"). This causes problems in practical identification of inclusion genesis (the secondary nature of inclusions is easy to establish, but their syngenetic or postgenetic relation to crystal frequently is very difficult to determine).

For instance, it is impossible to determine the genetic type of inclusions in a healed fissure in an anhedral crystal fragment. Such inclusions cannot be called secondary (sensu N.P. Ermakov) because they may be PS ones. But PS they also should not be named - maybe there is no syngenetic crystal zone for them. In such cases frequently inclusions are qualified incorrectly. In the author's opinion, such inclusions are secondary, and their distinction as the early or late variety may be determined eventually in further detailed investigations.

2. The words "primary" and "secondary" inclusions should reflect the relative sequence of their origin. N.P. Ermakov in addition to the above names, for the intermediate (as he believes) genetic type, uses also the term "primary-secondary inclusions," "uniting the features of both these and others" [70, p. 30]. But, taking into account the relative connection of inclusions with the determined elements of crystal, they cannot be such, but only either P or S ones. Similar inclusions (early secondary in the author's classification) have no contemporaneous features of P and S nature due to the following reasons:

a) with respect to the material healing fracture these inclusions are only primary; one has to consider that fracture healing is not a one-moment process and, strictly speaking, each inclusion in it has its own syngenetic part of material of the healed fracture; inclusions occurring in the mouth of fracture and sealed in the final moment together with precipitation of growth zone of crystal are primary with respect to the latter;

b) inclusions in a healed fracture are only secondary with respect to the adjacent growth zones of the crystal; usually material of the healed fracture is not taken into account during determination of the inclusion type, excluding only the healed wide fractures - bands, inclusions in which are regeneration primary (with respect to the material of the healed void);

c) comparison of the character of the inclusions of the healed fracture with the material of the respective growth zone of the crystal may be only approximate; those inclusions are near synchronous and only subsyngenetic to the given growth zone.

3. Use of the names "zonal" and "azonal" P inclusions for determination of inclusions distributed according or not according to the crystal growth zones [67], is supported neither by the sense of those words nor by their use for the studied objects. First, the sense of the word in its usual application, especially in geology, is different ("zonal deposits," "zonal pegmatites," "zonal crystals" etc.), and solid and certain fluid inclusions in fact may be zonal. Second, zones, formed by the inclusions (if N.P. Ermakov uses the name in this sense) are not independent but derivatives of the primary crystal zoning; crystals are always zoned (visible or hidden way) and inclusions only reveal this zoning in crystals. Third, the proposed names do not help in inclusion diagnostics; the essential problem is not in whether groups of inclusions form or do not form zones in crystals, but whether zones coeval with groups or individual inclusions occur or do not occur, i.e. are such inclusions primary (all P inclusions occur in zones of crystal growth syngenetic to them and hence they all are "zonal" in N.P. Ermakov's classification). Zoning determines whether inclusions are P or S and this is one of the numerous features being the basis of a genetic classification. Thus the proposed names have only apparent meanings and, in fact, they complicate terminology of the given branch of science.

Chapter 3

Modes of formation and examples of primary and secondary inclusions

Formation of primary inclusions. Experimental studies of crystallization process show that material on the crystal faces precipitates not uniformly, but with breaks. Factor controlling the pulsating growth is speed of inflow of material from oversaturated soluton to the face either by diffusion or by mechanical mixing of solution. Under conditions of interaction of medium and crystal, solution adjacent to the growing face is characterized by nonuniform degree of supersaturation at various points. The higher the total supersaturation, the more abrupt the contrast in concentration. Such a state of medium favors the origin of defects in the crystal. Hence, defects in crystal and trapping of parent solution occurs due to difference of supersaturation in various points on the boundary crystal-medium, not due to supersaturation itself [111, 202].

Nucleation of new layers begins in places of supersaturation of solution, usually at the corners and edges of crystal. Due to use of material for crystallization and lower speed of inflow of new material than speed of crystallization, in such places, a distinct decrease of concentration is observed [111]. However, for the formed step in the angle between it and the face of crystal, solution will be saturated (in agreement with the equation of Ostwald-Freundlich) and due to this fact the step rapidly grows parallel to the crystal face, continuously meeting new portions of supersaturated solution. Thickness of the step does not change during this growth. "Most frequently more and more steps appear before the previous ones completely cover the face. Stepped faces form and the steps coming one after another like waves may be observed under microscope during growth of hyposulfite crystals" [2, p. 1].

This is the mechanism of layer growth of faces. Under conditions of such nonuniform growth and the disequilibrium of concentrations, cases of inexact healing of steps and formation of P inclusions may occur.

In individual cases the healing of steps of different heights causes the formation of screw dislocations and crystal growth by spiral layers. In the initial moment the first rolls of spiral trap in the central part the parent solution, forming P inclusions [39].

Inclusions may form not only in places of healing of layers but also at the front of the growing layer. Due to nonuniform "feeding" in the front part of the layer, tooth-like projections form, between which elongated voids nucleate. During movement of the step of growth the voids become tubular channels filled by solution and are then covered by the crystal. Repeating many times, such a process causes the formation of chains of tubular P inclusions. This mode of trapping of crystallization medium was studied experimentally in detail by N.N. Sheftal [202].

In the process of further formation, depending on conditions of crystallization, P inclusions may achieve various habit. During this process the essential role, probably, is displayed by the speed of step-layer precipitation of material. When crystal growth is slow, inclusions form more rarely and are sealed more rapidly. They are single isolated inclusions and rarely inclusion groups, parallel to layers of crystal growth. Often such inclusions are flattened perpendicularly to layers of growth. During rapid growth of crystals there are many chances for formation of inclusions by incomplete healing of growth steps. The forming defects cannot be healed quickly because new steps of growth continually overlap the previous ones, decreasing the concentration of surrounding solution. In this way inclusions form that are elongated perpendicularly to the crystal faces and very frequently are complicated by numerous ramifications. More precisely, their habit depends on the development of the growth pyramids [122, vide p. 107].

Under conditions of slow diffusion, especially in viscous media, skeletal crystal forms develop. When crystallization conditions change, the depressions in the central parts of faces may be covered by subsequent layers of crystal, isolating parent solution inside the vacuoles. Such P inclusions have large dimensions and a complicated habit. They may be easily altered and for this reason they rarely preserve the initial filling.

Similar inclusions in quartz crystals of skeletal habit were described for hydrothermal veins in Carpathians (so-called Marmarosh diamonds), Donbass, Crimea, and the Alps [23, 112]. They have essentially hydrocarbon composition (mainly methane), relatively large dimensions and they are connected with growth pyramids of faces of the rhombohedrons. Inclusions have complicated surface morphology; they are flattened, with walls parallel to the rhombohedron faces. Smaller inclusions have the habit of ideal negative crystals. Some large voids remain unsealed and are open to the crystal faces.

Studies of the genesis of quartz crystals and inclusions in quartz shows that the mineral-forming medium was a water solution bearing methane bubbles. The latter were trapped in the forming vacuoles without or with a minimum amount of L water solution.

Also inclusions formed during multinucleated growth or by regeneration of the cracked parts of crystals should be called primary. Usually multinuclear growth is observed on crystal surfaces from cleavage, dissolution, melting or crystallographic planes that after breaking become the basis for precipitation of new mineral material. Inclusions formed during this process differ in habit and position relative to the crystal boundary. Two morphological types of such inclusions may be distinguished.

To the first type belong the inclusions occurring immediately on the regeneration plane. They most frequently are solid inclusions, more rarely inclusions of parent solutions. The latter have an irregular flat habit depending on irregularities of the regeneration surface. Solid inclusions are the cause of origin of fluid ones.

Associations of solid particles and relics of mineral-forming medium in quartz crystals from hydrothermal veins of Donbass are an example of such inclusions. Here zones with mica and chlorite flakes occur among which flat P G/L inclusions were found [103, p. 32]. Flakes of mica frequently occur inside G/L inclusions. Between the inclusions there were found radial aggregates of muscovite flakes with relics of parent solution in the interstices. Muscovite, overgrown by quartz, crystallized together with it. Shape of such G/L+solid inclusions has been shown [103, p. 34].

Frequently complicated joining of substances in P inclusions is not found, but there form inclusions of fluids or solid crystals-inclusions of contemporaneous growth with the host minerals. The latter, although they do not provide data about the crystallization medium, are the source of important and reliable information about paragenetic relations of the minerals. On the example of the Volyn pegmatite the possibility of close coexistence and contemporaneous crystallization of albite and topaz was proved. Such an unusual assemblage was fixed by a zone of P inclusions of albite radially elongated in the direction of the general growth of host topaz crystal. Also inclusions of fluorite proved it to be coeval in growth with topaz, although the two minerals used to be interpreted as mutually exclusive (fig. 5).

Morions from some pegmatites of Volyn in external zones of regeneration by light quartz bear inclusions of cassiterite with various habits that formed by coeval growth with the host mineral [98]. Habit of cassiterite inclusions reflects the complicated relations between medium and mineral, as it appears from fibrous, acicular, prismatic and partly dissolved lenticular, or arrow-like crystals [of cassiterite, A.K.].

Very specific by genesis and morphology are P inclusions in generations of minerals, healing large voids. (...) Crystals of skeletal quartz from Carpathians and Donbass bear voids-depressions on the faces of rhombohedrons. According to zones of smoky color the voids are partly sealed. On the basis of such zones of regeneration D.K. Voznyak [23] found P inclusions in quartz of regeneration of large voids. Their habit is flat, isometric. (...) Wide fractures in crystals may be healed due to development of subparallel individuals of multinucleated growth. Inclusions in such healed fractures are primary with respect to the material healing the fracture [63, p. 250].

I.T. Bakumenko described in detail and gave the systematics of regeneration inclusions of magmatic origin. He distinguishes P and PS (sensu N.P. Ermakov) regeneration inclusions; the essential difference between these two kinds of inclusions is that the first ones form on surfaces weakly destroyed by melting and "does not disturb the general zoning" and the second ones "contact with various earlier growth zones of crystals" [135, p. 38].

Ambiguity of this author's position in determination of the inclusion type is caused, in my opinion, by the unclear [definition] of primary and secondary inclusions, following N.P. Ermakov. The degree of destruction of crystals cannot be the determining factor in the classification of inclusions. In principle the first and the second inclusions are primary with respect to material of regeneration zone. But they are, however, neither primary nor secondary with respect to other earlier zones of crystal. Their genetic type cannot be defined with respect to ealrier zones of crystal, because the inclusions do not occur in those zones, and hence the problem of their primary or pseudosecondary classification is not at all a problem pertinent to those inclusions. Similarly, it is inappropriate for classification to compare P inclusions in zones of healing e.g. the cited above wide fracture in crystal of quartz from Alpine type vein Bristenstock [63, p. 251] with inclusions occurring in earlier part of the main crystal. One may only say about the earlier synchronous and later relative time of their sealing, i.e. pregenetic, syngenetic and post-genetic inclusions, in comparison with the others. In the same degree the above comments are pertinent to secondary inclusions, in what appears from principles of genetic distinguishing of inclusions, proposed by the present author. Inclusions in healed fractures are early or late secondary only with respect to the zones cut by the fracture or in contact with the fracture. For other zones they cannot be, in agreement with the sense of the word, either "first," primarily or "later," secondarily formed. Further understanding of the genetic sense of the discussed terms leads to great complication by the unlimited extention of the class of pseudosecondary inclusions after N.P. Ermakov [67, p. 189].

Inclusions of the second morphological type form at the next stage of the process of regeneration of the crystal, when numerous centers of crystallization due to their nonuniform distribution develop in individual, separate parallel crystals. On the boundaries of joining parallel crystals in the places with limited inflow of new portions of supersaturated solution, inclusion voids form, which are next but not immediately covered by new layers of crystal. These inclusions have elongated habit and crystallographic faces.

Inclusions of this type may be found frequently in quartz from pegmatite deposits of Volyn, where regeneration of crushed fragments of crystals by multinucleated growth is common. Characteristic depressions between subparallel terminations are sometimes observed; such depressions next develop into elongated inclusions. Usually they are parallel to the third crystallographic axis of quartz.

The rate of supply of crystal material is, most probably, the essential factor of nucleation, development and sealing of elongated voids-inclusions. During rapid growth the maximum difference in solution supersaturation form over the protruding terminations of the crystals and in depressions between them. Slower growth causes the joining of individual crystals and isolation (sealing) of inclusion voids. Sometimes such elongated voids remain opened, which presumably proves the shortage of input of material by the mineral-forming solution.

So called fibrous or acicular subparallel inclusions, similar to the above described and probably of that genesis, occur also in the regenerated part of crystals near the destroyed plane. They differ from the previously described inclusions in dimension and in an unusual density of distribution. For this reason during observations with a naked eye in reflected light they show a shiny, silky luster. It is worthy of note that elongation of such inclusions not always agrees with the crystallographic axes of the quartz.

Origin of elongated fibrous or tubular inclusions, as was shown by observations of natural and synthetic quartz crystals, is caused by nucleation of new generation of mineral on surfaces of mineral destruction, which before recrystallization had easily recognized evidence (but now traces) of intensive etching. Etching phenomena preceding crystal growth were proved on preparations of synthetic quartz, in which the nucleation of subparallel tubular inclusions is observable on the preserved parts of the crystallization nucleus plate and in the deep channels. Similar reasons caused the formation of inclusions of elongated habit in natural crystals. On the basis of regenerated parts of morion from Volyn similar traces of dissolution and etching were observed. But in addition to the above reason, the phase state of the crystallization medium undoubtedly has a major influence on the inclusion habit. Separation of G phase (boiling) as bubbles nucleated on the liquid/crystal phase boundary, favors the elongation of the vacuole along the direction of crystal face growth. Such a mechanism of formation of P regeneration inclusions was first described by G.G. Lemmlein et al. [127].

This way, one may conclude that subparallel elongated groups of inclusions which do not display the connection with healed fractures are P defects with respect to the given crystal zone and they are, possibly, a typical feature of abrupt change of solution concentration and its resultant dissolution of the host mineral.

Two crystals that grow simultaneously [in contact] may trap portions of parent solution or foreign substances on the induction faces. Such inclusions also should be called primary, as D.P. Grigor'yev suggested [37]. Crossing of growth zones of crystals by respective inclusions of induction faces cannot be regarded as sufficient sign of S nature of such inclusions [63], because any P (and S) inclusion cuts growth zones of the crystal. It is necessary to recognize exactly what zones are epigenetic and syngenetic with respect to the inclusions under consideration. Crossing (or contact) of inclusions with syngenetic growth zones is the only feature of primary origin. It is necessary to say that groups of inclusions of induction planes (pseudofaces) cannot be coeval one with another and their features change depending on time and place of trapping. Complete sealing of such inclusions also is doubtful.

N.P. Ermakov [63], on the basis of studies of P.S. Vadilo, explains the formation of P tubular inclusions by their nucleation on blunt edges due to a zone of immobile solution formed during concentration flow around the crystal. Almost the same reasons, after N.P. Ermakov, form tubular P inclusions in the path of movement of [fluid across the] crystal top. G.G. Grushkin [42] distinguishes P inclusions which form in stepped surfaces of the subsequent growth of the contacting faces.

Frequently tiny chips of foreign minerals or other substances are the cause of nucleation of P authigenic inclusions. Usually such inclusions incorrectly are called "stuck" inclusions, which may be justified to some degree only with respect to gas inclusions of heterogeneous origin. In one case inclusions of parent solution form next to foreign particles which remain in the initial place. Such inclusions occur on the surface of foreign grains or in contact with them, frequently being elongated in the growth direction of the host mineral. In other cases, as first stated by A.V. Shubnikov (204), inclusions form in the path of repulsion of foreign particles by host crystal. Due to this, the inclusions frequently are arranged in a chain perpendicular to the face.

M.M. Slivko [170] described tubular inclusions in tourmaline, elongated parallel to the three-fold crystallographic axis. They touch solid inclusions (foreign) at both ends (lower and upper) or with one end (lower or upper). Depending on the dimensions of solid inclusion, perfection of its surface and growth rate of mineral, various cases of trapping or repulsion of foreign particles occur and the respective position of inclusion vacuoles may be observed (Fig. 6).

D.K. Voznyak [112] presents the charcteristics of P inclusions of tubular habit, whose nucleation and formation was connected with the presence of particles of foreign minerals (epidote, quartz, etc.); the studied inclusions occurred in quartz from Krivoy Rog. similar to the above described inclusions [in tourmaline, A.K.], in that some touch solid particles with lower or upper end, and some are in close contact with solid particles and have an irregular habit. It is characteristic that tubular inclusions are connected with zones of regeneration of quartz crystals, seemingly due to multinucleated growth. The author notes the etching traces on surfaces of regenerating smoky crystals. Inclusions are elongated along the three-fold crystallographical axis. The above listed peculiarities of those inclusions are similar to features of P inclusions in regeneration quartz from Volyn and other regions.

Influence of supercooling (supersaturation) of melt on formation of P authigenic inclusions near xenogenic solid paticles was illustrated by V.Ya. Khaimov-Mal'kov [185] by crystallization of benzophenone from melt containing Lycopodium grains [i.e. spores, A.K.] (Fig. 7). When supercooling was small, all grains are repelled by the growing crystal and inclusions do not form. With increase in supercooling (supersaturation), particles of Lycopodium are partly repelled with formation in their trace of melt inclusions; when supercooling increases more, practically all xenogenic grains are trapped without formation of authigenic inclusions.

Author presents also interesting data on mechanism of interaction of liquid droplets or gas bubbles with growing crystals. Crystal of K-Al alum repels a droplet of mercury with formation of an inclusion vacuole under the droplet (Fig. 8). The vacuole may have a negative crystal habit (Fig. 8b). Thymol, crystallizing from the melt, trapped air bubble without admixture of parent medium, and the newly formed inclusions become elongated tubular channels perpendicular to the face on which the bubble was (Fig. 9). When Lycopodium particles were present, gas phase was not trapped but under the bubble a vacuole formed with a negative crystal habit (Fig. 10).

Experiments with trapping of foreign liquid droplets by growing crystals of borax and $Na(NH_4)HPO_4 \cdot 4H_2O$ were made in laboratory by G.G. Lemmlein, M.O. Kliya and I.G. Sokolov [106]. Although crystallization conditions were varied, droplets of oil were always trapped by borax as filled tubular inclusions without water solution (Fig. 11). In crystals of $Na(NH_4)HPO_4 \cdot 4H_2O$ when growth speed was from 7 to 30 μm/min on the path of repulsion of oil droplet, tubular inclusion of parent solution formed (Fig. 12). If growth speed of face is smaller than 7 μm/min, the droplet is not trapped and inclusion does not form; if growth speed exceeds 40 μm/min, the crystal traps oil in tubular vacuoles without admixture of water solution. If the crystallization conditions vary, the inclusion vacuole of tubular habit may trap both oil and water in changing proportions.

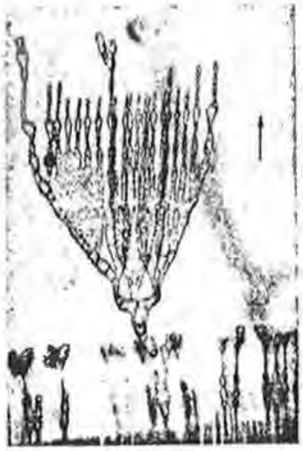
Trapping of gas bubbles without admixture of parent solution was observed by P. Powers [24] (Fig. 13).

The above examples prove the following:

1. Xenogenic solid particles trapped or repelled by growing crystal may yield authigenic inclusions; the latter occur on the contact: solid inclusions/mineral, on the path of movement of solid particle or in the "shaded" part of crystal above a solid particle.

2. Foreign fluids (droplets of oil, air bubbles, etc.) are frequently trapped by crystal in the "pure" state - without admixture of the parent medium.

3. Presence of the solid admixtures trapped by the crystal causes the formation under droplets (bubbles) of foreign fluids - inclusions of



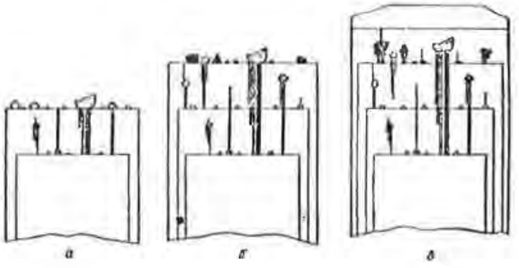


Fig. 5. Zone of fluorite inclusions syngenetic with topaz, x36. The arrow shows the direction of common growth.

Fig. 6. Scheme of distribution of solid xenogenic particles and fibrous vacuoles (inclusions) across growth zones of tourmaline crystal (Ural): a-c-sequence of growth of crystal zones.

Fig. 7. Trapping and repulsion of particles of Lycopodium by a growing benzophenone crystal: a - supercooling 0.1°C, x20; b - supercooling 0.5°C, x20; c - decrease of supercooling to 0.1°C and isolation of inclusions, formed under conditions b, x36; 1 - benzophenone melt with Lycopodium particles, 2 - growing benzophenone crystal.

Fig. 8. Repulsion of mercury droplet by growing crystal of K-Al alum: a - initial moment, b - somewhat later (L inclusion forms under the droplet).

Fig. 9. Trapping of gas bubble without admixture of parent medium (melt) by thymol crystal with increase of growth speed: a,b, - x10, c - x8.

Fig. 10. Formation of vacuole-melt inclusion in growing thymol crystal under air bubble, when a layer of Lycopodium particles occurs between thymol and air, x18.

parent solution without admixture of foreign fluid.

4. Complication of conditions with variable crystallization regime causes irregular trapping of both foreign fluid and parent medium.

5. Stable crystallization regime may cause the trapping of a series of inclusions with the same composition.

6. Droplets of foreign liquid or gas bubbles usually are trapped by growing crystal as tubular inclusion, elongated perpendicularly to the respective face; vacuole formed under a xenogenic particle almost always has negative crystal habit.

Using the above described types of P inclusions for solution of mineral genesis problems, it is necessary to remember not all the above types may submit sufficiently certain information about parameters of crystallization medium. It is pertinent to [discuss] inclusions immediately touching the solid particles and occurring in induction surfaces of growing mineral individuals. It is well known that crystal individuals very easily separate one from another exactly along those pseudofaces. Seemingly, crystal lattices in such surfaces have relatively weak connection, and for this reason solution may migrate from and to inclusions along the surfaces. The same is true of the surface of connection of foreign mineral particles with including host mineral. The two minerals may have different thermal expansion coefficients. For this reason T change both under natural and laboratory conditions may penetrate the fractures, changing the original phase ratios. Sometimes zeolites are trapped minerals; due to their sorption properties they may be the conducting channels or additional reservoirs for inclusion solutions, and in consequence the phase composition of inclusion is changed.

Formation of secondary solutions. Fissures in crystals, which may be the place of formation of S inclusions, form due to various reasons: dynamometamorphism, T change, polymorphic inversions, tension inside crystals.

Tectonic tension causes fracturing in the bases of the crystal [...]. Sometimes, however, secondary turbidity occupies the whole crystal and cannot be caused by dynamometamorphism, but rather by, e.g., abrupt T changes [38, p. 182]. Formation of secondary fractures due to polymorphic inversion was described by A.Ye. Fersman [184]. During the phase inversion α-β quartz, this mineral is reduced to polygonal fragments by numerous fractures due to the abrupt volume decrease. In section they have shape of an irregular reticulation, hence it is called "reticulate" quartz [...] [49, 197]. Yu.A. Dolgov, for instance, writes that abrupt T decrease caused by adiabatic expansion during opening of mineral-forming system is the reason of formation of "reticulate" quartz. A.A. Sternberg studied formation of fractures due to relaxation of tension inside synthetic crystals. Such fractures develop continuously in the process of face growth, following the face, but they do not appear on its surface. The number of fractures of this type depends on the growth speed of crystal. During very slow crystallization such relaxation fractures do not form. Rapid precipitation of material causes an increase in the number of fractures and their ramification.

Due to difference of thermal expansion coefficients of those particles and the host mineral, solid particles, trapped by the crystal and occurring close to a face, break the mineral and form fractures contacting with external medium. Similar fractures, but not contacting the crystal surface, form around solid or L inclusions coverd by a thicker layer of mineral.

Secondary inclusions (early and late) are characterized by the source or very close conditions of formation [in the same fracture, A.K.]. However, during healing of early S fractures, material may be transported from the outside parent solution by diffusion. In formation of S inclusions, evidently, the width of the fracture plays an important role, because on this factor depends the mode of healing and speed of transport of material form outside.

Secondary inclusions form in the process of healing of the described fractures. Those which are syngenetic with recognized elements of crystal growth are early secondary, and those which have no spatial and time connection with growth of a given crystal are late secondary. Inclusions in polygonal reticulate fractures in quartz are early secondary. Fracture formation and their healing usually repeats many times during the complicated and long process of mineral formation. In morion crystals from Volyn pegmatites, a large series of inclusions formed at various times, whose formation sequence was determined on the basis of refilling of inclusion vacuoles in crossing of fractures of various age.* Thus one may distinguish early secondary inclusions 1, 2, 3 ... etc. The same concerns P and late S inclusions, and determination of age sequence of the latter is one of the most important aims of mineral fluidology. The possibility of crossing, typical of fractures with S inclusions, is one of the main differences from groups of syngenetic P inclusions occurring in planes. Such planes coinciding with the former faces of crystal, never cross one with another.

In groups of S inclusions it is most important to determine the places in which the fracture formation started. In those places the contact with parent solution occurred. Here precipitated first layers of crystal after its damage and with those layers the early S inclusions of a given healed fracture are syngenetic. Differences in color of material of healed fracture and the main crystal also help to distinguish inclusions important for solution of genetic problems. For instance, in morions of Volyn sometimes fractures occur that are healed by light quartz. Inclusions in this fracture prove the precipitation of the latest regeneration quartz. There are known, however, rock crystals from Volyn in which fractures are healed by smoky quartz. Interesting relations of fractures of various age and inclusions in them were observed in one of crystals of Volyn morion [88, p. 125]. A relatively wide fracture in morion (thickness about 2-3 mm) was healed initially by transparent quartz and next by amethyst with included goethite needles (Fig. 14). It is easily visible under the microscope that a small fracture in morion, healed by light quartz, ramifies from the main fracture, not penetrating it. This is observable due to essentially G inclusions occurring in the fracture. Another healed fracture cuts morion and light quartz but it has no continuation in amethyst zone. Filling of inclusions of the latter fracture is about 90%. In this manner, a relatively distinct sequence of changes of mineral-forming medium during fracture healing may be observed.

G.G. Lemmlein [117] showed that thin fractures in sodium nitrate healed due to dendritic growth. Inclusions form by isolation of parent solution between branches of several dendrites, which, developing simultaneously, do not completely touch one another. This process starts from the wedge end of the fracture and then develops toward the wide end. The growth occurs without new material from outside but due to reprecipi-

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*This very effective method of reconstruction of regime of changes of crystallization conditions, discovered by G.G. Lemmlein [121] and first used practically by the present author [88, 91], earlier was not applied by anybody in any laboratory known to the author and was not published, in spite of statements by N.P. Ermakov [70, p. 43].

tation of host material from flat walls of the fracture to the angles of dendrites. This spontaneous process of alteration of a non-equilibrium fracture cavity is a result of the crystal changing toward the energetically more appropriate form with a minimum of free energy (Curie-Wulf law). "According to the Ostwald-Freundlich equation, the solubility of crystals (saturation concentration) exponentially increases with decrease of size, and concentration of solution filling the negative crystal (vacuole or fracture in crystal) decrease with decrease of its size. Solubility of convex surfaces is higher than solubility of flat ones, and of the latter - higher than of concave ones." [113, p. 142]. G.G. Lemmlein proved that this condition - like the previous one - is the main reason of reprecipitation of substance in fractures and inclusion vacuoles even under isothermic conditions.

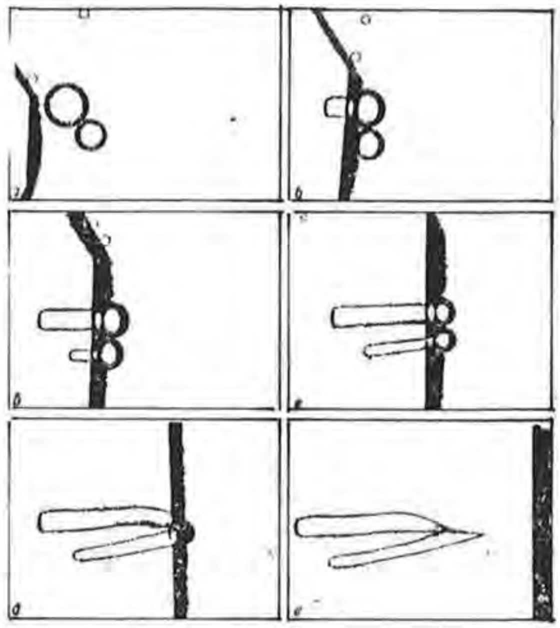
When a dendrite approaches the outer, wide part of the fracture, the process of healing becomes significantly slower. One may suppose that in a fracture of a certain thickness, the dendritic growth becomes so slow that due to entry of material from outside, the fracture will heal by multinuclear growth, as observed in quartz from Alpine-type vein by N.P. Ermakov [63]. Typical asterisk-type ("trigonal") distribution of early-secondary inclusions in quartz crystal from Nagol'nyi is also explained by the author by multinuclear growth healing [103]. Difference in distribution of inclusions in wide and wedge-shaped parts of a fracture confirms the above explanation (Fig. 15). Initial widening of fracture occurred due to dissolving of its walls. Probably, multinuclear growth in healing commonly occurs also in narrow fractures in crystals, especially those only slightly soluble. E.g., in morions from Volyn one may observe frequently inclusions occurring not in the fracture plane but distributed in various distances from it. Those distances are sometimes too large to be explained by dendritic regeneration. Usually such inclusions have negative crystal habit oriented in agreement with host crystal.

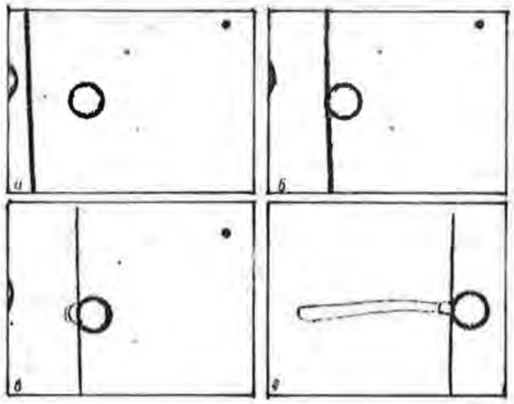
Healing of fractures in crystals and formation of inclusions from G parent solution is still inadequately studied. G.G. Lemmlein [119] made experiments with healing of fractures in ice crystals by G phase at T -6 to 0°C. This author writes that in fractures which were closed to the surrounding environment, the healing developed by sublimation-condensation of material through G phase from flat parts of fractures to the concave ones; the process does not differ from healing by solution. Opened fractures healed in a different way. At the wedge end the capillary condensation of water from surrounding environment was observed; this water next crystallized to ice.

Chapter 4 ALTERATION OF INCLUSIONS

Initial filling and habit of inclusions may change during long geological time. These may be insignificant or major, depending on the intensity of thermobaric, geochemical, physico-chemical and other factors, that acted through the crystal and changed phase equilibrium or the whole inclusion filling. Recognition of reasons and degree of such changes has special importance for evaluation of the validity of data about mineral genesis obtained from fluid inclusions.

Let us consider the scale of influence of the following phenomena on the initial parameters of inclusions: 1) migration (diffusion) of substance through the crystal lattice of mineral; 2) change in the state of isolation of inclusions by fractures in crystal, filled by the new parent fluid (refilling); 3) opening of inclusions due to their overheating (decrepitation); 4) change of energetically disequilibrium habit of inclusion





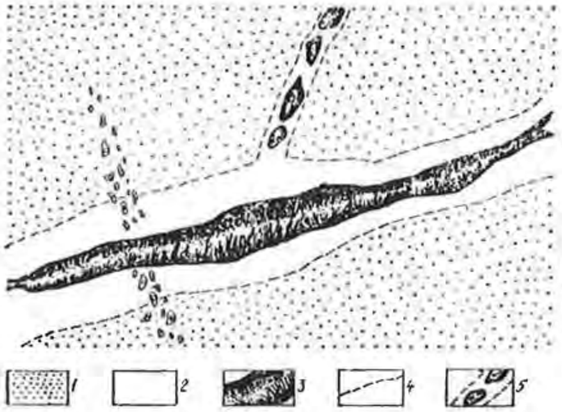


Fig. 11. Stages of trapping of oil droplets by growing crystal of borax; x430.

Fig. 12. Formation of inclusion of parent solution during repulsion of oil droplet by crystal of Na(NH$_4$)HPO$_4$·4H$_2$O; x400.

Fig. 13. Trapping of gas bubble without parent solution admixture in tubular vacuole by crystal of saccharose, x10.

Fig. 14. Fracture in morion healed by light quartz and amethyst: 1 - morion, 2 - light quartz, 3 - amethyst with acicular crystals of goethite, 4 - boundary between morion and light quartz, 5 - G inclusions, x13.

Fig. 15. Scheme of distribution of inclusions in "trigonal rosettes" in healed fracture (Donbass, Nagol'nyi), x10: a- wedge-shaped part of fracture, b - intermediate part, c - main thick part.

to negative crystals (includes also necking down, formation of light haloes, etc.); 5) migration of vacuoles in thermogradient field.

Analysis of genetic information coded in altered inclusions is well illustrated by examples of reconstruction of formation conditions of certain deposits of mineral raw materials.

Migration of substance through crystal

Changes of inclusion filling due to diffusion through the crystal were not detected by ordinary visual and experimental studies, that may suggest either an insignificant influence of this factor or its absence. Evidently, a great role is displayed by the specific conditions of post-genetic existence of inclusions, especially taking into account geological time. Let us quote some evidences of absence of changes of inclusion filling.

It is understandable that in case of a permeable mineral, water solutions might migrate from outside into an inclusion, increasing its degree of fill, or, in reverse, from inclusion to surrounding space, decreasing its filling. Such migration of substance may occur due to difference of P in environments, for a given mineral.

Processes of endogeneous hydrothermal mineral formation usually develop at elevated T and P with their gradual decrease. Thus, generally, parameters of P inclusions from crystal center to its periphery should reflect such a common T change, i.e., inclusions occurring in the center should have smaller degree of fill than those in the crystal periphery. Assuming the possibility of solution migration, the change of degree of fill from the center to the periphery should be reversal - inclusions in outer zone of crystal would lose their contents faster than inclusions in the inner zones. But in nature inclusions in outer zones have usually lower Th (and higher fill degree) than those in inner zones. Very frequently the outer zones of crystal terminations contain one-phase L inclusions even though that mineral existed for long (geological) time in vugs in rocks. Even at room temperature the inclusion contents are under significant P. For instance, opening of two-phase L/G inclusions in pegmatite minerals from Volyn in glycerine shows a 100-fold expansion of the G in inclusion, i.e., at room T the internal P in inclusion was ~10 MPa. Age of the host crystals of quartz from Volyn Zanorysh pegmatites is about 1,200 million years.

Frequently in the outer zone of crystals (Nagol'nyi, Donbass) inclusions were found filled to 100% by LCO_2. Internal P of such inclusions under surface conditions also might reach 8-10 MPa. However, in spite of long existence time, such inclusions preserved their filling.

Inclusions of organic (essentially methane) fluid in quartz from Transcarpathia have internal P under normal conditions >76 MPa [112]. Age of metamorphic rocks of Altai is about 200 million years, but nitrogen inclusions in kyanite preserve internal P ⩾100 MPa at 20°C [55]. The authors of that paper discuss the hermetic state of G inclusions in glass tektites (moldavites) and Lunar soil particles. In vacuoles of inclusions in tektites (of age 15 million yr.) the air components did not penetrate (especially oxygen), although the internal P is 1/3000th of atmospheric P. In glass globules and splashes from the Moon inclusions were found with relatively high gas content (on the Lunar atmosphere scale). [...] It is notable that in inclusions in tektites and in Lunar samples a high content of H_2 was found (10-95% by vol.), i.e., the element whose migration through the crystal lattice is believed to be especially fast.

The facts listed above concerning the state of inclusions under natural conditions prove the absence of influence of diffusion on the results of ordinary studies of inclusions. Experimental data also do not deny this.

B. Skinner [245] obtained lowered Th of gas-liquid inclusions in quartz after a 60-hour run in an autoclave under PH_2O 60-80 MPa at 70°C and he concluded that liquid penetrated through mineral substance into the inclusion. The erroneousness of that conclusion was proved by the author's experiments (Table 1) made with longer runs and at higher T [85], and with more accurate Th measurements, made with a new heating stage [87]. Inaccurate Th measurements in an imperfect heating stage were the reason for the erroneous results[sic]. Later B. Skinner, in collaboration with E. Roedder [243] made more detailed studies, which confirmed the author's experiments.

Table 1. Studies of hermiticity of inclusions in quartz

Number of inclusion	Deposit and sample	Th before run, °C	Experiment conditions			Th after run, °C
			T, °C	P, MPa	Time, Hours	
1	Briestenstock (Alps) rock crystal	190	150-160	83-88	90	190
2	Same.	191				191
3	Synthetic quartz	305				305
4	Volyn, pegmatite, morion	250				250
5	Same.	245				245
6	Same.	234				234
7	Same.	231				231

Experiments were made to stimulate migration of water solution from inclusion to surrounding space by heating to cause a significant excess of internal P in comparison with the external one. D. Richter and E. Ingerson [239] maintained inclusions at T exceeding Th by 25, 30 and 35°C during 3 and 6 hours. No leakage was found. The author [88] made runs with polyphase inclusions in topaz, bearing significant amounts of CO_2, N_2 and CH_4 at T 30-40°C above Th in liquid phase (Th 370-380°C, internal P during homogenization >50 MPa) for 23 days. The inclusions did not change the initial Th (and filling degree).

I.M. Volokhov [24] supposes the possibility of hydrogen migration from inclusions due to dissociation of water at elevated T. Such change of inclusion filling may be typical of magmatic and other high-temperature inclusions, heated in heating stages up to 800-1200°C. Yu.A. Dolgov and V.A. Simonov [53] made a series of experiments with L/G inclusions in "reticulate" quartz. Heating of certain such inclusions was carried up to 1000-1400°C in stages; in each run T was higher 50-60°C than in preceding run and then the sample was cooled 100-200°C below Th. The state of the inclusion filling and its hermiticity were checked each time by measuring of Th. Gradual but insignificant increments of Th after each run suggests (according to the authors of the experiment) the preservation of inclusion filling and a certain increment of the solution density due to dissolving of the walls of the vacuole. Leakage and partial migration of hydrogen (or other volatiles) would be indicated by a Th decrease[sic]. A more distinct change of density of the inclusion filling was observed during heating to T >1050°C, connected with fracturing or melting of host mineral.

The proposition that solution may migrate through the lattice of salts like NaCl, KCl, etc. [63] was not confirmed by the author's studies

[89]. Partial or complete leakage of solution from inclusions in such salts and in other minerals of low hardness and perfect cleavage (barite, gypsum, etc.) is caused by its expulsion into microfractures formed around the vacuole during experiments. These fractures usually are invisible and frequently don't contact with the preparation surface.*

The above data may be the evidence that leakage of inclusions is [so insignificant that is] not detectable by usual investigations of most minerals, especially such as quartz, topaz, calcite, fluorite, etc. The only exception are zeolites, with channels in their structures providing the ways of migration of molecules of foreign substances. Sealing may be incomplete for inclusions occurring in the planes of induction faces, on twin junctions, etc. in places of discontinuity of crystal lattice and incomplete continuation of structural units. However, this problem needs special studies. Usually the filling of P (and S) inclusions is altered when the inclusions contact solid inclusions, especially those displaying absorption properties like zeolites, hydromicas, etc.

Refilling of inclusions

G.G. Lemmlein [121] first paid the attention to the change of filling of inclusion vacuoles occurring on the line of intersection of healed fractures of various age and determined its genetic significance; later those phenomena were studied by the author [88, 91].

Inclusions may be opened by fractures formed due to external mechanical action or internal tension in crystal. Formation of fractures occurs during the whole process of crystal formation. Surrounding fluid through the opened fractures penetrates the inclusion vacuoles, changing their primary filling. New, later fractures may open the earlier sealed inclusions both in healed fractures and in growth zones of crystal (i.e., S and P inclusions). During this process the initial habit and dimensions of the opened inclusion usually are preserved but the filling (its composition and specific volume) essentially change.

Measurements of Th and pH of individual inclusions and cryometric studies prove that filling of altered inclusions is completely replaced by the new fluid of the later fracture, i.e., there occurs complete refilling of inclusions [91]. For instance, the refilled inclusions 1, 2, 3 (Fig. 16), by their size, habit and position in the fracture (they occur in the plane of the drawing) are similar to L/G inclusions a, but their filling is the same as the younger inclusions of LCO_2 occurring in the fracture bb almost perpendicular to the plane of the drawing. By cryometric analysis the salt concentration of L phase of inclusions a is 7% NaCl (last ice crystal disappears at -4.5°C, cryohydrate point -21 to -22°C). Water solution of refilled inclusions and inclusions of the fracture bb has lower salinity 1.5 to 2.0% NaCl (last ice crystal disappears at -1°C). Similar results were obtained from measurements of pH and Th of inclusions (refilled and occurring in the cross-cutting fracture).

The complete refilling of vacuoles is caused by the following reasons:

1. Fractures formed in the crystal are unusually thin and solution sucked into the fracture moves gradually in the direction of its development. Before the front of the moving solution the area of low pressure (vacuum) is formed (Fig. 17). This vacuum part of fracture first contacts with solution of vacuole, removing it from the vug; this causes the quick mixing of fluids.

2. Healing of fractures in slightly soluble minerals (quartz, topaz, feldspars, etc.) goes relatively slowly in comparison with process of dif-

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*Called "stretching of inclusions" in Western literature. (A.K.)

fusion and filtration. The latter relatively quickly unify the composition of gases and salts of the opened inclusion and the fracture contacting the surrounding parent solution.

3. Volume of the opened inclusion is immeasurably small in comparison with the volume of fracture and fluid surrounding the crystal; for this reason the influence of inclusion fluid on the general composition of fluid in fracture is not noticeable.

Figure 18 presents drawings made from microscope observations showing typical examples of the change of inclusion filling in crystals of quartz from Volyn pegmatites during crossing by later fractures. Crossings are best observable when one or both fractures are subparallel to the optical axis of microscope (or almost perpendicular to the surface of preparation). Figure 18 presents only those inclusions which are on the same level that refilled inclusions. Other vacuoles are out of focus.

A complete analogy was observed in the filling of refilled inclusions A and inclusions cutting fractures II-II (Fig. 18a, b, d, e, h-k). the same may be said also about other cases, although seemingly this analogy is absent. Families of syngenetic inclusions trapped from heterogeneous (liquid + vapor) fluids have various degrees of filling. If the cross-cutting fracture bears such inclusions filled in various degree, one may suppose that composition of refilled inclusion would be included in the general pattern of variable filling. Observations confirm this pattern (Fig. 18c, f, g); most commonly in this case refilled inclusions are gaseous and essentially gaseous. This is the consequence of expulsion of the former L phase by the vacuum part of the opening fracture and next action of the capillary forces precluding the filling of relatively large and isometric cavity from a thin, capillary fracture (Fig. 17b). Very rarely during refilling by heterogeneous solutions, the inclusions formed are of G/L or mixed (heterogeneous trapping) type. Thus, also in the above case complete refilling does occur.

Nearly insoluble trapped minerals may remain without change in refilled inclusions. Also if mixing of solutions causes precipitation of an insoluble product, the opened vacuoles would contain a xenogeneous solid phase, with respect to new fluid. This, however, does not influence (taking into account diffusion) the composition of fluid sealed in the newly-formed inclusion and its identity with the fluid penetrating the fracture.

Vacuoles in crystals opened by fractures causing the possible leakage of inclusions are a special case. Such vacuoles (according to the author's determination) do not belong to inclusions of mineral-forming fluids. Omitting inclusions opened by non-healed fractures one may recall cases (described many times in the literature) of magmatic glass inclusions with fractures joining them with surrounding environment. Such penetration of melt into fractures and its hardening as glass is typical of xenoliths of hydrothermal quartz and other minerals with inclusions of fluids. Only the recognition of lack of leakage of newly formed inclusions may be the basis for use of them as relics of mineral-forming solution.

Refilled inclusions are very important genetically. By this phenomenon the relative age of acting endogeneous fluids may be established. Since P inclusions are limited in distribution and the sequence of their formation is difficult to establish, refilling is essential for reconstruction of the details of evolution of properties of mineral-forming fluids in relative time. The large amount of S inclusions in crystals makes such investigations easier.

One may conclude about the relative age of the crossing fractures by

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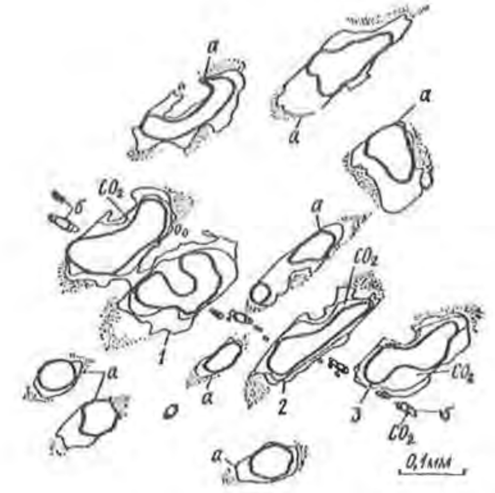
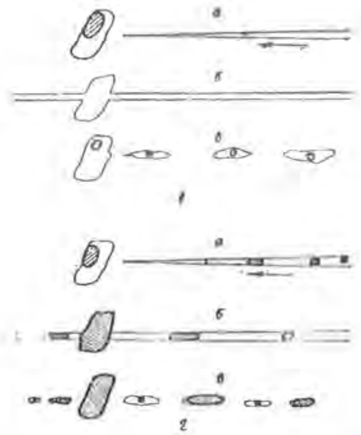
*Fig. 6 quoted here in the Russian text most probably is a misprint.(A.K.)





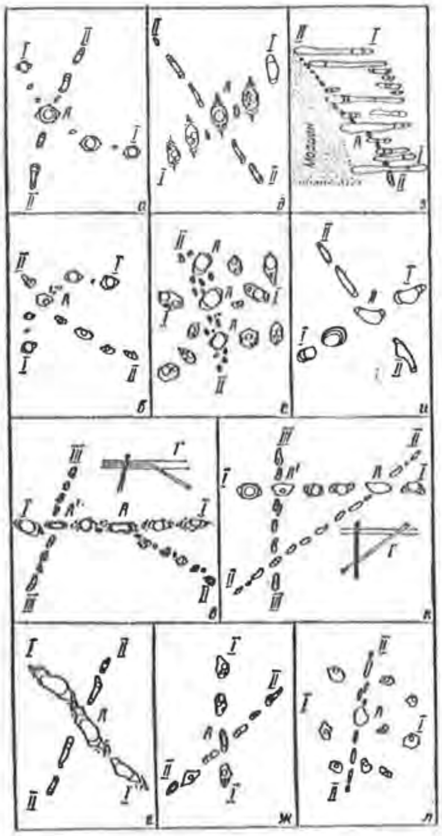


Fig. 16. Refilling of L/G inclusions with haloes of decrepitation (a) by LCO_2-LH_2 solutions (b).

Fig. 17. Scheme of refilling of inclusion by solution from an opening fracture: 1 - during healing of fracture from homogeneous solution; 2 - during healing of fracture from heterogeneous solution; a,b - stages of inclusion opening, c - healed fracture.

Fig. 18. Relative age and features of fluid inclusions in quartz of "zanorysh" (i.e., chamber) pegmatites of Volyn: a-I-"reticulate" (L = 40-45%, Th = 380-430°C in G, pH 6.3-6.9), II-inclusions of CO_2 (L = 5-10%, Th 300-320°C in G, pH 8.2-9.2); b-I-same as a,II-G/L (L = 70-80%, Th 325-340°C in L, pH 7.4-7.6); c-I-decrepitated with turbid haloes (L = 35-40%, Th 400-435°C in G, pH 8.0), II-polyphase with various filling degrees (L = 30 and 75%, solids = 5-10%, Th 400-550°C in L, 370°C in G, pH 5.2, Fe^{2+} 7%), III-filled in various degree (L = 5-10 and 75-80%, pH 7.8-8.0); d-I-same as in b,II-same as in a; e-I-polyphase (with trapped or dms) decrepitated (L = 20-30 and 70-75%, Th 550°C in L), II-same as in a; f-I-polyphase (L = 66-70%, pH 5.2-5.4), II-polyphase filled in various degree; g-I-polyphase (L = 50-55%, solids 7-8%, pH 5.2-5.4), II-filled in various degree (L = 0-2 and 85%, pH 7.8-8.0); h-I-CO_2-filled, P, filled in various degree (L = 5, 10, 80-85 etc. %, Th 240-270°C in L, pH 7.4-8.0); i-I-same as in a, II-essentially G (L = 1-2%); j-I-same as in a, II-essentially G, III-G/L (L = 95-97%, Th 80-100°C in L, pH 6.0, Ca 7.6%, Mg 4.3%), k-I-G/L (L = 75%, Th 225-270°C in L, pH 7.8-8.0), II-essentially G (L = 1-2%), I-III-sequence of inclusions formation from early to late, A, A', B - refilled inclusions, G-scheme of crossing of healed fractures, [...] pH values under normal (room) conditions.

comparing habit, dimensions, orientation and filling of inclusions in the fractures. Crossings of S and P inclusions fixed on Fig. 18* unambiguously show that all healed fractures I-I are earlier than fractures II-II. For this reason the time of action of mineral-forming solutions of the first fracture is earlier than the second fracture.

Not all fracture crossings permit unambiguous solution of the question about their age. Often refilling is not observed or it is nebulous. Such cases may be explained, e.g., by contemporaneous (or almost contemporaneous) healing of crossed fractures. Sometimes a large inclusion in one of the fractures occurs on a line of tiny inclusions of the second fracture, but the large inclusion was not refilled. Thus probably the fracture with large inclusions is younger, otherwise these inclusions should be refilled. This indirect method is less exact.

Usually refilling on crossings of two fractures were observed; unique and valuable are the joint refillings of inclusions of three and more fractures (sometimes they occur in one view field in microscope). Such cases surely show how significant are changes of composition and properties of endogeneous fluids in the process of formation of deposits. Two such crossings are presented in Fig. 18. First of them (Fig. 18c) shows that high-temperature fluids (producing inclusions with haloes of decrepitation in fracture I-I) were replaced by heterogeneous (boiling) high-temperature and highly concentrated solutions in fracture II-II, which next were changed by fluid of fracture III-III, also in a state of two-phase equilibrium (liquid-vapor). It is understandable that such large differences of the named fluids cannot prove sudden and abrupt change of solutions, because the discrete character of trapping of solution in vacuole makes possible the fixing of only certain moments of the process. For elucidation of the sudden changes of state of fluids there are other methods and objects of study, which fix directly the extremes.

In the second case of the triple crossing of fractures (Fig. 18j), the sequence of appearance of fluids typical of zanorysh pegmatite formation is shown. The fluids are saturated with CO_2 and relatively low-temperature. Essentially G inclusions homogenizing in G phase are not an unambiguous indicator of phase state of fluids with high specific volume. Existence of two-phase L-G equilibrium and possible trapping of only separated G phase in inclusions do not solve this problem in each case.

Sometimes refilling causes separation of inclusions to parts or the loss of the initial habit. Such cases are very rare but they may complicate the recognition of alteration and their true reason. Figure 19 shows the crossing of tubular inclusions by inclusions composed of CO_2 (G + LCO_2 + LH_2O). The path of fracture is traced not only by tiny S inclusions but also by dividing of P inclusions into two parts. Such dividing was observed only in very thin, fibrous inclusions (thickness <0.01 mm) and inclusions of larger thickness (left part of drawing) were not submitted to such alterations. The smaller the thickness of the tubular inclusion, the larger is the distance between the separated parts of the inclusion (from 0.14-0.24 mm for thickness ~0.01 mm to 1 mm for 0.002-0.003 mm). It is interesting that at the place of crossing the small inclusions form with elongation agreeing with elongation of P tubular inclusions (matched with arrow in the Fig. 19). The described phenomena are typical of tubular inclusions in tourmaline, apatite, beryl, etc.

Rarely during crossing of fractures the reverse scheme was observed. Inclusions opened and formed in the new fracture together join in one vacuole. Usually this is most easily observed when a flat vacuole of the cross-cutting fracture joins the refilled inclusion.

Opening of inclusions under action of internal pressure (decrepitation, breaking)*

If pressure made by fluid inside an inclusion exceeds a specific value, the walls break and inclusion filling leaks. This effect is possible during T increase or during sharp decrease of external P. The maximum P inside the inclusion depends on numerous factors, first on physical properties of mineral, dimension, habit, phase and composition of the inclusion [88, p. 134].

Experimental data obtained during studies of natural and synthetic crystals showed that there occur essentially two modes of opening of inclusions on heating: explosion of inclusion and its breaking.

First mode is typical of rock-forming minerals (quartz, topaz, calcite, etc.). During explosion of inclusions the opening fractures join the inclusion vacuole with the space surrounding the crystal. This almost always is connected with acoustic effects and breaking of the preparation into fragments or cleavage chips. It was always noticed that when the opening is vigorous, inclusions have carbon dioxide in their composition or a significant P of other gases occurs inside the vacuole.

The second mode of inclusion opening is typical of easily soluble minerals (halite, sylvite, etc.), but frequently appears also in quartz, barite, gypsum, calcite. Experimental studies of inclusions in $NaNO_3$ were made by G.G. Lemmlein and M.O. Kliya [126]. Under action of internal P, an elastically deformed area forms around the inclusion. P increase and overstepping of crystal resistivity leads to breaking of the crystal body continuity and forming of one or few microscopic fractures. Increase of inclusion volume due to those fractures causes an abrupt P decrease. Hence the fractures stop close to the inclusion (distance of a few inclusion diameters), not reaching the preparation surface. The fractures next are healed forming submicroscopic inclusions of a portion of parent solution. Usually elastic deformation of crystal lattice after such inclusion alteration remains and may be observed in polarized light. Inclusion volume after overheating increases because of new-formed submicroscopic vacuoles. Hence, the amount of solution that fills the primary volume of the inclusion vacuole decreases. After cooling a gas bubble appears in an inclusion that earlier was one-phase. Volume of this bubble in the ideal case would be equal the total volume of all submicroscopic inclusions of the healed [newly formed] fractures (Fig. 20).

The difference in the modes of inclusion opening is caused more by peculiarities of the development of internal P in inclusions connected with their composition than by features of minerals. Evidently, when compressed gases are present in inclusions, the volume increase caused by formation of small fractures around the inclusion is not sufficient for compensation of G pressure. For this reason the whole specimen breaks with relatively intense acoustic effect. In reverse, for P decrease in a weakly compressible liquid, an insignificant volume increment is sufficient, like formation of submicroscopic fractures. Thus, fracture deformation is observed only close to the inclusions.

The correctness of the above statement is confirmed by the simple calculations presented below. Let us show how large should be the volume increase due to newly-formed fractures and how the internal P decreases to finish the process of fracture widening. If one considers inclusions of the same dimensions and shape in the same mineral, the breaking pressure should be a constant value; for quartz, for instance, it may be equal 8 MPa [150]. Internal P of G/L inclusion H_2O with total specific volume γ =

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*Written together with D.K. Voznyak.

1.2 cm^3/g will reach [177, p. 347] 80 MPa and decrepitate at 280°C (initial filling of inclusion at 20°C L = 84%, Th ≈ 225°C). It may be supposed that the appearance in the inclusion vacuole of the equilibrium liquid-vapor and respective P decrease to 6.4 MPa (at 280°C) precludes the movement of fracture front far in the crystal. Since the mass of inclusion filling remains constant (fracture does not contact the crystal surface), the relative volume increment will be connected with the ratio of specific volumes $W_2:W_1 = \gamma_2:\gamma_1$ (here W_1, γ_1 and W_2, γ_2 are respectively initial and final inclusion volumes and total specific volumes of their filling).* After the manual [176] due to P decrease from 80 to 6.4 MPa at 280°C the total specific volume increases 1.1 times ($\gamma_2:\gamma_1 = 1.33:1.20$) and hence also volume of L inclusion should increase in the same ratio.

L/G inclusion of H_2O of total specific volume, e.g., 3.39 cm^3/g will homogenize in G at T ~370°C and it develops the breaking pressure 80 MPa at 600°C. Using data from the manual [176, p. 349] similarly as before, we find that P decrease after breaking at 600°C to 6.4 MPa it is necessary for the vacuole volume to increase 19.8 times ($W_2:W_1 = \gamma_2:\gamma_1 = 67.3:3.39$).

Inclusion of pure CO_2 of the same specific volume as the above discussed inclusion of H_2O ($\gamma = 1.2$ cm^3/g) will achieve the pressure 80 MPa at 150°C [176, p. 353]; on breaking its volume increases 9.4 times ($W_2:W_1 = \gamma_2:\gamma_1 = 11.27:1.20$).

It is interesting that inclusions of CO_2 and essentially G inclusions of H_2O have similar value of increase of volume in the moment of breaking, even if the initial parameters of GH_2O inclusions are similar to G/L inclusions of H_2O (Table 2).

Hence, for inhibition of fracture formation around H_2O inclusions of relatively low density and CO_2 inclusions of various degrees of fill needs an increase of the volume by fractures of one order of magnitude larger than for G/L inclusions of high density. The latter develop breaking fractures of volume less than 10% of the initial inclusion volume. Thus, the first of the above inclusions on heating break with a distinct acoustic effect and fragment the mineral grain, the second one gives very weak acoustic signals and preserves the initial filling in volume of new vacuole, which does not reach the surface of mineral grain.

Table 2. Increase of volume of inclusion vacuole due to joining fractures of optimum size, not reaching surface of crystal

No. of inclusion	Filling	Conditions of beginning of breaking			Conditions of end of breaking			Volume increment $W_2:W_1$
		P, MPa	T, °C	Specific volume, cm^3/g	P, MPa	T, °C	Specific volume, cm^3/g	
1	H_2O	80	280	1.20	6.4	280	1.33	1.1
2	H_2O	80	600	3.39	6.4	600	67.3	19.8
3	CO_2	80	150	1.20	6.4	150	11.27	9.4
4	H_2O	80	200	1.094	5.0	200	1.153	1.06
5	CO_2	80	200	1.35	5.0	200	17.06	12.6
6	CO_2	80	600	2.55	5.0	600	33.22	13.0
7	H_2O	80	360	1.38	5.0	360	53.18	38.5

Change of the PTV parameters (Table 2) is marked by the dotted lines on the PT diagrams of H_2O and CO_2 (Fig. 21 and 22). From their analysis it may be concluded that the ability of inclusions to extend their volume

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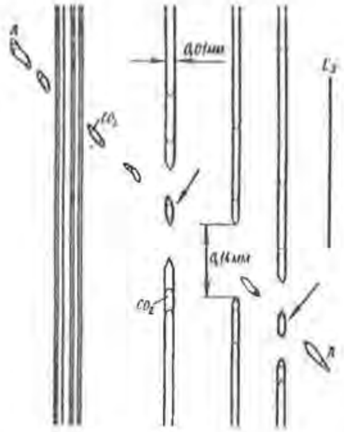
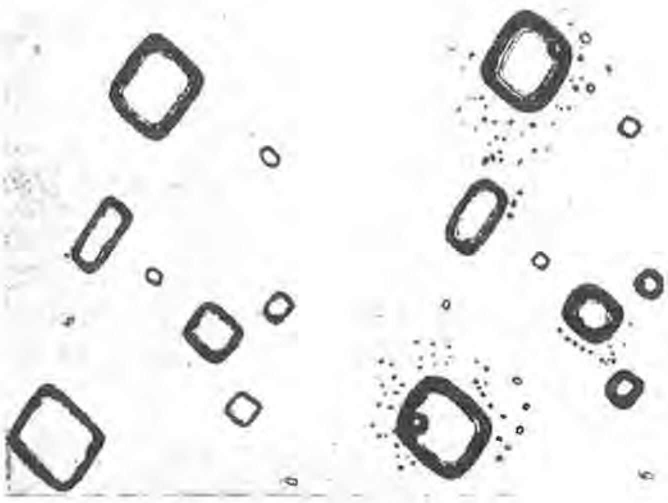
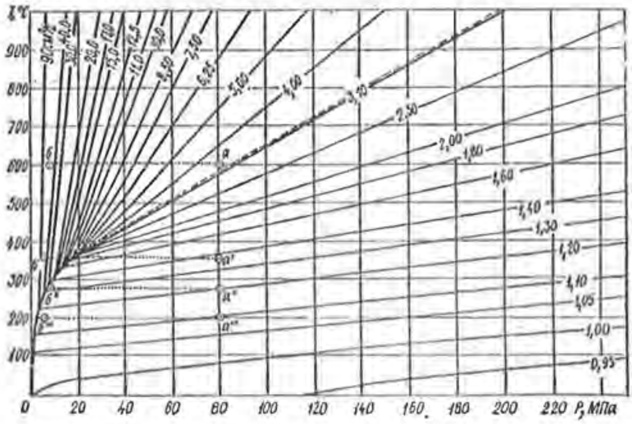
*Total specific volume means ratio of total volume of vacuole to total mass of phases.







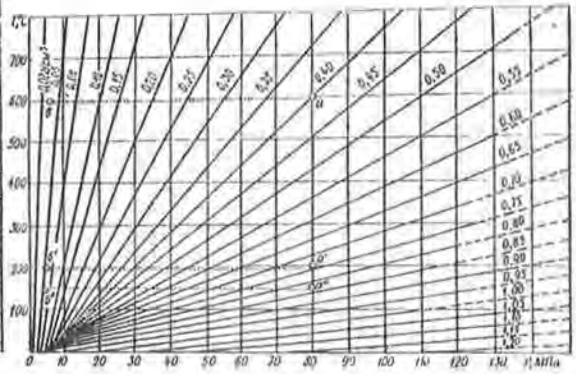


Fig. 19. Scheme of refilling of P tubular inclusions (type as in Fig. 6 and described in item 6, Table 3) in quartz by solutions of S inclusions of CO_2 type 8 in Table 3 (fracture A-A); explanation in the text.

Fig. 20. Inclusions of parent solutions in $NaNO_3$ crystal (a) and the same inclusions after overheating, breaking and formation of halo of healed fractures (b).

Fig. 21. PT diagram of H_2O with isochores for various specific volumes (made from data of G. Kennedy [176]). Dotted lines show P decrease in inclusions during their isothermal decrepitation.

Fig. 22. PT diagram of CO_2 with isochores for various densities (made from data of G. Kennedy [176]). Dotted lines - same as in Fig. 21.

during overheating is determined by value of P increase per unit of change of temperature, i.e., by slope of isochores with respect to P axis. This explains the similar character of decrepitation of inclusions of CO_2 and L/G inclusions of water. Value of lower limit of internal P in inclusions when fracture development stops, was accepted somewhat arbitrarily. Seemingly, P of 5-6 MPa does not exceed the real ranges; probably fracture formation stops even under higher P. If not, the expansion of fractures will continue, especially intensively during phase change L - vapor under preserved P (Table 2, inclusion 7). However, this supposition, like the other accepted by the author, cannot influence the conclusion about principal differences in type of decrepitation of inclusions of various composition and specific volume during the overheating.*

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*Overheating is called heating in excess of Th, here used for heating to T>Td.

To take into account the numerous factors determining the conditions of decrepitation of inclusions is a complicated problem and until now there is no complete mathematical equation for it. After M.O. Kliya and G.G. Lemmlein [105], value of internal P in inclusion necessary for destroying of crystal, may be calculated from the equation

$$P_{\text{int.}} = P_{\text{ext.}} + \frac{4}{3}\sigma - \frac{4}{3}\sigma\left(\frac{b}{a}\right)^3, \tag{1}$$

where $P_{\text{ext.}}$ - external pressure, σ - mechanical properties of mineral, a - size of sample, b - size of inclusion.

The author [103], on the basis of studies of decrepitation of inclusions with LCO_2, found that the maximum internal P approaches a constant value and is equal 55-65 MPa or more, depending on the habit and dimension of the inclusion.

From PT relations of solutions of L inclusions trapped during growth of synthetic quartz and T of beginning of decrepitation, the minimum P for breaking inclusions was determined to be 80-85 MPa [150, 180, 188].

Yu.N. Pashkov and G.O. Piloyan [160] found the equation linking critical P inside an empty sphere (P_{cr}), radius of an inclusion (R_1), distance from center to outer wall of inclusion (R_2) and critical tension of breaking (σ_{cr}):

$$P_{cr} = \frac{2\sigma_{cr}(L^3 - 1)}{2 + L^3}, \text{ where } L = \frac{R_2}{R_1}.$$

If equation (1) is used for evaluation of pressure ($P'_{\text{int.}}$) necessary for decrepitation of vacuole when a>>b, i.e., for formation of decrepitated inclusions, it has the shape:

$$P'_{\text{int.}} = P_{\text{ext.}} + \frac{4}{3}\sigma,$$

because part $4/3\sigma(b/a)^3$ may be omitted. From this it appears that for crystals being only under hydrostatic pressure of mineral-forming solution, decrepitation of L inclusions is possible only when the difference between P of inclusion fluid and the external P equals the determined positive value ΔP:

$$\Delta P = P'_{\text{int.}} - P_{\text{ext.}} \tag{2}$$

For quartz grains ΔP (for $P_{\text{ext.}} = 0.1$ MPa, T = 300 to 400°C, inclusion dimensions 0.08-0.5 mm) obtained experimentally [150, 180, 188] corresponds to the minimum value of resistivity limit for breaking, which equals 85 MPa [197]. Close value of ΔP but for inclusions occurring in crystals (a>>b) may be obtained with use of formula (1), if σ equals minimum value of resistivity limit for breaking.

It follows from equation (2) that decrepitation of inclusions may occur in two ways: a) by increase of internal P in inclusion ($P_{\text{int.}}$) i.e., by overstepping of T of mineral formation (overheating); b) due to decrease of external P of solutions ($P_{\text{ext.}}$). Both modes of inclusion decrepitation may occur in nature and investigations should lead to find PT conditions of their origin in each specific geological object. Part of the inclusion solution during decrepitation is trapped as daughter inclusions in healed fractures, changing the initial density. Let us consider relations between Th of inclusions of water of different filling, occurring only under external P of mineral-forming fluid and formed during short-duration overheating (Fig. 23). Such analysis makes possible the reconstruction of PT conditions of decrepitation of L inclusions on the basis of their alterations. Inclusions altered in the process of decrepitation the author (after G.G. Lemmlein) calls "parent" inclusion, and those formed during healing of fractures by solution from parent inclusion - "daughter" inclusions; T_0, P_0 - temperature and internal pressure of solution at the moment of homogenization before decrepitation; T_1 - Th of parent inclusion; T'_1, $P'_{int.}$ - T and internal P of solution in inclusion at moment of inclusion breaking under external P 0.1 MPa; T", $P''_{int.}$ - minimum T and P of solution inside inclusion at moment of inclusion breaking under external P of mineral-forming solution; T'" - the highest temperature that influenced decrepitated inclusion; d_0, d_1, d_2 - isochores of (respectively) non-decrepitated inclusion and decrepitated inclusions.

Inclusions which, under external atmospheric pressure, decrepitate above Th ($T' > T_0$). 1. Inclusions before decrepitation homogenized in G phase. As appears from diagram (Fig. 23a), at T' the determined critical P' will be achieved and the inclusion will decrepitate (external P 0.1 MPa). Due to the addition of some volume to the original vacuole the solution density will decrease (d_1). Healing of break with formation of daughter inclusions (for this example Th of parent and daughter inclusions are equal) lead to the fact that Th of parent inclusion (T_1) will be lower not only than T of breaking (T'), but also than Th of inclusion before breaking (T_0), i.e., $T' > T_{)} > T_1$.

External pressure of solutions increases the breaking temperature of inclusions. The T of beginning of breaking is the minimum T of natural decrepitation (T") which is higher than T. The difference T"-T is higher when the external P is higher and density of inclusion fluid is lower.

Natural healing (T'") of mineral-forming system may be higher than T" (of beginning of inclusion break) under a determined external P. Thus, $T''' > T'' > T' > T_0 > T_1$.

2. More complicated relations between T_0, T_1, T', T", T'" occur for inclusions homogenizing in L phase before breaking:

a) During breaking the phase state of the solution does not change (Fig. 23b): $T' < T'' < T''' > T_1 > T_0$. When aureoles of decrepitation are very small, the initial density of solution almost does not change and $T_1 \geqslant T_0$, i.e., decrepitated inclusions may be used for estimation of T of its trapping. If haloes of decrepitation are significant, T_1 is significantly higher than T_0 and it may approach T'". Dimension of haloes of decrepitation of inclusions (when all other conditions are the same) would be determined by difference T'"-T";

b) At T of breaking the inclusion solution becomes heterogeneous (Fig. 23c): $T_1 > T''' > T'' > T' > T_0$. Depending on original inclusion filling and size of the added volume, the parent inclusion may homogenize already in G phase (d_2);

c) At T of breaking the inclusion solution becomes G (Fig. 23d): $T' < T'' < T''' > T_1$, T_0; and $T_1 > T_0$ or $T_1 < T_0$, depending on the volume added by decrepitated inclusion and its initial filling (isochores d_1 and $_2$).

Inclusions, which under external atmospheric P, decrepitate before homogenization ($T' < T_0$). Similarly as above, the relation may be found between T_0, T_1, T' and T" for inclusions, whose minimum overheating ($T' - T_0$) has a negative value. Under external P of mineral-forming fluids, temperature of break (T', T'") may be higher than T_0 and in such case the earlier presented relations are true.

From analysis of conditions of decrepitation of L inclusions there appears the following:

1. Decrepitation of L inclusions in nature may occur due to T increase (overheating) and also due to rapid decrease of external P of mineral-forming solutions.

2. Th of parent inclusions (T_1) with small haloes of daughter inclu-

sions are close to Th before decrepitation (T_0). Depending on initial filling of inclusions $T_1>T_0$ or $T_1<T_0$.

3. Th of parent inclusions homogenizing in L phase may approach Td or even be higher, however in all cases they are higher than Th of inclusions before decrepitation.

4. Homogenization of parent inclusion in L also proves a similar process before decrepitation, whereas homogenization in G phase not always proves its initial trapping from G.

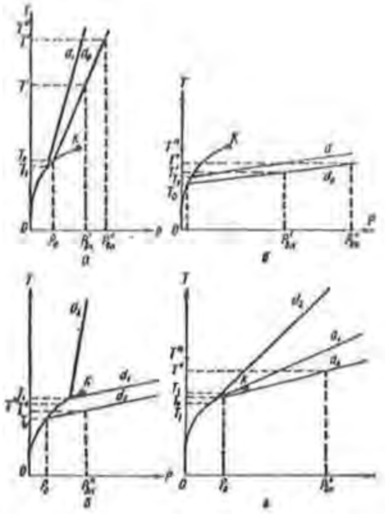
5. Studies of daughter inclusions may provide evidence about the true T of healing of fractures. Moreover, healing of fractures proves the authigenic nature [18] of the solution of decrepitated inclusion with respect to the mineral bearing it. This conclusion has important meaning during studies of decrepitated inclusions of non-aqueous inclusions.

Morphology of inclusions caused to decrepitate is determined mainly by the character of the distribution of the fractures around the inclusion. The vacuoles themselves usually change their habit little. Commonly, the healed fractures are plainly visible due to clusters of microscopic or submicroscopic daughter inclusions. Sometimes healing of fractures is incomplete and hence parent inclusions become ramified on their edges [...]. Unhealed but isolated (from the outside) fractures occur very rarely. Examples are found in the fractures in calcite around large inclusions during freezing of solution in subpolar areas.

Decrepitated inclusions were studied mainly in quartz and occasionally in other minerals (fluorite, calcite, beryl). Oriented and disoriented healed fractures were observed in quartz. The first ones usually are beaded by submicroscopic daughter inclusions and occur in planes parallel to faces of prism $\{11\bar{2}0\}$, and the negative and positive rhombohedrons. They occur around inclusions whose habit is close to that of negative crystals. The second ones are connected with inclusions of irregular habit, formed during healing of uneven surfaces of fractures and made of planes without determined orientation.

Orientation of fractures around L inclusions in quartz is determined not only by mineral structure but also by the habit of inclusions and their distribution. If parent inclusion is a negative prismatic crystal, daughter inclusions occur only in planes parallel to prism faces $\{11\bar{2}0\}$. In projection on (0001) plane these planes have the habit of trigonal bundles and are parallel to edges formed by faces of positive rhombohedron. Trigonal bundle of fractures in one of the vertices of L inclusion is turned over an angle of 60°C with respect to the second vertex (Fig. 24). Habit of such inclusions recalls the negative crystals with "hoods" described by G.G. Lemmlein [116]. Two more healed fractures parallel to face of the negative rhombohedron $(\bar{1}011)$ occur around inclusions of pseudocubic habit formed by faces of the positive rhombohedron, in addition to two trigonal bundles of fractures. Fractures parallel to faces of the positive rhombohedron form in special cases when the inclusions occur close one to another and significant overheating strongly deforms the quartz occurring between them with formation of rhombohedral blocks. Angles between the fractures measured with Fedorov's stage were equal 94 ± 30 and 86° ± 30°[sic, A.K.]. It is interesting that decrepitated inclusions in these fragments also have rhombohedral (pseudocubic) habit. As before, here also trigonal bundles of healed fractures occur. Around inclusions of irregular habit, the fractures usually are uneven surfaces; sometimes the trigonal bundles of fractures are observed around them.

Dimensions and morphology of fracture size of daughter inclusions and habit of the parent inclusions depend on: a) interval of natural overheating [126]; b) dimensions, habits and distribution of inclusions. Moreover, absolute dimensions of daughter inclusions depend on their position



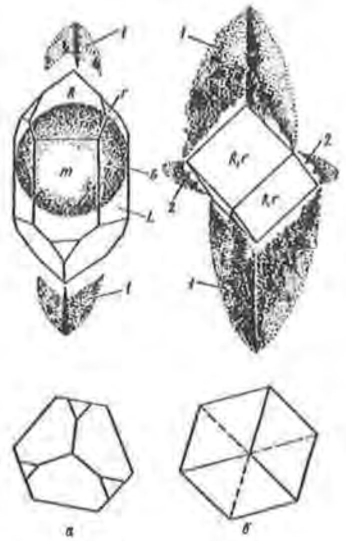


Fig. 23. Relation between T_0, T_1, T', T", T'" of aqueous inclusions in which decrepitation occurred due to short-time T increase (explanations in the text).

Fig. 24. Distribution and shape of healed fractures around negative crystals of prismatic (a) and rhombohedral (b) habits: 1 - submicroscopic daughter inclusions in planes parallel to faces of prism $(11\bar{2}0)$; 2 - same inclusions but distributed parallel to faces of negative rhombohedron $(\bar{1}011)$.

in the fracture.

Sometimes certain inclusions of the healed fracture are weakly decrepitated. This is caused only by differences in habit, size and distribution of inclusions, because external factors causing decrepitation are the same. Solution density in inclusions of the fracture is the same, only Th of the broken inclusions is somewhat higher than that of the others.

Neighboring inclusions often are joined by fractures during decrepitation. On healing inclusions of complicated habit form, sometimes filled in various degree. Inclusions also were found that have only large daughter inclusions and so the characteristic feature as a halo of submicroscope inclusions is absent. Parts of fractures immediately adjacent to the present vacuole of the parent inclusion of size 0.1-0.4 mm frequently bear relatively large daughter inclusions with distinctly varying phase composition. Their amount increases with increase of parent inclusion size. Thermometric studies of such inclusions make possible the determination of true T of fracture healing.

G.G. Lemmlein and M.O. Kliya [126] showed that fractures around inclusions during overheating usually are oriented parallel to cleavage of the crystal or, in general case, perpendicular to the direction of the weakest bond. It is interesting to compare the directions of quartz cleavage occurring most frequently with orientation of daughter inclusion planes.

G.W. Fernberg [vide 197] theoretically considered the possibility of obtaining of the imperfect cleavage in quartz and he arranged the following sequence of its diminution:

$$R(10\bar{1}1)>r(01\bar{1}1)>m(10\bar{1}0)>c(0001)>a(11\bar{2}0)>s(11\bar{2}1)>X(51\bar{6}1).$$

Cleavage along the prism a is in the fifth place, but most frequent breaks around inclusions are parallel to faces of this prism $a\{11\bar{2}0\}$, more rarely to r or R rhombohedrons, the best cleavage and the weakest bonds in crystal structure. Regular distribution of fractures with submicroscopic inclusions was noted also around P glass inclusions in high-T quartz of effusive rocks [122]. Data about habit of decrepitated inclusions in other minerals are almost lacking, detracting from the quality of reconstruction of history of forming of geological objects.

Aureoles of decrepitation around inclusions provide the possibility of obtaining additional data about the mode of T regime of mineral formation. The fact of decrepitation itself proves the episodes of T increase or sudden P decrease against a background of general gradual evolution of PT parameters. Th of daughter inclusions in decrepitation haloes may show the true T of fracture healing, because formation of such inclusions from homgeneous trapping occurred under conditions of two-phase equilibrium L-G (vapor). Detailed study of decrepitation haloes, growth zones of crystals and genetic types of inclusions makes possible the establishing of the relative age (sequence) of action of high-temperature solutions and [trapping of] inclusions. Also inclusions altered by breaking in certain determined cases may be used for estimation of PT conditions of crystallization [18]. These and other problems are explained also in the chapter about genetic significance of altered inclusions.

Alteration of inclusion morphology (necking-down, precipitation of substance on the vacuole walls, forming of negative crystals)

Thin fissures in minerals formed during crystallization and filled by parent solution, are disequilibrium systems with excess surface energy. Their healing develops due to loss of free energy according to the Curie-Wulf principle [118]. Experiments of G.G. Lemmlein and M.O. Kliya [125] show that due to dendritic growth, the fracture opening is divided into isolated fragments, in which the parent solution is trapped. These inclusions in the crystal are the subject of self-alteration as they obtain a more stable equilibrium habit. Negative crystals, i.e., a faceted cavity with morphology like the crystallographic forms of the host mineral (with its symmetry), that might form under conditions of equilibrium with parent solution, is for these inclusions the ideal habit, with minimum surface energy. If inclusion alteration occurs during T decrease, they may divide (neck down), and the G bubble or dms may remain in one of the isolated parts of inclusion and homogeneous solution in another. Finally, at room T, inclusions in the same healed fracture will have different phase and composition and they yield different Th (Fig. 25). Inclusion habit and composition of inclusion filling may also change due to precipitation from solution the same substance as host mineral on the vacuole walls. The first report about presence of rims of precipitated substance [on the walls of inclusions] were published by G.G. Lemmlein [116] and N.P. Ermakov [63]. G.G. Lemmlein [116] explains wide rims around inclusions in topaz occupying 50-70% of vacuole volume by precipitation from inclusion solution after its trapping and sealing. Such rims, according to N.P. Ermakov [63], formed during the process of inclusion formation before its sealing. He thought that very thin rims visible on the periphery of inclusions in quartz, topaz and other minerals, may dissolve during heating and precipitate again on cooling. Wide rims did not show such changes.

Special experiments made by the author with long heating of inclusions (up to 23 days) at Th or at T a little higher than Th did not reveal any change of either inclusion habit (also those with rims) or Th [88]. However, experiments in autoclaves under high external P of G (300 MPa) and T ~700°C caused melting of inclusion vacuole walls and increase in size of the vacuole [128]. Later the author, with D.K. Voznyak [20, 22], studied the detail inclusions with rims in topaz (Fig. 26). It was found that early S and P inclusions of this type formed from heterogeneous

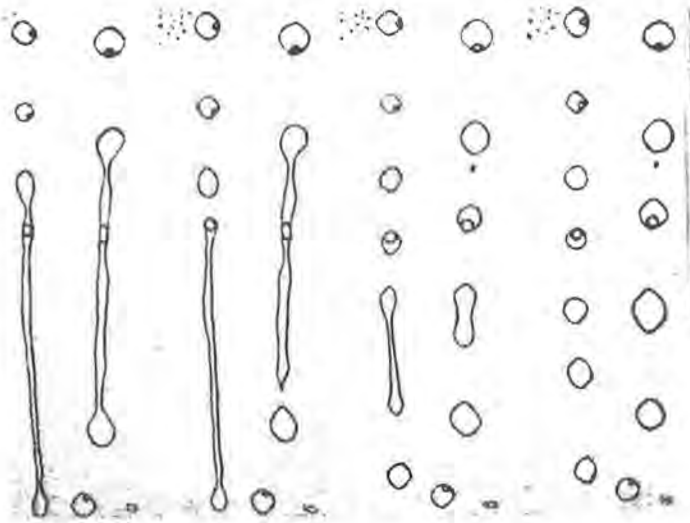


Fig. 25. Epigenetic alteration (necking down) of inclusions in sodium nitrate, x 275; a - immediately after cooling of preparation from 100°C to room T, b - after 3 hours, c - after 8 hours, d - after 21 hours.

Fig. 26. Inclusion in topaz in the plane of the cleavage, lined by a rim. Refractive index of rim is lower than refractive index of main part of crystal, x 300.

(boiling) solution. Hence Th and P of homogenization of homogeneous trapped inclusions (370-415°C, 30-40 MPa) are the true conditions of crystallization and heating of such inclusions to 700°C for reestablishing of initial parameters is not justified. This is confirmed by studies of syngenetic inclusion groups in numerous topaz crystals where solid phases occurring in inclusions were not authigenic but xenogenic substance (see Fig. 3). Moreover, relative topaz volume in rim around inclusions of the same type may range from 0 to 200% of the present volume of inclusion vacuole. There were found also cases of surrounding of two or several P inclusions by one common rim. In preparations cut perpendicularly to cleavage, the present vacuole always extends behind the rim. The face (001) of the vacuole looks like it "penetrated" the essential mass of topaz (Fig. 27, 28). These facts negate the possibility of precipitation of rim substance from an originally oversaturated solution, very concentrated with respect to topaz, sealed at that time. It is doubtful if crystallization occurred in stagnate conditions with the inclusion still not isolated from the surrounding fluid [63].[sic] The facts prove that crystallization of low-refractive topaz ($n<0.001$), surrounding the inclusion occurred in isolated space of vacuole due to reprecipitation of mineral under action of factors tending toward minimum free energy of a negative crystal. This agrees with the regularities found by G.G. Lemmlein for inclusions in highly-soluble salts.

The author supposes that the process of achieving of negative crystal equilibrium state by the inclusion sealed in a crystal developed gradually and most actively under conditions of high T, and also gradually decreased with T decrease, and commonly did not obtain the ideal habit of a completely faceted vacuole. Of course, dendritic healing of capillary fracture with later formed S inclusions first developed relatively quickly, just as dendrites grew quickly in the wedge-shaped end of fracture in easily soluble salt [125]. This was connected with separation of vug of thin fracture into isolated inclusions, limited by straight parts of adjoining dendrites. The latter formed the regular limitation of vacuole contours, now marked by the external boundary rims. Next substance reprecipitated

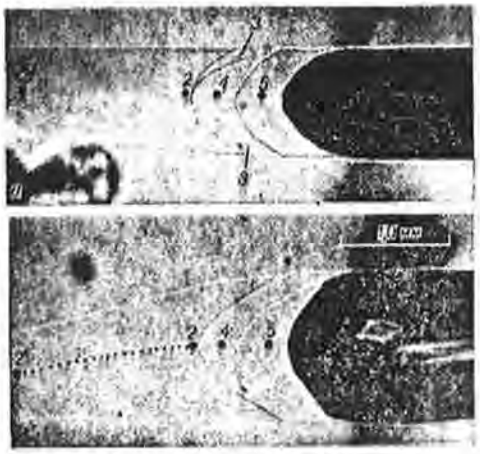


Fig. 27. Relation between form and distribution of topaz substance reprecipitated by solution of P inclusion, and T change and time (see Fig. 28). Only part of inclusion vacuole is shown, its G phase (dark); a - image in plane (001), b - image in plane (010).

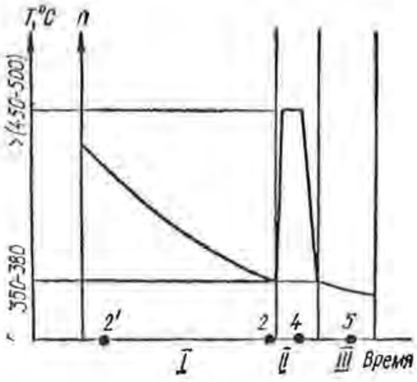


Fig. 28. Relation between refractive index n of reprecipitated substance and T and time; 1-5 - zones of topaz with various refractive indices: $n_4 \geqslant n_1 \geqslant n_3 > n_2$; $n_1 > n_5$ (see Fig. 27); zone 4 fixes temporary T increment that is reflected in higher n, 1-111 - periods of topaz reprecipitation.

in the closed space (the second stage). But again the growth centers formed and grew from several points of the flat disequilibrium vacuole, yielding the pattern of "teeth-like" contours. This is proved by "teeth-like" intermediate lines inside the rims (see Fig. 26). The second stage, however, developed against a background of T decrease and increase of inclusions vacuole thickness, sharply diminishing the growth volocity of dendrite-like projections [125]. Their crystallization practically stopped later, without achieving the equilibrium habit of a negative crystal.

Migration of inclusions in a thermogradient field

The unusual phenomenon of migration of L inclusion toward a heat source was first noted in crystals of sodium nitrate by G.G. Lemmlein [122]. Next Ya.Ye. Geguzin [29], using NaCl* and KCl, studied the process of change of inclusion habit and velocity of inclusion migration in a thermogradient field.

Although the velocity of such alteration for natural minerals is much less than for experimentally studied salts, the duration of natural processes makes visible the consequence of this process. Hence, milky-white quartz of the inner core of zanorysh pegmatites of Volyn' in zones

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*Also studied in natural salts by E. Roedder and H. Belkin, 1980, Thermal gradient migration of fluid inclusions in single crystals of salt from the Waste Isolation Pilot Plant site (WIPP), 453-464, in Scientific basis for nuclear waste management, vol. 2, C.J.M. Northrup (Editor), Plenum Press, New York, and same authors, 1980, Migration of fluid inclusions in polycrystalline salt under thermal gradients in the laboratory and Salt Block II (abst.). Proc. 1980 National Waste Storage Program Information Meeting, ONWI-212, 361-363, see also E. Roedder, 1982, Application of studies of fluid inclusions in salt samples to the problems of nuclear waste storage, Acta Geol. Polon., v. 23, no. 1-2, p. 109-133.

of fracturing, when submitted to activity of mineral-forming solutions of T>T of wall rocks, becomes transparent around fractures due to the elimination of G/L inclusions. Similar results are observed during the overlapping high-T processes on semitransparent vein quartz of hydrothermal formations.

Genetic significance of altered inclusions

Certain investigators [66, 67] categorically denied the significance of epigenically altered inclusions for obtaining information about conditions of mineral genesis. Presently, the gradual change of opinions may be observed [70, p. 40-43]. However, in mineral genetic practice the important data about mineral origin and association, that may be derived from studies of inclusions that are decrepitated, refilled, or with altered habit, is still used very rarely. For this reason below the reader may find examples, showing the very interesting and valuable results of properly performed studies of altered inclusions in minerals of Volynian pegmatites; the studies were made by the author with D.K. Voznyak.

The method of determination of relative age of crossing fractures on the basis of inclusions occurring in them, was widely used by the author at the Volyn' and Donbass geological sites [91, 103]. Crystals of quartz and topaz, where the distinct features of groups of S inclusions may be observed, are most useful for reconstruction of the sequence of origin of inclusions of various age. Normally formed large crystals of quartz from Volyn' pegmatites have a zonal structure. From crystal center to its periphery the following quartz zones are visible, 1) icy, smoky and morion or 2) "reticulate" (result of healing of contraction fractures during inversion from high to low quartz), icy, smoky and morion (Fig. 29). Changes to smoky and morion color are gradual, and from "reticulate" to icy and smoky-sharp. Moreover, broken fractures in crystals (and platy chips of blocky quartz) are regenerated by colorless transparent quartz. Colorless quartz forms also a thin external zone on the crystals. Rarely crystal faces have very thin, discontinuous envelope of amethyst.

In certain pegmatite bodies quartz crystals have the normal zoning disturbed. Usually in their central part the large chips of earlier varieties occur - "reticulate," "banded" or icy quartz. Structure of one of such crystals is shown schematically in paper [21], where, moreover, the age relations between main inclusion types are shown, confirmed by respective refillings. Characteristic features of the ten main types of inclusions distinguished in quartz, showing their generalized systematics on the basis of studies of numerous pegmatite bodies of the region, is quoted in the age sequence from earliest to latest in Table 3. The types of inclusions found have their analogs also in other minerals (topaz, beryl, fluorite).

Figure 18 shows the sketches of most interesting and important cases of refilling of inclusions in quartz.

The following inclusions display the most clear connection with growth elements of quartz crystals: 1) early S inclusions of "reticulate" quartz that occurs in the root part of quartz crystals, 2) P, tubular inclusions occurring in the zone of regeneration of crystals by transparent quartz. These groups of inclusions are the starting (fixed points) for determination of the relative age of the other inclusions. "Reticulate" inclusions having the habit of negative crystals, are refilled by solutions which correspond to essentially G faceted inclusions (L 30 to 40%), complex CO_2 inclusions (see Fig. 18a), G/L with L 95 to 97% (Fig. 18b) and one-phase L inclusions. Solutions of all those inclusions were trapped later than fluids that healed "reticulate" fractures in high-T quartz.

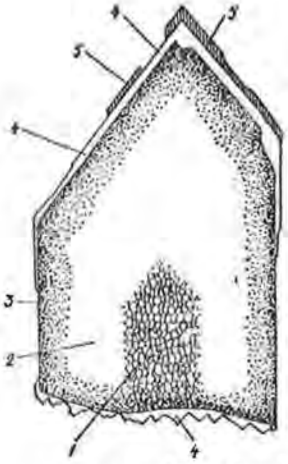

Fig. 29. Scheme of zonal structure of morion crystals from zanorysh pegmatites of Volyn': 1 - "reticulate" quartz, 2 - icy-transparent quartz, 3 - morion, 4 - colorless regeneration quartz, 5 - amethystine quartz.

P complex inclusions of CO_2 formed from heterogeneous (boiling) solution and S inclusion corresponding to the previous ones with their composition, are opened by fractures with G/L (L 70 to 80%, see Fig. 18h), essentially G (L 1 to 2%, see Fig. 18k), G and essentially L (L 95 to 97%, see Fig. 18j) inclusions. They are younger than inclusions with LCO_2. Age relations between the inclusions listed above may be also well established from the refilling phenomena (Fig. 18j, k). Fractures with inclusions of CO_2 refill decrepitated inclusions with haloes of daughter inclusions (L = 40%, see Fig. 18d) and polyphase decrepitated inclusions (see Fig. 18e), i.e., two last groups, intermediate between the "fixed points." Age relations between G>L and polyphase (with dms) inclusions are shown in Fig. 18c, f, g. All S inclusions in quartz crystals are early S, with the exception of, possibly, those which formed after sealing of complicated vacuoles with LCO_2 (late S).

Determination of the phase state of mineral-forming solutions from inclusions homogenizing in G phase, as it was already mentioned, is ambiguous. One may suppose that before formation of polyphase (with dms) inclusions crystallization occurred from dense G solution close to the critical state. After this, as it appears from fracture crossing and traces of healing, hydrothermal L solutions prevailed, almost in all stages being in the state of two-phase equilibrium (boiling). Earlier the author found such state of mineral-forming solutions of zanorysh pegmatites and the presented sketches of refilling confirm this (see Fig. 18c, f-h).

Sequence of inclusions show significant variations of total solution concentration and its individual components, as well as pH of inclusions. Solutions of "reticulate" inclusions are weakly acid (pH 6.3 to 6.9). The relatively low total salt concentration was found in solutions of this type, equal 7.3 ± 0.8%. Earlier concentration of solutions in those inclusions was thought to be several times higher [50]. Relatively low-concentration alkaline solutions (see Fig. 18c, d) were followed by highly-concentrated acid solutions of polyphase inclusions (Fig. 18c, f), which next were replaced by more dilute alkaline solutions with LCO_2 (see Fig. 18e) and filled in various degree G/L inclusions with L 70-80% (Fig. 18c, h). Change of concentration of solutions of inclusions with dms is well recognizable from refilling (see Table 3). Solutions of complex CO_2 inclusions trapped by crystal at final stage of mineral genesis again are replaced by solutions of late S low-T inclusions, more saturated with salt components (Fig. 18i-k).

Crystallization of quartz occurred under conditions of general T decrease and against this background sharp decreases and increases appeared, caused by disturbances of normal evolution of the physico-chemical

Table 3. Characteristic features of different age types of liquid inclusions in quartz, in age sequence [from earliest [top] to latest [bottom]].

Quartz generation, that still contains inclusions of a given type	Type of inclusions	Features and composition of inclusions considered in the age sequence
Blocky quartz	Not detem.	G, G>L, G<L, G+solids etc., hardly are to be systematized in age sequence.
"Reticulate" quartz	1	Early secondary, G/L (LH_2O 25-40%, pH 6.6, Th 380-410°C in G phase).
	2	Early S solid>G and G>solid (trapped minerals: topaz, microcline, etc., up to 90-95% of vacuole), pH 5.2-5.4.
"Banded" quartz	3	Early S, G/L (LH_2O 35-40%, pH 7.8, Th 390-395°C in G phase).
Icy, smoky, morion ("patchy" quartz)	4	Early S and P, G/L (LH_2O 25-40%, pH 7.8-8.2, decrepitated, Th 420-435°C in L phase[sic, A.K.]. Th of daughter inclusions 350-360°C in L phasa; in solution ions Mg, Fe^{2+}, Fe^{3+}, Mn were not found).
	5	Early S, families of polyphase inclusions filled to various degree, bearing 1-2 and more dms (NaCl, KCl, elpasolite, cryolite, $FeCl_2 \cdot 2H_2O$, etc.), relation L:G:solids varies from 80:15:5 to 30:30:40, pH 5.2-5.6, Th 250-500°C in L phase, Fe = 7%, found Mg. Typical in one inclusion family both polyphase L and essentially G inclusions are present. The subtypes of inclusions were distinguished: 5a - L (50 to 65%) + solids (20 to 25%) + G (15 to 20%), sometimes weakly decrepitated, occur together with G>L inclusions L (10 to 30%) + G (70 to 90%), Th 340-350°C; 5b - solids (40 to 45%) + G (30%) + L (20 to 30%), Th 450-500°C and higher. Syngenetic essentially G inclusions + L (2 to 5%) + solids (2 to 3%). 5c - L (90 to 90%) + G (10 to 15%) + solids (5 to 8%), Th 200-250°C in L phase, sometimes decrepitated.
Transparent quartz of zones of crystal regeneration	6	P tubular inclusions with LCO_2:LH_2O:G = 15:5:80 at +15°C, pH 7.4-7.6 to 8.0, Th 260-300°C in G phase, Mg, Fe^{2+} and Fe^{3+} are absent.
	7	P, G/L (L 80 to 85%) Th 230-240°C. Inclusions of types 6 and 7 are coeval one with another and they fix the heterogeneous state of solutions (...), P 23-25 MPa.
	8	S (early S), complex inclusions of CO_2, Th 300-320°C, P ~25 MPa.
	9	S (early S), G/L (L 70 to 80%), pH 7.4-7.8 to 8.1, Fe^{2+} and Fe^{3+} are absent, Mg-traces.
	10	S (late S), G/L (L 90 to 95%), pH 5.5-6.7, Fe^{2+} and Fe^{3+} not found, noticeable amounts of NaCl, Ca, Mg, K, and SO_4, total salt concentration in inclusion solutions about 17%.

system of the pegmatite. Formation of "reticulate" quartz marks the borderline of two stages of precipitation of this mineral: pre- and post-inversion (Fig. 30). T of high-low quartz inversion under normal P is equal 573°C. It may exceed this value under high P or it may vary in certain ranges for reason of presence of admixtures of Al, Li and Ge. Study of quartz shows that inversion T is in ranges 570-620°C. Thus, crystallization of the earlier, blocky quartz occurred at T ~600 to 700°C. Concluding from distribution of syngenetic zones of "reticulate" quartz in root zones of morion cyrstals, essential mass of monomineralic blocky zone formed just in this stage. At T<570-620°C, zanorysh crystals essentially formed (morion, topaz, etc.). From the age sequence of inclusions, T decreased from 570-620°C ("reticulate" inclusions) to 80-100°C (one-phase liquid and G/L inclusions with L 95-97%), with two distinct T increases against a background of general gradual T decrease.

Maxima in the T line (Fig. 30) are connected with important changes of parageneses in pegmatite crystallization and they are detectable not only from Th, but also from the type of decrepitation and alteration of habit of successively formed inclusions.

Inclusions of types 1-4 (see Table 3) bear L and G phase in a similar ratio (about 2:3); they are characterized by similar salt concentration of solutions and narrow Th range (380-435°C) in G phase. This proves the gradual change of PT parameters of mineral-forming fluid. Later mineral-forming solutions differed by heterogeneous state and high salt concentration. Fracture crossing shows that parent solutions of polyphase inclusions of type 5b had higher (>500°C) T (true T are here determined as Th due to solution boiling) than parent solutions of polyphase inclusions of type 5a and G>L inclusions of type 4, taking into account the relatively low P of the crystallization medium. That was the first T maximum. The second maximum was determined from the true T of type 6-9 inclusion trapping from heterogeneous fluid. T of trapping of inclusion types 8 and 9 was 70-80°C higher than T of trapping for earlier inclusion types 6 and 7.

Inclusions with decrepitation haloes show more dramatically time and conditions of episodic T increase. Decrepitated inclusions were observed in all groups, except the P and S complex CO_2 inclusions (types 6 and 8) and inclusions type 10. However, the decrepitation haloes are not the same in size for various inclusions in quartz of a given pegmatitic body or for various pegmatites of this region. This depends first on the presence or absence of inflow of high-T fluids to a given pegmatite and how intensive was that inflow. Decrepitated inclusions were not found in some pegmatites. Sometimes only in inclusions with L = 40% were haloes of daughter inclusions found; notably, these inclusions always are most altered by this process. As a result, the altered inclusions of this type have the following features: a) in family of syngenetic inclusions of the same composition and filling, the cloudy haloes are proportional to inclusion dimension, but in tiny inclusions frequently no such haloes are found (those inclusions resist higher T of overheating); b) syngenetic inclusions of various degrees of filling have haloes of various size, and the haloes even may be absent; c) syngenetic inclusions of the same filling and composition in healed fracture of large dimension do not show differences in decrepitation haloes, even taking into account the various depths of their positions in crystal (with respect to growth zones or faces).

The relative time of the first T increment and respective inclusion decrepitation developed after formation of the type 4 inclusions and before trapping of type 5c inclusions and crystallization of regeneration quartz, bearing in the root parts P complex CO_2 inclusions of type 6. This is confirmed by the following observations. As was mentioned above, inclusions of type 4 are most subject to decrepitation. The earlier inclusions of "reticulate" quartz rarely have decrepitation haloes. The decrepitated type 4 inclusions refilled by solutions of polyphase inclusion type 5 solutions, in one case have decrepitation haloes (see Fig. 18c), in other cases not (Fig. 31). This proves that crossing of them by fractures with inclusions of type 5c occurred later than decrepitation, and by fractures with inclusions of types 5a and 5b - before decrepitation. Although sometimes around inclusions of type 5a also there are fine haloes, but then refilled by this solution inclusions of type 4 are surrounded by very fine cloudy haloes; non-refilled inclusions of type 4 have large decrepitation haloes.

The earlier T increase than crystallization of regeneration quartz is indicated by limitation of decrepitation haloes of inclusions of type 4 in a newly-formed zone of the mineral; on the basis of the latter zone the tubular vacuoles of type 6 inclusions develop frequently from places of its contact with the haloes (Fig. 32). Decrepitated type 4 inclusions, refilled by solution of complex S CO_2 inclusions (type 8), have the same haloes of daughter inclusions as the non-refilled ones (see Fig. 18d). If one takes into account that in inclusions of type 8 the haloes are absent, such crossing undoubtedly proves that decrepitation of G>L inclusions of type 4 (L 40%) occurred before their refilling.

The second T maximum is connected with the activity of solutions

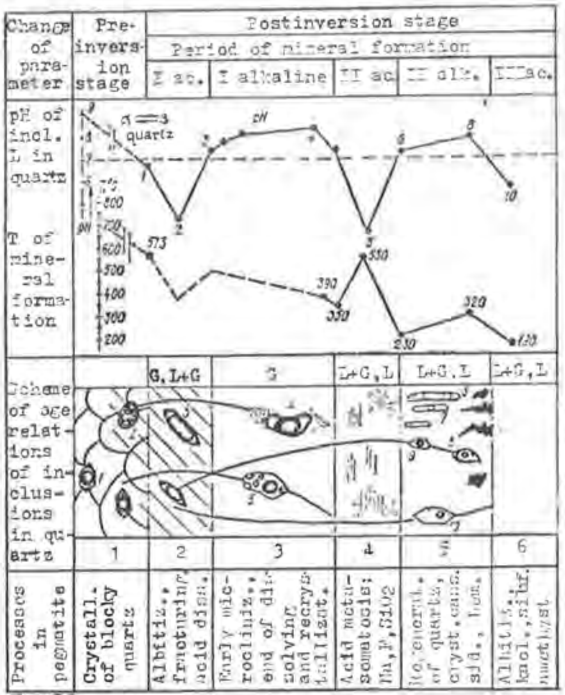

FIG.30
1 - "reticulate" quartz, 2 - "banded" quartz, 3 - icy and smoky quartz, morion 4 - patchy quartz, 5 - colorless quartz, 6 - amethyst, opal; ac = acid

Fig. 30. Scheme of evolution of pH and T during formation of Volyn' pegmatites in the post-inversion stage, from the data of investigation of essential types (1-10) of inclusions in quartz [146]. (Translation not available at press time.)

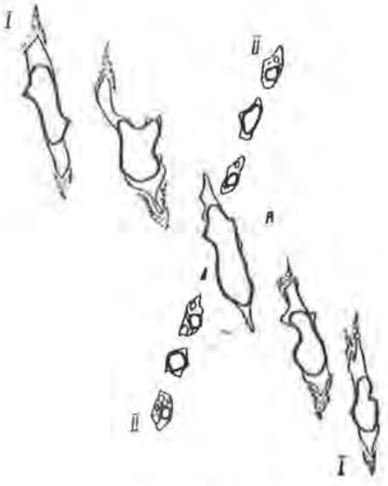

Fig. 31. Crossing of various-age fractures, next healed, with decrepitated (I-I) and polyphase (II-II) inclusions filled to various degrees. Absence of cloudy halo around refilled inclusion A points the earlier refilling than decrepitation.

Fig. 32. Scheme of distribution of early S decrepitated and P tubular inclusions in the contact of morion (G) and later colorless regeneration quartz (D). Numbers refer to inclusion types as in Table 3, L_1 - water solution.

respective to inclusions of types 8 and 9. The solutions caused decrepitation of inclusions of type 7 and possibly 5c.

The convincing fact, confirming the episodic T increment, may be the discussed reprecipitation above of topaz substance around inclusions in that mineral. During careful observation in blended light the rim of low-refraction topaz appears nonhomogeneous. Moreover, in the distribution of inhomogeneous areas and contrast of lines, the reqularly determined outer part of the rim (see Figs. 3 and 27) becomes more and more contrasty approaching the inclusions, that proves the gradual change of optical properties of reprecipitated topaz. Closer to the inclusion several more zones of topaz with various refractivity may be seen (see Fig. 28). The [variations of] 2V of reprecipitated topaz in various parts occurs in the ranges of measurement error, thus, difference in the indices of refraction of topaz does not exceed 0.002-0.003.

Because the inclusion alteration occurs in vacuoles isolated from the external medium, the reasons of alteration may be only internal intensive factors plus T. General T decrease led to increase of fluorine ion activity and this way to more intensive (in comparison with OH group) entering the topaz structure, causing the decrease of refractive index of reprecipitated mineral [113]. On the other hand, the origin of rim band of type 4 (see Fig. 27) with higher refractive index indicates the sharp T increase in the crystallization medium of the pegmatite. The insignificant amount of substance disturbing the smooth decrease of refractive indices and its place in the reprecipitated mass of topaz indicate that the T increase was short in time and occurred in the end of pegmatite formation. This T increase is sharply marked against the background of evolution T decrease.

KULIKOV, I.V., DEVIATOV, V.E. and GROMOV, A.V., 1982, A new natural compound - calcium fluoride-chloride: Izvest. Vyssh. Uchebn. Zaved. Geol. Razved., v. 25, no. 7, p. 120-122 (in Russian).

During the study of the solid phase of large (0.1-1, sometimes up to 1.5-3 mm.) multiphase inclusions in fluorite of the Tyrny Auz Mo-W deposit (northern Caucasus), there was found a flattened crystal (0.12 mm. in diameter) of a colorless, birefringent daughter mineral, which proved to be a compound previously unknown in nature, calcium fluoride-chloride (CaFCl).

The studied crystals of fluorite of octahedral habit are rich in primary inclusions of highly concentrated mineral-forming solution-brine, occupying sometimes up to 5% of the volume of the mineral host. Most of the inclusions, besides the gas and liquid phases (not more than 20-30 vol.%) contain many daughter minerals, differing in form and size of deposit, color, indices of refraction, magnitude of birefringence, and other optical properties. During heating, the solid phases dissolve, some up to the moment of the disappearance of the gas phase, other after it. The temperature of complete homogenization of the primary inclusions is 650-800°C and more (1, 2, 3). If all the solid phases are dissolved in the liquid preserved in the inclusions, the concentration of such a brine attains 60-90% ($CaCl_2$+NaCl+KCl+$FeCl_2$), found by a direct method (2); according to indirect methods it is also known that the brines also contain silicon, aluminum, sulfur, and CaF_2.

The largest inclusions were opened, and the solid phases contained in them, together with unavoidable droplets of mother brine, were extracted by means of a steel needle on a microscope slide. From these microcrystals there was prepared a sample by the method of rolling a globule of rubber cement, from which there was obtained a powder pattern by the Debye method. The samples were photographed in the RKD-57.3 X-ray camera, FeK_α radiation in the URS-60 apparatus (current 6MA, voltage 40kV, FeK_α radiation, time 9 hours). As shown by deciphering the x-ray patterns, the usual daughter-minerals in the described inclusions are halite, calcite, magnetite; often occurring are fluorite, sulfides, and graphite. For each of the microminerals there were obtained up to several distinct powder patterns. Sphalerite, cubanite, pyrrhotite, arsenopyrite, sylvite, chlorite, ankerite, tungstenite, and CaFCl were found, according to the identity of powder patterns for each of them (in all, 54 powder patterns were made). Some minerals in the inclusions were found in intergrowths (sphalerite and chalcopyrite, sphalerite and calcite); besides there were recorded two x-ray amorphous minerals of unknown composition. Such data on microminerals of fluid inclusions of fluorite were first obtained in (2).

Table (p. 121)

Interplanar spacings of CaFCl, extracted from fluid inclusions in fluorite, compared with data of ASTM

ASTM no.24-186		Data of authors				ASTM no.24-186		Data of authors			
		First photograph		Repeated photograph after 1.5 months				First photograph		Repeated photograph after 1.5 months	
I/I_1	$\frac{d}{a}$	I	$\frac{d}{a}$	I	d,A.	I/I_1	d,A.	I	d,A.	I	d,A.
10	6.81	-	-	-	-	16	1.5621	3	1.565	-	-
9	3.409	1	3.42	-	-	25	1.5502	3	1.550	-	-
6	3.377	2	3.19**	8	3.18**	5	1.4497	0.5	1.465	-	-
-	-	3	2.82*	4	2.83*	8	1.3821	0.5	1.388	-	-
50	2.751	3	2.75	1	2.72	11	1.3757	0.5	1.379	2	1.373**
100	2.564	10	2.57	-	-	9	1.3643	-	-	-	-
2	2.275	-	-	-	-	2	1.2875	-	-	-	-
50	2.142	5	2.14	1	2.14	-	-	1	1.26*	2	1.26*
-	-	2	1.995*	3	1.995*	5	1.2302	1	1.230	-	-
17	1.963	1	1.96	10	1.94**	5	1.2227	1	1.223	-	-
35	1.945	4	1.94	-	-	11	1.2184	1	1.218	-	-
4	1.754	-	-	-	-	8	1.2124	1	1.213	-	-
-	-	1	1.655**	5	1.655**	6	1.1576	1	1.157	1	1.152*
5	1.691	-	-	-	-	12	1.1172	2	1.118	4	1.120**
-	-	1	1.625*	1	1.63*	5	1.0290	1	1.029	2	1.052**

* lines coinciding with lines of halite

** lines coinciding with lines of fluorite

The calcium fluoride-chloride, found by x-ray analysis, occurs in close intergrowth with halite, and probably also with a small amount of fluorite. Together with it in the same vacuole occur halite, fluorite, magnetite, and some other minerals, not identified by us because of their small size. The interplanar spacings for the calcium fluoride-chloride are given in the table, along with standard ASTM data.

As is well-known, calcium, fluorine, and chlorine are widely distributed and often are principal elements of the (operative) mineral-forming medium. Nevertheless, a mineral of this composition has not been reported previously. On the one hand this is connected to the fact that the compound CaFCl is unstable in air (ASTM, no. 24-186). Repeated photographs of our sample of CaFCl after 1.5 months showed that the mineral had decomposed and that on the x-ray pattern there appeared distinct lines of CaF_2. On the other hand, it may be explained by the fact that for the formation of calcium fluoride-chloride it is necessary to have unusually high temperatures for hydrothermal conditions.

The colorless material CaFCl[1] was synthesized in the U.S.A. from equimolar mixtures of CaF_2+CaCl_2, purified and dried at high temperatures (4). The mixture was held at 820° for 16 hours and then cooled to room temperature. In the final product of calcium fluoride-chloride there was present a small admixture of CaF_2 (4, 5). Analysis of the ternary system $CaCl_2-CaF_2-CaO$, studied by (5), showed that the crystallization of the phase CaFCl occurred in the interval 735-625°. The latter temperature is that of the eutectic $CaCl_2-CaFCl-CaO \cdot 2CaCl_2$. In this system, studied experimentally, water, which lowers the temperature of crystallization, was absent. Judging from the character of the inclusions of fluorite, in one of which the solid phase CaFCl was found, the medium of crystallization was a brine, similar in properties to a melt with low viscosity, containing not more than 10-20% H_2O. Nonetheless, the relatively high concentration of silicon, aluminium, and iron in this brine permit one to state that the finding in inclusions in fluorite of the compound CaFCl, previously unknown in nature, confirms the high temperature of formation of these inclusions

(650-800°). The unusually high temperatures of formation of this fluorite are confirmed by other data, for example by the sharp, extreme impoverishment of the Tyrny Auz fluorite in rare-earth elements (1), and also the complete similarity of the gas-salt composition of the inclusions of fluorite with the chemical composition of some high-temperature metal-bearing subsurface brines of many geothermal regions, the temperature of which sometimes already at depths of 2-3 km. are about 400° (2). Besides, brine with concentration up to 60-90% cannot exist in homogeneous liquid form at lower temperatures (2). Consequently, the new natural compound CaFCl can, probably, be used as a mineral thermometer.

Literature

1. Vasil'kova, N.N. and others, Fluorite, an indicator of conditions of formation and zoning of scheelite-fluorite mineralization of Tyrny-Auz. Mineral. Zhurnal. V. 2, no. 6 (1980).
2. Kulikov, I.V., Mineralogy and genesis of scheelite-sulfide-mineralization of Tryny-Auz deposit. Abstract of dissertation for degree of candidate geol.-mineralog. science, Moscow: MGRI, 1981.
3. Mel'nikov, F.P., Kulikov, I.V., and Gromov, A.V., Multiphase inclusions in fluorite of Tryny-Auz deposit, Deposited in V.I.N.I.G.I., no. 3965-79, Moscow 1979.
4. United States National Bureau of Standards. Monograph 25, Section 10, Nov. 1972.
5. Wenz, D.A., Johnson, I., Wolson, R.D. $CaCl_2$-CaF_2-CaO System. J. Chem. Eng. Data 14, 250, 1969.

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1/ Handbook data of calcium fluoride-chloride (4). Structure: tetragonal, $\bar{P}4/nmm$ (129), Z = 2, isostructural with matlockite; the structure of matlockite (PbClF) was determined by Nieurenkamp and Bijvoet (1932) (4). Density 3.039 g/cu.cm. (calcd.) Unit cell parameters, a 3.8911, c 6.8228A.

(Translation courtesy Dr. M. Fleischer)

SHUGUROVA, N.A. and SHOKHONOVA, L.A., 1982, Methodology recommendations for gas phase analysis of individual inclusions in minerals, in N.P. Ermakov, ed., Thermobarogeochemistry in Geology - Materials of the Sixth All-Union Symposium on Thermobarogeochemistry: Vladivostok, Far East Sci. Center, Acad. Sci. USSR Pub. House, p. 151-156 (in Russian).

Until now the analysis of gases in inclusions is performed most precisely for gas bubbles of diameter >0.06 mm. So large inclusions are typical mostly for hydrothermal minerals. However, dimensions of the majority of inclusions from magmatic and metamorphic minerals are smaller than 0.06 mm. This feature complicates the gas analysis. Additional complications appear in the observation of gas sorption and measurements of bubble dimensions, that decrease the accuracy of the volume percent values for individual components. The most important problem is the precise measurement of initial bubble size (>0.06 mm), especially for rapidly absorbed gases (H_2S, SO_2, HCl, HF, NH_3) and their various mixtures. Such measurements have to be made not in moment of inclusion opening, because this is practically impossible, but after certain time (10-15 sec.).

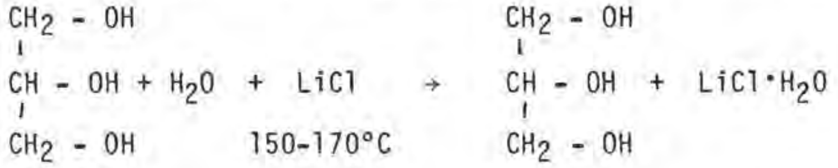
The essential principle for the choice of an inert liquid is not known presently. Physical nature of absorption process is explained by so-called film theory. Separation surface between L and G should be imagined not as geometric boundary but as thin layer (few molecular diameters).

Gravitation tends to separate G from L, forcing the bubble movement toward the surface, and L from the bubble walls - to flow down to the essential mass of L. Surface tension causes coalescence and bubble disappearance. All this finally causes interruption of L layer.

The higher the viscosity, the lower the velocity of decrease in bubble size and the process becomes self-inhibiting. Frequently viscosity of L layers is higher than the viscosity of the main mass of L, sometimes due to the fact that the layer has lower T (because of evaporation from its surface, sometimes due to influence of solution concentration (floating or dissolved particles move toward the phase boundary and cause usual or anomalous increment of viscosity). However, in most cases the viscosity increase cannot be explained.

Selecting the inert liquid for gas analysis, the authors studied the properties of 21 liquids and 15 compositions of glycerine mixtures. Most appropriate is a glycerine solution bearing 25 g of dried LiCl per 150 g of glycerine (Louri 1943). Admixture of LiCl is necessary to increase the aggregate stability of glycerine[sic].

During saturation of glycerine with LiCl, according to opinion of chemists, the crystalhydrate $LiCl\cdot H_2O$ forms and glycerine loses its water:



$$\begin{array}{llcll}
\mathrm{CH_2-OH} & & & \mathrm{CH_2-OH} & \\
| & & & | & \\
\mathrm{CH-OH} + \mathrm{H_2O} + \mathrm{LiCl} & & \rightarrow & \mathrm{CH-OH} & + \mathrm{LiCl\cdot H_2O} \\
| & & & | & \\
\mathrm{CH_2-OH} & 150\text{-}170^\circ\mathrm{C} & & \mathrm{CH_2-OH} &
\end{array}$$

Raw glycerine   Anhydrous

(binary system)   glycerine

Process of glycerine dehydration goes gradually, without change of its structure. Forming of crystalhydrates during dehydration stabilizes glycerine and thus increases its viscosity. Crystalhydrate of LiCl also improves stability and decreases fluidity of glycerine at elevated T. Viscosity changes but gradually, not abruptly. Addition of LiCl precludes the sorption of moisture from air by glycerine (Rebinder 1936, Rebinder, Trapeznikov 1938). An opinion exists that with T increase, viscosity of glycerine saturated with LiCl strongly decreases and this affects results of measurements of gas bubble volumes. For evaluation of this condition the authors determined viscosity of glycerine and LiCl-saturated glycerine with use of viscosimeter VPZh-1. During T increase from 24°C to 30°C viscosity of glycerine saturated with LiCl decreased insignificantly, from 1250 to 1240 mPa x sec (Fig. 1).

In a series of experiments with small bubbles, the velocity of absorption was measured for CO_2, H_2S (Fig. 2) and HF, HCl, NH_3, SO_2, $H_2S+CO_2+SO_2$, H_2S+CO_2 (Fig. 3), and plots of absorption were made. Solubility of O_2, N_2, CO, H_2 and CH_4 in glycerine is minute in the authors' opinion and it cannot disturb the analytical determinations.

The analysis sequence remains as before with certain modifications. For gas extraction the mineral specimen with the studied inclusion is put on the lower lens with 2-3 drops of LiCl-saturated glycerine. Next inclusion is opened and immediately timer is started. Results are arranged in the table (p. 337)

Initial diameter of gas bubble is determined either graphically (from values D_1, D_2, D_3, D_4 - method of smooth curves) or mathematically (external value of argument):

Table	min.:	1	2	3	4
	D_0 (diameter*)	96.5	83.5	74.0	64.0
	$\sqrt[3]{D_0(y)}$**	4.57	4.37	4.2	4.0

*Most probably diameter, but not explained in the paper;
**Expression not explained directly in the paper, probably should be $\sqrt[3]{D_0}=y$. (A.K.)

$$\sqrt[3]{D_0} = \frac{2y_1+y_2-y_4}{2} = \frac{2\cdot 4.57+4.37-4.0}{2} = 4.75$$

The obtained calculation and graphic data should agree within the measurement error limits. Thus, the possibility exists for calculation of percent content of individual gas components with sufficeint accuracy. Deviations from [a smooth] experimental curve on a time plot indicate the presence of gas mixtures.

Gas components SO_2, HCl, HF, H_2S and NH_3 are given as a total value (Fig. 3). Separate quantitative determination from a small bubble is not now possible, only qualitative determination is possible.

For qualitative analysis of gas components the authors used a ultramicrochemical method. During crushing of the studied plate it is necessry to check initially the absorption of the above (acid) gases. If their content is significant, the bubble is sorbed quickly. If such gases are absent, bubble volume does not change and it may be analyzed by the usual methods.

For determination of gas content by the usual methods, the series of experiments was performed for definition of possibility of separation of H_2S from CO_2 in gas mixture. For practical determination of percent content of H_2S and CO_2 separately, a nomogram was plotted (Fig. 4). Smoothing of empirical values of H_2S and CO_2 contents was made by the method of a simple sliding average (Plokhinskiy 1961). The obtained relation was complex non-linear, because practically it is impossible to prepare gas bubbles with exactly needed diameters from various mixture of H_2S and CO_2. Absorption of CO_2 in cadmium acetate depends on quantitative relation of H_2S and H_2O. The new data obtained agree exactly with points found earlier (1968). Absorption of CO_2 for gas bubbles of dia. 70 μm in $Cd(CH_3COO)_2$ does not exceed 25% of gas bubble volume. For small bubbles (57 to 10 μm) absorption in glycerine equals 75-84% and during the placing of the bubble in $Cd(CH_3COO)_2$ is 15% for bubble dia. 10 μm, 21.8% for bubble dia. 100-280 μm and 25% for bubble dia. 70 μm[sic].

Nomogram is plotted for 23 gas mixtures prepared in laboratory.

Considering the results of studies for improvement and checking of the method, we conclude the following:

1. The inert liquid: LiCl-saturated glycerine, is used correctly. Principle of the method for analytical determination remains as before.
2. The improved method of analysis of gas phase of inclusions in minerals needs special preparation of sample, proper inclusion opening and time of complete absorption of the determined component.
3. Sorbent reagent for gases are appropriate; they were checked with use of pure gases and gas mixtures.

Inclusion gas mixtures may be analyzed using an exact regime of operation sequence and time of analysis.

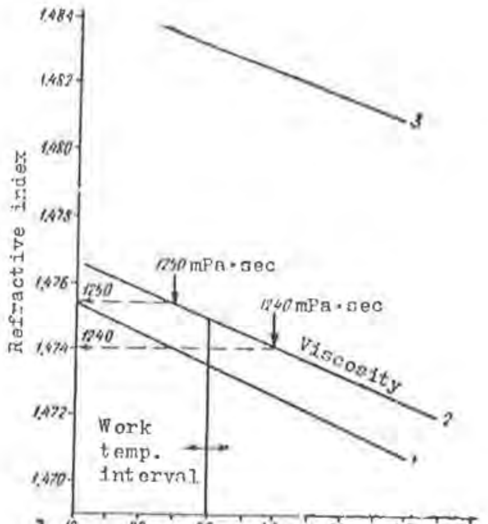
Literature

Adam, N.K. Physics and chemistry of surface. Moscow, Leningrad, 1947.
Louri [Lowry?], Dzh. Glycerine and glycols. Leningrad, 1943.
Plokhinskiy, N.A. Biometry. Novosibirsk, 1961.

Rebinder, P.A. Absorbing layers and their influence on properties of dispersion systems. Izv. AN SSSR, Otd. matemat. i estestv. nauk, ser. khim., 1936, no. 5.

Rebinder, P.A., Trapeznikov, A.A. Mechanical properties and stabilizing action of absorption layers in dependence of degree of their saturation. Zhurn. Fizicheskoy Khimii, 1938, v. 12, no. 5-6.

(Translated by A. Kozlowski, Zawoja, 28.I.1985)



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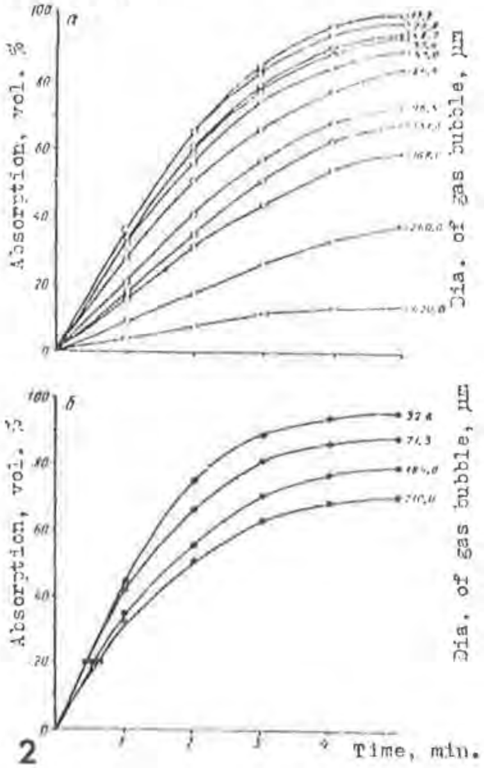

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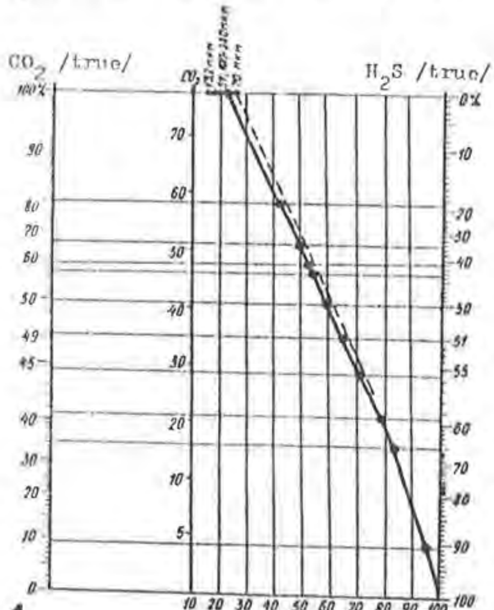

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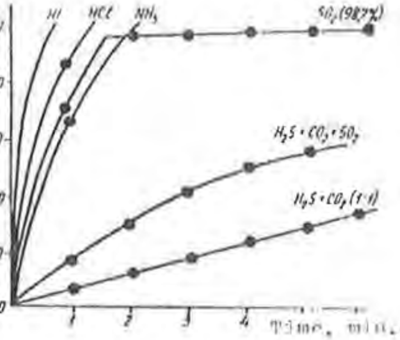

3

Fig. 1. Relation between viscosity of glycerine liquids and T. 1 - usual glycerine, 2 - LiCl-saturated glycerine, good for determinations, 3 - LiCl-saturated glycerine not suitable for determinations.

Fig. 2. Plots of absorption of CO_2 (a) and H_2S (b) in LiCl-saturated glycerine.

Fig. 3. Plot of absorption of gases in LiCl-saturated glycerine.

Fig. 4. Nomogram for separation of H_2S and O_2 (absorption in cadmium acetate).

Indices

The user should keep in mind the following features of these indices. The indexing procedures and entries are evolving and hence are not uniform from one volume of COFFI to the next, and even within a given volume consistency cannot be claimed, so caveat emptor. Where several different items in the given category occur on the same page, the number of such items is put in parentheses after the page reference. Some items may continue on to following pages. Transliteration of Cyrillic has not been uniform in the various sources used, and hence the user must look under the several possible spellings, e.g., Ye and E, ...iy and ...ii, etc. As all entries in the Translation section are also cited in the Abstracts section in alphabetical order, no Author index is needed.

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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moment process and, strictly speaking, each inclusion in it has its own syngenetic part of material of the healed fracture; inclusions occurring in the mouth of fracture and sealed in the final moment together with precipitation of growth zone of crystal are primary with respect to the latter;

b) inclusions in a healed fracture are only secondary with respect to the adjacent growth zones of the crystal; usually material of the healed fracture is not taken into account during determination of the inclusion type, excluding only the healed wide fractures - bands, inclusions in which are regeneration primary (with respect to the material of the healed void);

c) comparison of the character of the inclusions of the healed fracture with the material of the respective growth zone of the crystal may be only approximate; those inclusions are near synchronous and only subsyngenetic to the given growth zone.

3. Use of the names "zonal" and "azonal" P inclusions for determination of inclusions distributed according or not according to the crystal growth zones [67], is supported neither by the sense of those words nor by their use for the studied objects. First, the sense of the word in its usual application, especially in geology, is different ("zonal deposits," "zonal pegmatites," "zonal crystals" etc.), and solid and certain fluid inclusions in fact may be zonal. Second, zones, formed by the inclusions (if N.P. Ermakov uses the name in this sense) are not independent but derivatives of the primary crystal zoning; crystals are always zoned (visible or hidden way) and inclusions only reveal this zoning in crystals. Third, the proposed names do not help in inclusion diagnostics; the essential problem is not in whether groups of inclusions form or do not form zones in crystals, but whether zones coeval with groups or individual inclusions occur or do not occur, i.e. are such inclusions primary (all P inclusions occur in zones of crystal growth syngenetic to them and hence they all are "zonal" in N.P. Ermakov's classification). Zoning determines whether inclusions are P or S and this is one of the numerous features being the basis of a genetic classification. Thus the proposed names have only apparent meanings and, in fact, they complicate terminology of the given branch of science.

Chapter 3

Modes of formation and examples of primary and secondary inclusions

Formation of primary inclusions. Experimental studies of crystallization process show that material on the crystal faces precipitates not uniformly, but with breaks. Factor controlling the pulsating growth is speed of inflow of material from oversaturated soluton to the face either by diffusion or by mechanical mixing of solution. Under conditions of interaction of medium and crystal, solution adjacent to the growing face is characterized by nonuniform degree of supersaturation at various points. The higher the total supersaturation, the more abrupt the contrast in concentration. Such a state of medium favors the origin of defects in the crystal. Hence, defects in crystal and trapping of parent solution occurs due to difference of supersaturation in various points on the boundary crystal-medium, not due to supersaturation itself [111, 202].

Nucleation of new layers begins in places of supersaturation of solution, usually at the corners and edges of crystal. Due to use of material for crystallization and lower speed of inflow of new material than speed of crystallization, in such places, a distinct decrease of concentration is observed [111]. However, for the formed step in the angle between it and the face of crystal, solution will be saturated (in agreement with the equation of Ostwald-Freundlich) and due to this fact the step rapidly grows parallel to the crystal face, continuously meeting new portions of supersaturated solution. Thickness of the step does not change during this growth. "Most frequently more and more steps appear before the previous ones completely cover the face. Stepped faces form and the steps coming one after another like waves may be observed under microscope during growth of hyposulfite crystals" [2, p. 1].

This is the mechanism of layer growth of faces. Under conditions of such nonuniform growth and the disequilibrium of concentrations, cases of inexact healing of steps and formation of P inclusions may occur.

In individual cases the healing of steps of different heights causes the formation of screw dislocations and crystal growth by spiral layers. In the initial moment the first rolls of spiral trap in the central part the parent solution, forming P inclusions [39].

Inclusions may form not only in places of healing of layers but also at the front of the growing layer. Due to nonuniform "feeding" in the front part of the layer, tooth-like projections form, between which elongated voids nucleate. During movement of the step of growth the voids become tubular channels filled by solution and are then covered by the crystal. Repeating many times, such a process causes the formation of chains of tubular P inclusions. This mode of trapping of crystallization medium was studied experimentally in detail by N.N. Sheftal [202].

In the process of further formation, depending on conditions of crystallization, P inclusions may achieve various habit. During this process the essential role, probably, is displayed by the speed of step-layer precipitation of material. When crystal growth is slow, inclusions form more rarely and are sealed more rapidly. They are single isolated inclusions and rarely inclusion groups, parallel to layers of crystal growth. Often such inclusions are flattened perpendicularly to layers of growth. During rapid growth of crystals there are many chances for formation of inclusions by incomplete healing of growth steps. The forming defects cannot be healed quickly because new steps of growth continually overlap the previous ones, decreasing the concentration of surrounding solution. In this way inclusions form that are elongated perpendicularly to the crystal faces and very frequently are complicated by numerous ramifications. More precisely, their habit depends on the development of the growth pyramids [122, vide p. 107].

Under conditions of slow diffusion, especially in viscous media, skeletal crystal forms develop. When crystallization conditions change, the depressions in the central parts of faces may be covered by subsequent layers of crystal, isolating parent solution inside the vacuoles. Such P inclusions have large dimensions and a complicated habit. They may be easily altered and for this reason they rarely preserve the initial filling.

Similar inclusions in quartz crystals of skeletal habit were described for hydrothermal veins in Carpathians (so-called Marmarosh diamonds), Donbass, Crimea, and the Alps [23, 112]. They have essentially hydrocarbon composition (mainly methane), relatively large dimensions and they are connected with growth pyramids of faces of the rhombohedrons. Inclusions have complicated surface morphology; they are flattened, with walls parallel to the rhombohedron faces. Smaller inclusions have the habit of ideal negative crystals. Some large voids remain unsealed and are open to the crystal faces.

Studies of the genesis of quartz crystals and inclusions in quartz shows that the mineral-forming medium was a water solution bearing methane bubbles. The latter were trapped in the forming vacuoles without or with a minimum amount of L water solution.

Also inclusions formed during multinucleated growth or by regeneration of the cracked parts of crystals should be called primary. Usually multinuclear growth is observed on crystal surfaces from cleavage, dissolution, melting or crystallographic planes that after breaking become the basis for precipitation of new mineral material. Inclusions formed during this process differ in habit and position relative to the crystal boundary. Two morphological types of such inclusions may be distinguished.

To the first type belong the inclusions occurring immediately on the regeneration plane. They most frequently are solid inclusions, more rarely inclusions of parent solutions. The latter have an irregular flat habit depending on irregularities of the regeneration surface. Solid inclusions are the cause of origin of fluid ones.

Associations of solid particles and relics of mineral-forming medium in quartz crystals from hydrothermal veins of Donbass are an example of such inclusions. Here zones with mica and chlorite flakes occur among which flat P G/L inclusions were found [103, p. 32]. Flakes of mica frequently occur inside G/L inclusions. Between the inclusions there were found radial aggregates of muscovite flakes with relics of parent solution in the interstices. Muscovite, overgrown by quartz, crystallized together with it. Shape of such G/L+solid inclusions has been shown [103, p. 34].

Frequently complicated joining of substances in P inclusions is not found, but there form inclusions of fluids or solid crystals-inclusions of contemporaneous growth with the host minerals. The latter, although they do not provide data about the crystallization medium, are the source of important and reliable information about paragenetic relations of the minerals. On the example of the Volyn pegmatite the possibility of close coexistence and contemporaneous crystallization of albite and topaz was proved. Such an unusual assemblage was fixed by a zone of P inclusions of albite radially elongated in the direction of the general growth of host topaz crystal. Also inclusions of fluorite proved it to be coeval in growth with topaz, although the two minerals used to be interpreted as mutually exclusive (fig. 5).

Morions from some pegmatites of Volyn in external zones of regeneration by light quartz bear inclusions of cassiterite with various habits that formed by coeval growth with the host mineral [98]. Habit of cassiterite inclusions reflects the complicated relations between medium and mineral, as it appears from fibrous, acicular, prismatic and partly dissolved lenticular, or arrow-like crystals [of cassiterite, A.K.].

Very specific by genesis and morphology are P inclusions in generations of minerals, healing large voids. (...) Crystals of skeletal quartz from Carpathians and Donbass bear voids-depressions on the faces of rhombohedrons. According to zones of smoky color the voids are partly sealed. On the basis of such zones of regeneration D.K. Voznyak [23] found P inclusions in quartz of regeneration of large voids. Their habit is flat, isometric. (...) Wide fractures in crystals may be healed due to development of subparallel individuals of multinucleated growth. Inclusions in such healed fractures are primary with respect to the material healing the fracture [63, p. 250].

I.T. Bakumenko described in detail and gave the systematics of regeneration inclusions of magmatic origin. He distinguishes P and PS (sensu N.P. Ermakov) regeneration inclusions; the essential difference between these two kinds of inclusions is that the first ones form on surfaces weakly destroyed by melting and "does not disturb the general zoning" and the second ones "contact with various earlier growth zones of crystals" [135, p. 38].

Ambiguity of this author's position in determination of the inclusion type is caused, in my opinion, by the unclear [definition] of primary and secondary inclusions, following N.P. Ermakov. The degree of destruction of crystals cannot be the determining factor in the classification of inclusions. In principle the first and the second inclusions are primary with respect to material of regeneration zone. But they are, however, neither primary nor secondary with respect to other earlier zones of crystal. Their genetic type cannot be defined with respect to ealrier zones of crystal, because the inclusions do not occur in those zones, and hence the problem of their primary or pseudosecondary classification is not at all a problem pertinent to those inclusions. Similarly, it is inappropriate for classification to compare P inclusions in zones of healing e.g. the cited above wide fracture in crystal of quartz from Alpine type vein Bristenstock [63, p. 251] with inclusions occurring in earlier part of the main crystal. One may only say about the earlier synchronous and later relative time of their sealing, i.e. pregenetic, syngenetic and post-genetic inclusions, in comparison with the others. In the same degree the above comments are pertinent to secondary inclusions, in what appears from principles of genetic distinguishing of inclusions, proposed by the present author. Inclusions in healed fractures are early or late secondary only with respect to the zones cut by the fracture or in contact with the fracture. For other zones they cannot be, in agreement with the sense of the word, either "first," primarily or "later," secondarily formed. Further understanding of the genetic sense of the discussed terms leads to great complication by the unlimited extention of the class of pseudosecondary inclusions after N.P. Ermakov [67, p. 189].

Inclusions of the second morphological type form at the next stage of the process of regeneration of the crystal, when numerous centers of crystallization due to their nonuniform distribution develop in individual, separate parallel crystals. On the boundaries of joining parallel crystals in the places with limited inflow of new portions of supersaturated solution, inclusion voids form, which are next but not immediately covered by new layers of crystal. These inclusions have elongated habit and crystallographic faces.

Inclusions of this type may be found frequently in quartz from pegmatite deposits of Volyn, where regeneration of crushed fragments of crystals by multinucleated growth is common. Characteristic depressions between subparallel terminations are sometimes observed; such depressions next develop into elongated inclusions. Usually they are parallel to the third crystallographic axis of quartz.

The rate of supply of crystal material is, most probably, the essential factor of nucleation, development and sealing of elongated voids-inclusions. During rapid growth the maximum difference in solution supersaturation form over the protruding terminations of the crystals and in depressions between them. Slower growth causes the joining of individual crystals and isolation (sealing) of inclusion voids. Sometimes such elongated voids remain opened, which presumably proves the shortage of input of material by the mineral-forming solution.

So called fibrous or acicular subparallel inclusions, similar to the above described and probably of that genesis, occur also in the regenerated part of crystals near the destroyed plane. They differ from the previously described inclusions in dimension and in an unusual density of distribution. For this reason during observations with a naked eye in reflected light they show a shiny, silky luster. It is worthy of note that elongation of such inclusions not always agrees with the crystallographic axes of the quartz.

Origin of elongated fibrous or tubular inclusions, as was shown by observations of natural and synthetic quartz crystals, is caused by nucleation of new generation of mineral on surfaces of mineral destruction, which before recrystallization had easily recognized evidence (but now traces) of intensive etching. Etching phenomena preceding crystal growth were proved on preparations of synthetic quartz, in which the nucleation of subparallel tubular inclusions is observable on the preserved parts of the crystallization nucleus plate and in the deep channels. Similar reasons caused the formation of inclusions of elongated habit in natural crystals. On the basis of regenerated parts of morion from Volyn similar traces of dissolution and etching were observed. But in addition to the above reason, the phase state of the crystallization medium undoubtedly has a major influence on the inclusion habit. Separation of G phase (boiling) as bubbles nucleated on the liquid/crystal phase boundary, favors the elongation of the vacuole along the direction of crystal face growth. Such a mechanism of formation of P regeneration inclusions was first described by G.G. Lemmlein et al. [127].

This way, one may conclude that subparallel elongated groups of inclusions which do not display the connection with healed fractures are P defects with respect to the given crystal zone and they are, possibly, a typical feature of abrupt change of solution concentration and its resultant dissolution of the host mineral.

Two crystals that grow simultaneously [in contact] may trap portions of parent solution or foreign substances on the induction faces. Such inclusions also should be called primary, as D.P. Grigor'yev suggested [37]. Crossing of growth zones of crystals by respective inclusions of induction faces cannot be regarded as sufficient sign of S nature of such inclusions [63], because any P (and S) inclusion cuts growth zones of the crystal. It is necessary to recognize exactly what zones are epigenetic and syngenetic with respect to the inclusions under consideration. Crossing (or contact) of inclusions with syngenetic growth zones is the only feature of primary origin. It is necessary to say that groups of inclusions of induction planes (pseudofaces) cannot be coeval one with another and their features change depending on time and place of trapping. Complete sealing of such inclusions also is doubtful.

N.P. Ermakov [63], on the basis of studies of P.S. Vadilo, explains the formation of P tubular inclusions by their nucleation on blunt edges due to a zone of immobile solution formed during concentration flow around the crystal. Almost the same reasons, after N.P. Ermakov, form tubular P inclusions in the path of movement of [fluid across the] crystal top. G.G. Grushkin [42] distinguishes P inclusions which form in stepped surfaces of the subsequent growth of the contacting faces.

Frequently tiny chips of foreign minerals or other substances are the cause of nucleation of P authigenic inclusions. Usually such inclusions incorrectly are called "stuck" inclusions, which may be justified to some degree only with respect to gas inclusions of heterogeneous origin. In one case inclusions of parent solution form next to foreign particles which remain in the initial place. Such inclusions occur on the surface of foreign grains or in contact with them, frequently being elongated in the growth direction of the host mineral. In other cases, as first stated by A.V. Shubnikov (204), inclusions form in the path of repulsion of foreign particles by host crystal. Due to this, the inclusions frequently are arranged in a chain perpendicular to the face.

M.M. Slivko [170] described tubular inclusions in tourmaline, elongated parallel to the three-fold crystallographic axis. They touch solid inclusions (foreign) at both ends (lower and upper) or with one end (lower or upper). Depending on the dimensions of solid inclusion, perfection of its surface and growth rate of mineral, various cases of trapping or repulsion of foreign particles occur and the respective position of inclusion vacuoles may be observed (Fig. 6).

D.K. Voznyak [112] presents the charcteristics of P inclusions of tubular habit, whose nucleation and formation was connected with the presence of particles of foreign minerals (epidote, quartz, etc.); the studied inclusions occurred in quartz from Krivoy Rog. similar to the above described inclusions [in tourmaline, A.K.], in that some touch solid particles with lower or upper end, and some are in close contact with solid particles and have an irregular habit. It is characteristic that tubular inclusions are connected with zones of regeneration of quartz crystals, seemingly due to multinucleated growth. The author notes the etching traces on surfaces of regenerating smoky crystals. Inclusions are elongated along the three-fold crystallographical axis. The above listed peculiarities of those inclusions are similar to features of P inclusions in regeneration quartz from Volyn and other regions.

Influence of supercooling (supersaturation) of melt on formation of P authigenic inclusions near xenogenic solid paticles was illustrated by V.Ya. Khaimov-Mal'kov [185] by crystallization of benzophenone from melt containing Lycopodium grains [i.e. spores, A.K.] (Fig. 7). When supercooling was small, all grains are repelled by the growing crystal and inclusions do not form. With increase in supercooling (supersaturation), particles of Lycopodium are partly repelled with formation in their trace of melt inclusions; when supercooling increases more, practically all xenogenic grains are trapped without formation of authigenic inclusions.

Author presents also interesting data on mechanism of interaction of liquid droplets or gas bubbles with growing crystals. Crystal of K-Al alum repels a droplet of mercury with formation of an inclusion vacuole under the droplet (Fig. 8). The vacuole may have a negative crystal habit (Fig. 8b). Thymol, crystallizing from the melt, trapped air bubble without admixture of parent medium, and the newly formed inclusions become elongated tubular channels perpendicular to the face on which the bubble was (Fig. 9). When Lycopodium particles were present, gas phase was not trapped but under the bubble a vacuole formed with a negative crystal habit (Fig. 10).

Experiments with trapping of foreign liquid droplets by growing crystals of borax and $Na(NH_4)HPO_4 \cdot 4H_2O$ were made in laboratory by G.G. Lemmlein, M.O. Kliya and I.G. Sokolov [106]. Although crystallization conditions were varied, droplets of oil were always trapped by borax as filled tubular inclusions without water solution (Fig. 11). In crystals of $Na(NH_4)HPO_4 \cdot 4H_2O$ when growth speed was from 7 to 30 μm/min on the path of repulsion of oil droplet, tubular inclusion of parent solution formed (Fig. 12). If growth speed of face is smaller than 7 μm/min, the droplet is not trapped and inclusion does not form; if growth speed exceeds 40 μm/min, the crystal traps oil in tubular vacuoles without admixture of water solution. If the crystallization conditions vary, the inclusion vacuole of tubular habit may trap both oil and water in changing proportions.

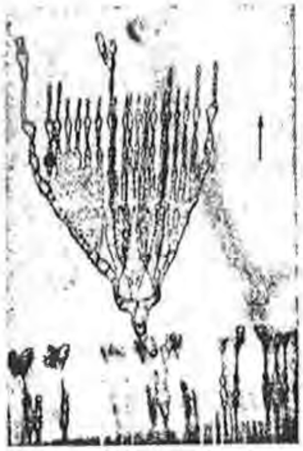
Trapping of gas bubbles without admixture of parent solution was observed by P. Powers [24] (Fig. 13).

The above examples prove the following:

1. Xenogenic solid particles trapped or repelled by growing crystal may yield authigenic inclusions; the latter occur on the contact: solid inclusions/mineral, on the path of movement of solid particle or in the "shaded" part of crystal above a solid particle.

2. Foreign fluids (droplets of oil, air bubbles, etc.) are frequently trapped by crystal in the "pure" state - without admixture of the parent medium.

3. Presence of the solid admixtures trapped by the crystal causes the formation under droplets (bubbles) of foreign fluids - inclusions of



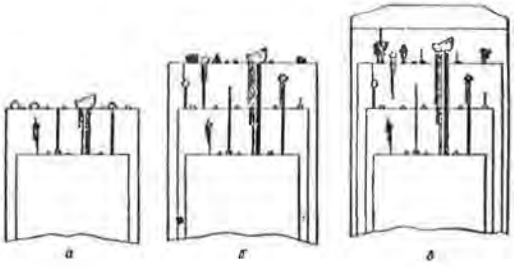


Fig. 5. Zone of fluorite inclusions syngenetic with topaz, x36. The arrow shows the direction of common growth.

Fig. 6. Scheme of distribution of solid xenogenic particles and fibrous vacuoles (inclusions) across growth zones of tourmaline crystal (Ural): a-c-sequence of growth of crystal zones.

Fig. 7. Trapping and repulsion of particles of Lycopodium by a growing benzophenone crystal: a - supercooling 0.1°C, x20; b - supercooling 0.5°C, x20; c - decrease of supercooling to 0.1°C and isolation of inclusions, formed under conditions b, x36; 1 - benzophenone melt with Lycopodium particles, 2 - growing benzophenone crystal.

Fig. 8. Repulsion of mercury droplet by growing crystal of K-Al alum: a - initial moment, b - somewhat later (L inclusion forms under the droplet).

Fig. 9. Trapping of gas bubble without admixture of parent medium (melt) by thymol crystal with increase of growth speed: a,b, - x10, c - x8.

Fig. 10. Formation of vacuole-melt inclusion in growing thymol crystal under air bubble, when a layer of Lycopodium particles occurs between thymol and air, x18.

parent solution without admixture of foreign fluid.

4. Complication of conditions with variable crystallization regime causes irregular trapping of both foreign fluid and parent medium.

5. Stable crystallization regime may cause the trapping of a series of inclusions with the same composition.

6. Droplets of foreign liquid or gas bubbles usually are trapped by growing crystal as tubular inclusion, elongated perpendicularly to the respective face; vacuole formed under a xenogenic particle almost always has negative crystal habit.

Using the above described types of P inclusions for solution of mineral genesis problems, it is necessary to remember not all the above types may submit sufficiently certain information about parameters of crystallization medium. It is pertinent to [discuss] inclusions immediately touching the solid particles and occurring in induction surfaces of growing mineral individuals. It is well known that crystal individuals very easily separate one from another exactly along those pseudofaces. Seemingly, crystal lattices in such surfaces have relatively weak connection, and for this reason solution may migrate from and to inclusions along the surfaces. The same is true of the surface of connection of foreign mineral particles with including host mineral. The two minerals may have different thermal expansion coefficients. For this reason T change both under natural and laboratory conditions may penetrate the fractures, changing the original phase ratios. Sometimes zeolites are trapped minerals; due to their sorption properties they may be the conducting channels or additional reservoirs for inclusion solutions, and in consequence the phase composition of inclusion is changed.

Formation of secondary solutions. Fissures in crystals, which may be the place of formation of S inclusions, form due to various reasons: dynamometamorphism, T change, polymorphic inversions, tension inside crystals.

Tectonic tension causes fracturing in the bases of the crystal [...]. Sometimes, however, secondary turbidity occupies the whole crystal and cannot be caused by dynamometamorphism, but rather by, e.g., abrupt T changes [38, p. 182]. Formation of secondary fractures due to polymorphic inversion was described by A.Ye. Fersman [184]. During the phase inversion α-β quartz, this mineral is reduced to polygonal fragments by numerous fractures due to the abrupt volume decrease. In section they have shape of an irregular reticulation, hence it is called "reticulate" quartz [...] [49, 197]. Yu.A. Dolgov, for instance, writes that abrupt T decrease caused by adiabatic expansion during opening of mineral-forming system is the reason of formation of "reticulate" quartz. A.A. Sternberg studied formation of fractures due to relaxation of tension inside synthetic crystals. Such fractures develop continuously in the process of face growth, following the face, but they do not appear on its surface. The number of fractures of this type depends on the growth speed of crystal. During very slow crystallization such relaxation fractures do not form. Rapid precipitation of material causes an increase in the number of fractures and their ramification.

Due to difference of thermal expansion coefficients of those particles and the host mineral, solid particles, trapped by the crystal and occurring close to a face, break the mineral and form fractures contacting with external medium. Similar fractures, but not contacting the crystal surface, form around solid or L inclusions coverd by a thicker layer of mineral.

Secondary inclusions (early and late) are characterized by the source or very close conditions of formation [in the same fracture, A.K.]. However, during healing of early S fractures, material may be transported from the outside parent solution by diffusion. In formation of S inclusions, evidently, the width of the fracture plays an important role, because on this factor depends the mode of healing and speed of transport of material form outside.

Secondary inclusions form in the process of healing of the described fractures. Those which are syngenetic with recognized elements of crystal growth are early secondary, and those which have no spatial and time connection with growth of a given crystal are late secondary. Inclusions in polygonal reticulate fractures in quartz are early secondary. Fracture formation and their healing usually repeats many times during the complicated and long process of mineral formation. In morion crystals from Volyn pegmatites, a large series of inclusions formed at various times, whose formation sequence was determined on the basis of refilling of inclusion vacuoles in crossing of fractures of various age.* Thus one may distinguish early secondary inclusions 1, 2, 3 ... etc. The same concerns P and late S inclusions, and determination of age sequence of the latter is one of the most important aims of mineral fluidology. The possibility of crossing, typical of fractures with S inclusions, is one of the main differences from groups of syngenetic P inclusions occurring in planes. Such planes coinciding with the former faces of crystal, never cross one with another.

In groups of S inclusions it is most important to determine the places in which the fracture formation started. In those places the contact with parent solution occurred. Here precipitated first layers of crystal after its damage and with those layers the early S inclusions of a given healed fracture are syngenetic. Differences in color of material of healed fracture and the main crystal also help to distinguish inclusions important for solution of genetic problems. For instance, in morions of Volyn sometimes fractures occur that are healed by light quartz. Inclusions in this fracture prove the precipitation of the latest regeneration quartz. There are known, however, rock crystals from Volyn in which fractures are healed by smoky quartz. Interesting relations of fractures of various age and inclusions in them were observed in one of crystals of Volyn morion [88, p. 125]. A relatively wide fracture in morion (thickness about 2-3 mm) was healed initially by transparent quartz and next by amethyst with included goethite needles (Fig. 14). It is easily visible under the microscope that a small fracture in morion, healed by light quartz, ramifies from the main fracture, not penetrating it. This is observable due to essentially G inclusions occurring in the fracture. Another healed fracture cuts morion and light quartz but it has no continuation in amethyst zone. Filling of inclusions of the latter fracture is about 90%. In this manner, a relatively distinct sequence of changes of mineral-forming medium during fracture healing may be observed.

G.G. Lemmlein [117] showed that thin fractures in sodium nitrate healed due to dendritic growth. Inclusions form by isolation of parent solution between branches of several dendrites, which, developing simultaneously, do not completely touch one another. This process starts from the wedge end of the fracture and then develops toward the wide end. The growth occurs without new material from outside but due to reprecipi-

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*This very effective method of reconstruction of regime of changes of crystallization conditions, discovered by G.G. Lemmlein [121] and first used practically by the present author [88, 91], earlier was not applied by anybody in any laboratory known to the author and was not published, in spite of statements by N.P. Ermakov [70, p. 43].

tation of host material from flat walls of the fracture to the angles of dendrites. This spontaneous process of alteration of a non-equilibrium fracture cavity is a result of the crystal changing toward the energetically more appropriate form with a minimum of free energy (Curie-Wulf law). "According to the Ostwald-Freundlich equation, the solubility of crystals (saturation concentration) exponentially increases with decrease of size, and concentration of solution filling the negative crystal (vacuole or fracture in crystal) decrease with decrease of its size. Solubility of convex surfaces is higher than solubility of flat ones, and of the latter - higher than of concave ones." [113, p. 142]. G.G. Lemmlein proved that this condition - like the previous one - is the main reason of reprecipitation of substance in fractures and inclusion vacuoles even under isothermic conditions.

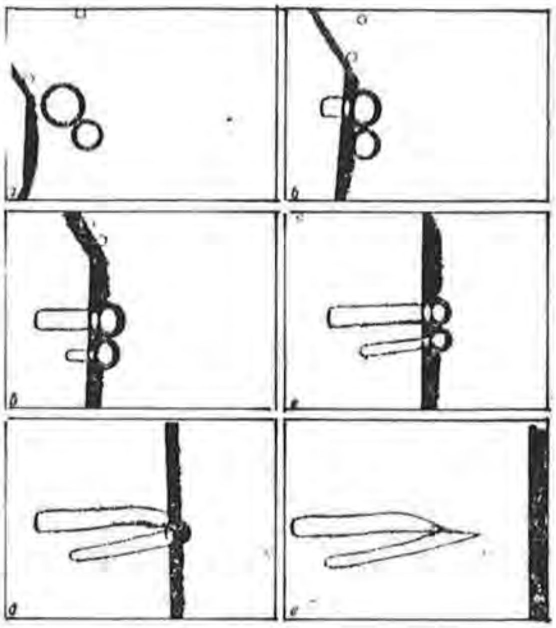
When a dendrite approaches the outer, wide part of the fracture, the process of healing becomes significantly slower. One may suppose that in a fracture of a certain thickness, the dendritic growth becomes so slow that due to entry of material from outside, the fracture will heal by multinuclear growth, as observed in quartz from Alpine-type vein by N.P. Ermakov [63]. Typical asterisk-type ("trigonal") distribution of early-secondary inclusions in quartz crystal from Nagol'nyi is also explained by the author by multinuclear growth healing [103]. Difference in distribution of inclusions in wide and wedge-shaped parts of a fracture confirms the above explanation (Fig. 15). Initial widening of fracture occurred due to dissolving of its walls. Probably, multinuclear growth in healing commonly occurs also in narrow fractures in crystals, especially those only slightly soluble. E.g., in morions from Volyn one may observe frequently inclusions occurring not in the fracture plane but distributed in various distances from it. Those distances are sometimes too large to be explained by dendritic regeneration. Usually such inclusions have negative crystal habit oriented in agreement with host crystal.

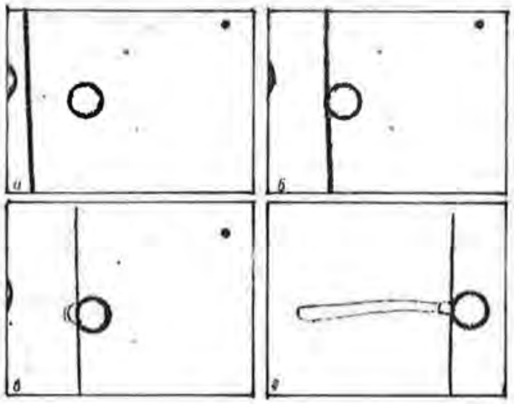
Healing of fractures in crystals and formation of inclusions from G parent solution is still inadequately studied. G.G. Lemmlein [119] made experiments with healing of fractures in ice crystals by G phase at T -6 to 0°C. This author writes that in fractures which were closed to the surrounding environment, the healing developed by sublimation-condensation of material through G phase from flat parts of fractures to the concave ones; the process does not differ from healing by solution. Opened fractures healed in a different way. At the wedge end the capillary condensation of water from surrounding environment was observed; this water next crystallized to ice.

Chapter 4 ALTERATION OF INCLUSIONS

Initial filling and habit of inclusions may change during long geological time. These may be insignificant or major, depending on the intensity of thermobaric, geochemical, physico-chemical and other factors, that acted through the crystal and changed phase equilibrium or the whole inclusion filling. Recognition of reasons and degree of such changes has special importance for evaluation of the validity of data about mineral genesis obtained from fluid inclusions.

Let us consider the scale of influence of the following phenomena on the initial parameters of inclusions: 1) migration (diffusion) of substance through the crystal lattice of mineral; 2) change in the state of isolation of inclusions by fractures in crystal, filled by the new parent fluid (refilling); 3) opening of inclusions due to their overheating (decrepitation); 4) change of energetically disequilibrium habit of inclusion





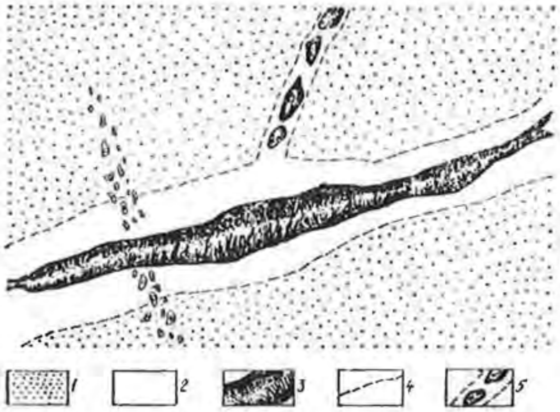


Fig. 11. Stages of trapping of oil droplets by growing crystal of borax; x430.

Fig. 12. Formation of inclusion of parent solution during repulsion of oil droplet by crystal of $Na(NH_4)HPO_4 \cdot 4H_2O$; x400.

Fig. 13. Trapping of gas bubble without parent solution admixture in tubular vacuole by crystal of saccharose, x10.

Fig. 14. Fracture in morion healed by light quartz and amethyst: 1 - morion, 2 - light quartz, 3 - amethyst with acicular crystals of goethite, 4 - boundary between morion and light quartz, 5 - G inclusions, x13.

Fig. 15. Scheme of distribution of inclusions in "trigonal rosettes" in healed fracture (Donbass, Nagol'nyi), x10: a- wedge-shaped part of fracture, b - intermediate part, c - main thick part.

to negative crystals (includes also necking down, formation of light haloes, etc.); 5) migration of vacuoles in thermogradient field.

Analysis of genetic information coded in altered inclusions is well illustrated by examples of reconstruction of formation conditions of certain deposits of mineral raw materials.

Migration of substance through crystal

Changes of inclusion filling due to diffusion through the crystal were not detected by ordinary visual and experimental studies, that may suggest either an insignificant influence of this factor or its absence. Evidently, a great role is displayed by the specific conditions of post-genetic existence of inclusions, especially taking into account geological time. Let us quote some evidences of absence of changes of inclusion filling.

It is understandable that in case of a permeable mineral, water solutions might migrate from outside into an inclusion, increasing its degree of fill, or, in reverse, from inclusion to surrounding space, decreasing its filling. Such migration of substance may occur due to difference of P in environments, for a given mineral.

Processes of endogeneous hydrothermal mineral formation usually develop at elevated T and P with their gradual decrease. Thus, generally, parameters of P inclusions from crystal center to its periphery should reflect such a common T change, i.e., inclusions occurring in the center should have smaller degree of fill than those in the crystal periphery. Assuming the possibility of solution migration, the change of degree of fill from the center to the periphery should be reversal - inclusions in outer zone of crystal would lose their contents faster than inclusions in the inner zones. But in nature inclusions in outer zones have usually lower Th (and higher fill degree) than those in inner zones. Very frequently the outer zones of crystal terminations contain one-phase L inclusions even though that mineral existed for long (geological) time in vugs in rocks. Even at room temperature the inclusion contents are under significant P. For instance, opening of two-phase L/G inclusions in pegmatite minerals from Volyn in glycerine shows a 100-fold expansion of the G in inclusion, i.e., at room T the internal P in inclusion was ~10 MPa. Age of the host crystals of quartz from Volyn Zanorysh pegmatites is about 1,200 million years.

Frequently in the outer zone of crystals (Nagol'nyi, Donbass) inclusions were found filled to 100% by LCO_2. Internal P of such inclusions under surface conditions also might reach 8-10 MPa. However, in spite of long existence time, such inclusions preserved their filling.

Inclusions of organic (essentially methane) fluid in quartz from Transcarpathia have internal P under normal conditions >76 MPa [112]. Age of metamorphic rocks of Altai is about 200 million years, but nitrogen inclusions in kyanite preserve internal P ⩾100 MPa at 20°C [55]. The authors of that paper discuss the hermetic state of G inclusions in glass tektites (moldavites) and Lunar soil particles. In vacuoles of inclusions in tektites (of age 15 million yr.) the air components did not penetrate (especially oxygen), although the internal P is 1/3000th of atmospheric P. In glass globules and splashes from the Moon inclusions were found with relatively high gas content (on the Lunar atmosphere scale). [...] It is notable that in inclusions in tektites and in Lunar samples a high content of H_2 was found (10-95% by vol.), i.e., the element whose migration through the crystal lattice is believed to be especially fast.

The facts listed above concerning the state of inclusions under natural conditions prove the absence of influence of diffusion on the results of ordinary studies of inclusions. Experimental data also do not deny this.

B. Skinner [245] obtained lowered Th of gas-liquid inclusions in quartz after a 60-hour run in an autoclave under PH_2O 60-80 MPa at 70°C and he concluded that liquid penetrated through mineral substance into the inclusion. The erroneousness of that conclusion was proved by the author's experiments (Table 1) made with longer runs and at higher T [85], and with more accurate Th measurements, made with a new heating stage [87]. Inaccurate Th measurements in an imperfect heating stage were the reason for the erroneous results[sic]. Later B. Skinner, in collaboration with E. Roedder [243] made more detailed studies, which confirmed the author's experiments.

Table 1. Studies of hermiticity of inclusions in quartz

Number of inclusion	Deposit and sample	Th before run, °C	Experiment conditions			Th after run, °C
			T, °C	P, MPa	Time, Hours	
1	Briestenstock (Alps) rock crystal	190	150-160	83-88	90	190
2	Same.	191				191
3	Synthetic quartz	305				305
4	Volyn, pegmatite, morion	250				250
5	Same.	245				245
6	Same.	234				234
7	Same.	231				231

Experiments were made to stimulate migration of water solution from inclusion to surrounding space by heating to cause a significant excess of internal P in comparison with the external one. D. Richter and E. Ingerson [239] maintained inclusions at T exceeding Th by 25, 30 and 35°C during 3 and 6 hours. No leakage was found. The author [88] made runs with polyphase inclusions in topaz, bearing significant amounts of CO_2, N_2 and CH_4 at T 30-40°C above Th in liquid phase (Th 370-380°C, internal P during homogenization >50 MPa) for 23 days. The inclusions did not change the initial Th (and filling degree).

I.M. Volokhov [24] supposes the possibility of hydrogen migration from inclusions due to dissociation of water at elevated T. Such change of inclusion filling may be typical of magmatic and other high-temperature inclusions, heated in heating stages up to 800-1200°C. Yu.A. Dolgov and V.A. Simonov [53] made a series of experiments with L/G inclusions in "reticulate" quartz. Heating of certain such inclusions was carried up to 1000-1400°C in stages; in each run T was higher 50-60°C than in preceding run and then the sample was cooled 100-200°C below Th. The state of the inclusion filling and its hermiticity were checked each time by measuring of Th. Gradual but insignificant increments of Th after each run suggests (according to the authors of the experiment) the preservation of inclusion filling and a certain increment of the solution density due to dissolving of the walls of the vacuole. Leakage and partial migration of hydrogen (or other volatiles) would be indicated by a Th decrease[sic]. A more distinct change of density of the inclusion filling was observed during heating to T >1050°C, connected with fracturing or melting of host mineral.

The proposition that solution may migrate through the lattice of salts like NaCl, KCl, etc. [63] was not confirmed by the author's studies

[89]. Partial or complete leakage of solution from inclusions in such salts and in other minerals of low hardness and perfect cleavage (barite, gypsum, etc.) is caused by its expulsion into microfractures formed around the vacuole during experiments. These fractures usually are invisible and frequently don't contact with the preparation surface.*

The above data may be the evidence that leakage of inclusions is [so insignificant that is] not detectable by usual investigations of most minerals, especially such as quartz, topaz, calcite, fluorite, etc. The only exception are zeolites, with channels in their structures providing the ways of migration of molecules of foreign substances. Sealing may be incomplete for inclusions occurring in the planes of induction faces, on twin junctions, etc. in places of discontinuity of crystal lattice and incomplete continuation of structural units. However, this problem needs special studies. Usually the filling of P (and S) inclusions is altered when the inclusions contact solid inclusions, especially those displaying absorption properties like zeolites, hydromicas, etc.

Refilling of inclusions

G.G. Lemmlein [121] first paid the attention to the change of filling of inclusion vacuoles occurring on the line of intersection of healed fractures of various age and determined its genetic significance; later those phenomena were studied by the author [88, 91].

Inclusions may be opened by fractures formed due to external mechanical action or internal tension in crystal. Formation of fractures occurs during the whole process of crystal formation. Surrounding fluid through the opened fractures penetrates the inclusion vacuoles, changing their primary filling. New, later fractures may open the earlier sealed inclusions both in healed fractures and in growth zones of crystal (i.e., S and P inclusions). During this process the initial habit and dimensions of the opened inclusion usually are preserved but the filling (its composition and specific volume) essentially change.

Measurements of Th and pH of individual inclusions and cryometric studies prove that filling of altered inclusions is completely replaced by the new fluid of the later fracture, i.e., there occurs complete *refilling of inclusions* [91]. For instance, the refilled inclusions 1, 2, 3 (Fig. 16), by their size, habit and position in the fracture (they occur in the plane of the drawing) are similar to L/G inclusions *a*, but their filling is the same as the younger inclusions of LCO_2 occurring in the fracture *bb* almost perpendicular to the plane of the drawing. By cryometric analysis the salt concentration of L phase of inclusions *a* is 7% NaCl (last ice crystal disappears at -4.5°C, cryohydrate point -21 to -22°C). Water solution of refilled inclusions and inclusions of the fracture *bb* has lower salinity 1.5 to 2.0% NaCl (last ice crystal disappears at -1°C). Similar results were obtained from measurements of pH and Th of inclusions (refilled and occurring in the cross-cutting fracture).

The complete refilling of vacuoles is caused by the following reasons:

1. Fractures formed in the crystal are unusually thin and solution sucked into the fracture moves gradually in the direction of its development. Before the front of the moving solution the area of low pressure (vacuum) is formed (Fig. 17). This vacuum part of fracture first contacts with solution of vacuole, removing it from the vug; this causes the quick mixing of fluids.

2. Healing of fractures in slightly soluble minerals (quartz, topaz, feldspars, etc.) goes relatively slowly in comparison with process of dif-

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*Called "stretching of inclusions" in Western literature. (A.K.)

fusion and filtration. The latter relatively quickly unify the composition of gases and salts of the opened inclusion and the fracture contacting the surrounding parent solution.

3. Volume of the opened inclusion is immeasurably small in comparison with the volume of fracture and fluid surrounding the crystal; for this reason the influence of inclusion fluid on the general composition of fluid in fracture is not noticeable.

Figure 18 presents drawings made from microscope observations showing typical examples of the change of inclusion filling in crystals of quartz from Volyn pegmatites during crossing by later fractures. Crossings are best observable when one or both fractures are subparallel to the optical axis of microscope (or almost perpendicular to the surface of preparation). Figure 18 presents only those inclusions which are on the same level that refilled inclusions. Other vacuoles are out of focus.

A complete analogy was observed in the filling of refilled inclusions A and inclusions cutting fractures II-II (Fig. 18a, b, d, e, h-k). the same may be said also about other cases, although seemingly this analogy is absent. Families of syngenetic inclusions trapped from heterogeneous (liquid + vapor) fluids have various degrees of filling. If the cross-cutting fracture bears such inclusions filled in various degree, one may suppose that composition of refilled inclusion would be included in the general pattern of variable filling. Observations confirm this pattern (Fig. 18c, f, g); most commonly in this case refilled inclusions are gaseous and essentially gaseous. This is the consequence of expulsion of the former L phase by the vacuum part of the opening fracture and next action of the capillary forces precluding the filling of relatively large and isometric cavity from a thin, capillary fracture (Fig. 17b). Very rarely during refilling by heterogeneous solutions, the inclusions formed are of G/L or mixed (heterogeneous trapping) type. Thus, also in the above case complete refilling does occur.

Nearly insoluble trapped minerals may remain without change in refilled inclusions. Also if mixing of solutions causes precipitation of an insoluble product, the opened vacuoles would contain a xenogeneous solid phase, with respect to new fluid. This, however, does not influence (taking into account diffusion) the composition of fluid sealed in the newly-formed inclusion and its identity with the fluid penetrating the fracture.

Vacuoles in crystals opened by fractures causing the possible leakage of inclusions are a special case. Such vacuoles (according to the author's determination) do not belong to inclusions of mineral-forming fluids. Omitting inclusions opened by non-healed fractures one may recall cases (described many times in the literature) of magmatic glass inclusions with fractures joining them with surrounding environment. Such penetration of melt into fractures and its hardening as glass is typical of xenoliths of hydrothermal quartz and other minerals with inclusions of fluids. Only the recognition of lack of leakage of newly formed inclusions may be the basis for use of them as relics of mineral-forming solution.

Refilled inclusions are very important genetically. By this phenomenon the relative age of acting endogeneous fluids may be established. Since P inclusions are limited in distribution and the sequence of their formation is difficult to establish, refilling is essential for reconstruction of the details of evolution of properties of mineral-forming fluids in relative time. The large amount of S inclusions in crystals makes such investigations easier.

One may conclude about the relative age of the crossing fractures by

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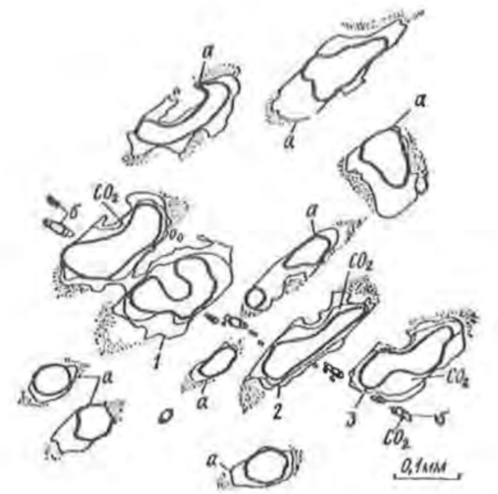
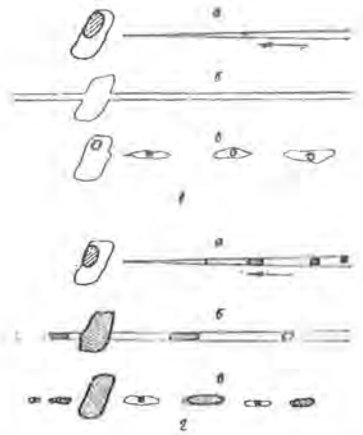
*Fig. 6 quoted here in the Russian text most probably is a misprint.(A.K.)





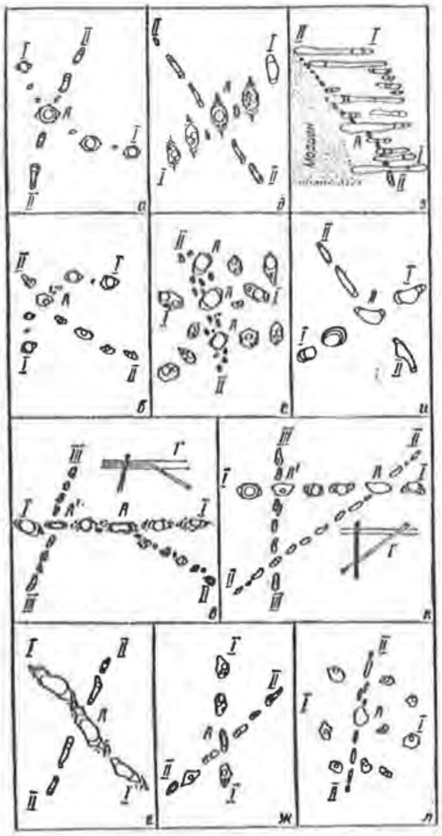


Fig. 16. Refilling of L/G inclusions with haloes of decrepitation (a) by LCO_2-LH_2 solutions (b).

Fig. 17. Scheme of refilling of inclusion by solution from an opening fracture: 1 - during healing of fracture from homogeneous solution; 2 - during healing of fracture from heterogeneous solution; a,b - stages of inclusion opening, c - healed fracture.

Fig. 18. Relative age and features of fluid inclusions in quartz of "zanorysh" (i.e., chamber) pegmatites of Volyn: a-I-"reticulate" (L = 40-45%, Th = 380-430°C in G, pH 6.3-6.9), II-inclusions of CO_2 (L = 5-10%, Th 300-320°C in G, pH 8.2-9.2); b-I-same as a,II-G/L (L = 70-80%, Th 325-340°C in L, pH 7.4-7.6); c-I-decrepitated with turbid haloes (L = 35-40%, Th 400-435°C in G, pH 8.0), II-polyphase with various filling degrees (L = 30 and 75%, solids = 5-10%, Th 400-550°C in L, 370°C in G, pH 5.2, Fe^{2+} 7%), III-filled in various degree (L = 5-10 and 75-80%, pH 7.8-8.0); d-I-same as in b,II-same as in a; e-I-polyphase (with trapped or dms) decrepitated (L = 20-30 and 70-75%, Th 550°C in L), II-same as in a; f-I-polyphase (L = 66-70%, pH 5.2-5.4), II-polyphase filled in various degree; g-I-polyphase (L = 50-55%, solids 7-8%, pH 5.2-5.4), II-filled in various degree (L = 0-2 and 85%, pH 7.8-8.0); h-I-CO_2-filled, P, filled in various degree (L = 5, 10, 80-85 etc. %, Th 240-270°C in L, pH 7.4-8.0); i-I-same as in a, II-essentially G (L = 1-2%); j-I-same as in a, II-essentially G, III-G/L (L = 95-97%, Th 80-100°C in L, pH 6.0, Ca 7.6%, Mg 4.3%), k-I-G/L (L = 75%, Th 225-270°C in L, pH 7.8-8.0), II-essentially G (L = 1-2%), I-III-sequence of inclusions formation from early to late, A, A', B - refilled inclusions, G-scheme of crossing of healed fractures, [...] pH values under normal (room) conditions.

comparing habit, dimensions, orientation and filling of inclusions in the fractures. Crossings of S and P inclusions fixed on Fig. 18* unambiguously show that all healed fractures I-I are earlier than fractures II-II. For this reason the time of action of mineral-forming solutions of the first fracture is earlier than the second fracture.

Not all fracture crossings permit unambiguous solution of the question about their age. Often refilling is not observed or it is nebulous. Such cases may be explained, e.g., by contemporaneous (or almost contemporaneous) healing of crossed fractures. Sometimes a large inclusion in one of the fractures occurs on a line of tiny inclusions of the second fracture, but the large inclusion was not refilled. Thus probably the fracture with large inclusions is younger, otherwise these inclusions should be refilled. This indirect method is less exact.

Usually refilling on crossings of two fractures were observed; unique and valuable are the joint refillings of inclusions of three and more fractures (sometimes they occur in one view field in microscope). Such cases surely show how significant are changes of composition and properties of endogeneous fluids in the process of formation of deposits. Two such crossings are presented in Fig. 18. First of them (Fig. 18c) shows that high-temperature fluids (producing inclusions with haloes of decrepitation in fracture I-I) were replaced by heterogeneous (boiling) high-temperature and highly concentrated solutions in fracture II-II, which next were changed by fluid of fracture III-III, also in a state of two-phase equilibrium (liquid-vapor). It is understandable that such large differences of the named fluids cannot prove sudden and abrupt change of solutions, because the discrete character of trapping of solution in vacuole makes possible the fixing of only certain moments of the process. For elucidation of the sudden changes of state of fluids there are other methods and objects of study, which fix directly the extremes.

In the second case of the triple crossing of fractures (Fig. 18j), the sequence of appearance of fluids typical of zanorysh pegmatite formation is shown. The fluids are saturated with CO_2 and relatively low-temperature. Essentially G inclusions homogenizing in G phase are not an unambiguous indicator of phase state of fluids with high specific volume. Existence of two-phase L-G equilibrium and possible trapping of only separated G phase in inclusions do not solve this problem in each case.

Sometimes refilling causes separation of inclusions to parts or the loss of the initial habit. Such cases are very rare but they may complicate the recognition of alteration and their true reason. Figure 19 shows the crossing of tubular inclusions by inclusions composed of CO_2 (G + LCO_2 + LH_2O). The path of fracture is traced not only by tiny S inclusions but also by dividing of P inclusions into two parts. Such dividing was observed only in very thin, fibrous inclusions (thickness <0.01 mm) and inclusions of larger thickness (left part of drawing) were not submitted to such alterations. The smaller the thickness of the tubular inclusion, the larger is the distance between the separated parts of the inclusion (from 0.14-0.24 mm for thickness ~0.01 mm to 1 mm for 0.002-0.003 mm). It is interesting that at the place of crossing the small inclusions form with elongation agreeing with elongation of P tubular inclusions (matched with arrow in the Fig. 19). The described phenomena are typical of tubular inclusions in tourmaline, apatite, beryl, etc.

Rarely during crossing of fractures the reverse scheme was observed. Inclusions opened and formed in the new fracture together join in one vacuole. Usually this is most easily observed when a flat vacuole of the cross-cutting fracture joins the refilled inclusion.

Opening of inclusions under action of internal pressure (decrepitation, breaking)*

If pressure made by fluid inside an inclusion exceeds a specific value, the walls break and inclusion filling leaks. This effect is possible during T increase or during sharp decrease of external P. The maximum P inside the inclusion depends on numerous factors, first on physical properties of mineral, dimension, habit, phase and composition of the inclusion [88, p. 134].

Experimental data obtained during studies of natural and synthetic crystals showed that there occur essentially two modes of opening of inclusions on heating: explosion of inclusion and its breaking.

First mode is typical of rock-forming minerals (quartz, topaz, calcite, etc.). During explosion of inclusions the opening fractures join the inclusion vacuole with the space surrounding the crystal. This almost always is connected with acoustic effects and breaking of the preparation into fragments or cleavage chips. It was always noticed that when the opening is vigorous, inclusions have carbon dioxide in their composition or a significant P of other gases occurs inside the vacuole.

The second mode of inclusion opening is typical of easily soluble minerals (halite, sylvite, etc.), but frequently appears also in quartz, barite, gypsum, calcite. Experimental studies of inclusions in $NaNO_3$ were made by G.G. Lemmlein and M.O. Kliya [126]. Under action of internal P, an elastically deformed area forms around the inclusion. P increase and overstepping of crystal resistivity leads to breaking of the crystal body continuity and forming of one or few microscopic fractures. Increase of inclusion volume due to those fractures causes an abrupt P decrease. Hence the fractures stop close to the inclusion (distance of a few inclusion diameters), not reaching the preparation surface. The fractures next are healed forming submicroscopic inclusions of a portion of parent solution. Usually elastic deformation of crystal lattice after such inclusion alteration remains and may be observed in polarized light. Inclusion volume after overheating increases because of new-formed submicroscopic vacuoles. Hence, the amount of solution that fills the primary volume of the inclusion vacuole decreases. After cooling a gas bubble appears in an inclusion that earlier was one-phase. Volume of this bubble in the ideal case would be equal the total volume of all submicroscopic inclusions of the healed [newly formed] fractures (Fig. 20).

The difference in the modes of inclusion opening is caused more by peculiarities of the development of internal P in inclusions connected with their composition than by features of minerals. Evidently, when compressed gases are present in inclusions, the volume increase caused by formation of small fractures around the inclusion is not sufficient for compensation of G pressure. For this reason the whole specimen breaks with relatively intense acoustic effect. In reverse, for P decrease in a weakly compressible liquid, an insignificant volume increment is sufficient, like formation of submicroscopic fractures. Thus, fracture deformation is observed only close to the inclusions.

The correctness of the above statement is confirmed by the simple calculations presented below. Let us show how large should be the volume increase due to newly-formed fractures and how the internal P decreases to finish the process of fracture widening. If one considers inclusions of the same dimensions and shape in the same mineral, the breaking pressure should be a constant value; for quartz, for instance, it may be equal 8 MPa [150]. Internal P of G/L inclusion H_2O with total specific volume γ =

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*Written together with D.K. Voznyak.

1.2 cm^3/g will reach [177, p. 347] 80 MPa and decrepitate at 280°C (initial filling of inclusion at 20°C L = 84%, Th ≈ 225°C). It may be supposed that the appearance in the inclusion vacuole of the equilibrium liquid-vapor and respective P decrease to 6.4 MPa (at 280°C) precludes the movement of fracture front far in the crystal. Since the mass of inclusion filling remains constant (fracture does not contact the crystal surface), the relative volume increment will be connected with the ratio of specific volumes $W_2:W_1 = \gamma_2:\gamma_1$ (here W_1, γ_1 and W_2, γ_2 are respectively initial and final inclusion volumes and total specific volumes of their filling).* After the manual [176] due to P decrease from 80 to 6.4 MPa at 280°C the total specific volume increases 1.1 times ($\gamma_2:\gamma_1 = 1.33:1.20$) and hence also volume of L inclusion should increase in the same ratio.

L/G inclusion of H_2O of total specific volume, e.g., 3.39 cm^3/g will homogenize in G at T ~370°C and it develops the breaking pressure 80 MPa at 600°C. Using data from the manual [176, p. 349] similarly as before, we find that P decrease after breaking at 600°C to 6.4 MPa it is necessary for the vacuole volume to increase 19.8 times ($W_2:W_1 = \gamma_2:\gamma_1 = 67.3:3.39$).

Inclusion of pure CO_2 of the same specific volume as the above discussed inclusion of H_2O ($\gamma = 1.2$ cm^3/g) will achieve the pressure 80 MPa at 150°C [176, p. 353]; on breaking its volume increases 9.4 times ($W_2:W_1 = \gamma_2:\gamma_1 = 11.27:1.20$).

It is interesting that inclusions of CO_2 and essentially G inclusions of H_2O have similar value of increase of volume in the moment of breaking, even if the initial parameters of GH_2O inclusions are similar to G/L inclusions of H_2O (Table 2).

Hence, for inhibition of fracture formation around H_2O inclusions of relatively low density and CO_2 inclusions of various degrees of fill needs an increase of the volume by fractures of one order of magnitude larger than for G/L inclusions of high density. The latter develop breaking fractures of volume less than 10% of the initial inclusion volume. Thus, the first of the above inclusions on heating break with a distinct acoustic effect and fragment the mineral grain, the second one gives very weak acoustic signals and preserves the initial filling in volume of new vacuole, which does not reach the surface of mineral grain.

Table 2. Increase of volume of inclusion vacuole due to joining fractures of optimum size, not reaching surface of crystal

		Conditions of beginning of breaking			Conditions of end of breaking			
No. of inclusion	Filling	P, MPa	T, °C	Specific volume, cm^3/g	P, MPa	T, °C	Specific volume, cm^3/g	Volume increment $W_2:W_1$
1	H_2O	80	280	1.20	6.4	280	1.33	1.1
2	H_2O	80	600	3.39	6.4	600	67.3	19.8
3	CO_2	80	150	1.20	6.4	150	11.27	9.4
4	H_2O	80	200	1.094	5.0	200	1.153	1.06
5	CO_2	80	200	1.35	5.0	200	17.06	12.6
6	CO_2	80	600	2.55	5.0	600	33.22	13.0
7	H_2O	80	360	1.38	5.0	360	53.18	38.5

Change of the PTV parameters (Table 2) is marked by the dotted lines on the PT diagrams of H_2O and CO_2 (Fig. 21 and 22). From their analysis it may be concluded that the ability of inclusions to extend their volume

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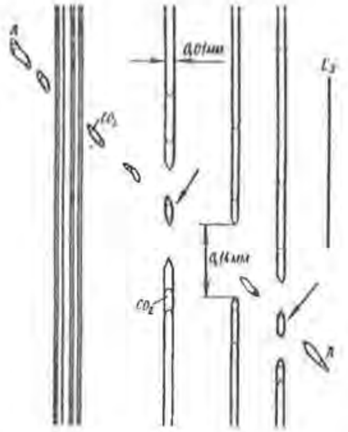
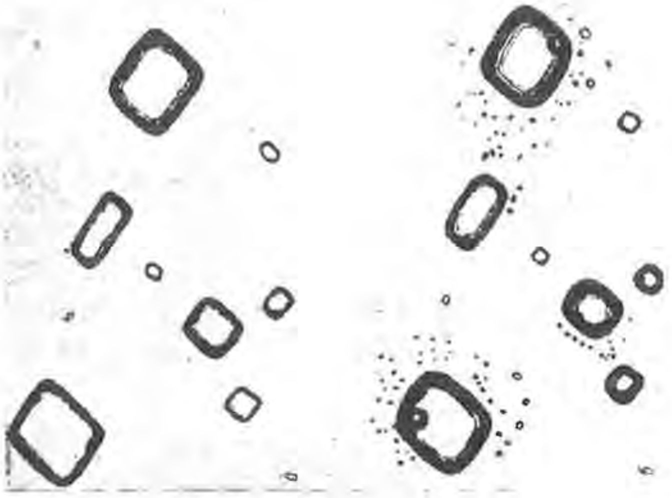
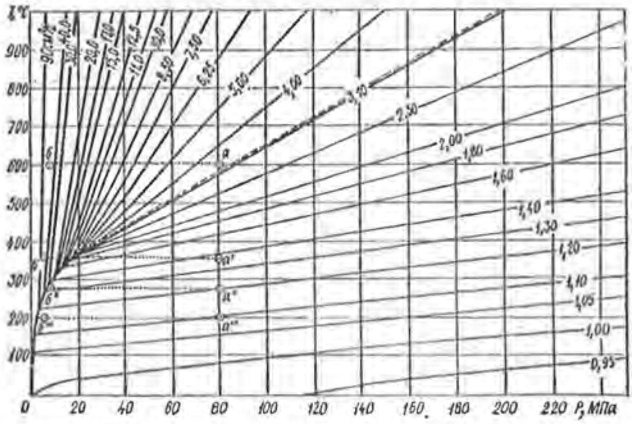
*Total specific volume means ratio of total volume of vacuole to total mass of phases.







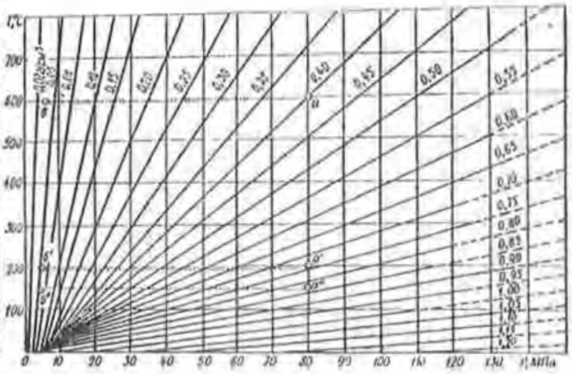


Fig. 19. Scheme of refilling of P tubular inclusions (type as in Fig. 6 and described in item 6, Table 3) in quartz by solutions of S inclusions of CO_2 type 8 in Table 3 (fracture A-A); explanation in the text.

Fig. 20. Inclusions of parent solutions in $NaNO_3$ crystal (a) and the same inclusions after overheating, breaking and formation of halo of healed fractures (b).

Fig. 21. PT diagram of H_2O with isochores for various specific volumes (made from data of G. Kennedy [176]). Dotted lines show P decrease in inclusions during their isothermal decrepitation.

Fig. 22. PT diagram of CO_2 with isochores for various densities (made from data of G. Kennedy [176]). Dotted lines - same as in Fig. 21.

during overheating is determined by value of P increase per unit of change of temperature, i.e., by slope of isochores with respect to P axis. This explains the similar character of decrepitation of inclusions of CO_2 and L/G inclusions of water. Value of lower limit of internal P in inclusions when fracture development stops, was accepted somewhat arbitrarily. Seemingly, P of 5-6 MPa does not exceed the real ranges; probably fracture formation stops even under higher P. If not, the expansion of fractures will continue, especially intensively during phase change L - vapor under preserved P (Table 2, inclusion 7). However, this supposition, like the other accepted by the author, cannot influence the conclusion about principal differences in type of decrepitation of inclusions of various composition and specific volume during the overheating.*

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*Overheating is called heating in excess of Th, here used for heating to T>Td.

To take into account the numerous factors determining the conditions of decrepitation of inclusions is a complicated problem and until now there is no complete mathematical equation for it. After M.O. Kliya and G.G. Lemmlein [105], value of internal P in inclusion necessary for destroying of crystal, may be calculated from the equation

$$P_{int.} = P_{ext.} + \frac{4}{3}\sigma - \frac{4}{3}\sigma\left(\frac{b}{a}\right)^3, \qquad (1)$$

where $P_{ext.}$ - external pressure, σ - mechanical properties of mineral, a - size of sample, b - size of inclusion.

The author [103], on the basis of studies of decrepitation of inclusions with LCO_2, found that the maximum internal P approaches a constant value and is equal 55-65 MPa or more, depending on the habit and dimension of the inclusion.

From PT relations of solutions of L inclusions trapped during growth of synthetic quartz and T of beginning of decrepitation, the minimum P for breaking inclusions was determined to be 80-85 MPa [150, 180, 188].

Yu.N. Pashkov and G.O. Piloyan [160] found the equation linking critical P inside an empty sphere (P_{cr}), radius of an inclusion (R_1), distance from center to outer wall of inclusion (R_2) and critical tension of breaking (σ_{cr}):

$$P_{cr} = \frac{2\sigma_{cr}(L^3 - 1)}{2 + L^3}, \text{ where } L = \frac{R_2}{R_1}.$$

If equation (1) is used for evaluation of pressure ($P'_{int.}$) necessary for decrepitation of vacuole when a>>b, i.e., for formation of decrepitated inclusions, it has the shape:

$$P'_{int.} = P_{ext.} + \frac{4}{3}\sigma,$$

because part $4/3\sigma(b/a)^3$ may be omitted. From this it appears that for crystals being only under hydrostatic pressure of mineral-forming solution, decrepitation of L inclusions is possible only when the difference between P of inclusion fluid and the external P equals the determined positive value ΔP:

$$\Delta P = P'_{int.} - P_{ext.} \qquad (2)$$

For quartz grains ΔP (for $P_{ext.}$ = 0.1 MPa, T = 300 to 400°C, inclusion dimensions 0.08-0.5 mm) obtained experimentally [150, 180, 188] corresponds to the minimum value of resistivity limit for breaking, which equals 85 MPa [197]. Close value of ΔP but for inclusions occurring in crystals (a>>b) may be obtained with use of formula (1), if σ equals minimum value of resistivity limit for breaking.

It follows from equation (2) that decrepitation of inclusions may occur in two ways: a) by increase of internal P in inclusion ($P_{int.}$) i.e., by overstepping of T of mineral formation (overheating); b) due to decrease of external P of solutions ($P_{ext.}$). Both modes of inclusion decrepitation may occur in nature and investigations should lead to find PT conditions of their origin in each specific geological object. Part of the inclusion solution during decrepitation is trapped as daughter inclusions in healed fractures, changing the initial density. Let us consider relations between Th of inclusions of water of different filling, occurring only under external P of mineral-forming fluid and formed during short-duration overheating (Fig. 23). Such analysis makes possible the reconstruction of PT conditions of decrepitation of L inclusions on the basis of their alterations. Inclusions altered in the process of decrepitation the author (after G.G. Lemmlein) calls "parent" inclusion, and those formed during healing of fractures by solution from parent inclusion - "daughter" inclusions; T_0, P_0 - temperature and internal pressure of solution at the moment of homogenization before decrepitation; T_1 - Th of parent inclusion; T'_1, $P'_{int.}$ - T and internal P of solution in inclusion at moment of inclusion breaking under external P 0.1 MPa; T", $P''_{int.}$ - minimum T and P of solution inside inclusion at moment of inclusion breaking under external P of mineral-forming solution; T'" - the highest temperature that influenced decrepitated inclusion; d_0, d_1, d_2 - isochores of (respectively) non-decrepitated inclusion and decrepitated inclusions.

Inclusions which, under external atmospheric pressure, decrepitate above Th ($T'>T_0$). 1. Inclusions before decrepitation homogenized in G phase. As appears from diagram (Fig. 23a), at T' the determined critical P' will be achieved and the inclusion will decrepitate (external P 0.1 MPa). Due to the addition of some volume to the original vacuole the solution density will decrease (d_1). Healing of break with formation of daughter inclusions (for this example Th of parent and daughter inclusions are equal) lead to the fact that Th of parent inclusion (T_1) will be lower not only than T of breaking (T'), but also than Th of inclusion before breaking (T_0), i.e., T'>T)>T_1.

External pressure of solutions increases the breaking temperature of inclusions. The T of beginning of breaking is the minimum T of natural decrepitation (T") which is higher than T. The difference T"-T is higher when the external P is higher and density of inclusion fluid is lower.

Natural healing (T'") of mineral-forming system may be higher than T" (of beginning of inclusion break) under a determined external P. Thus, $T'''>T''>T'>T_0>T_1$.

2. More complicated relations between T_0, T_1, T', T", T'" occur for inclusions homogenizing in L phase before breaking:

a) During breaking the phase state of the solution does not change (Fig. 23b): $T'<T''<T'''>T_1>T_0$. When aureoles of decrepitation are very small, the initial density of solution almost does not change and $T_1 \geq T_0$, i.e., decrepitated inclusions may be used for estimation of T of its trapping. If haloes of decrepitation are significant, T_1 is significantly higher than T_0 and it may approach T'". Dimension of haloes of decrepitation of inclusions (when all other conditions are the same) would be determined by difference T'"-T";

b) At T of breaking the inclusion solution becomes heterogeneous (Fig. 23c): $T_1>T'''>T''>T'>T_0$. Depending on original inclusion filling and size of the added volume, the parent inclusion may homogenize already in G phase (d_2);

c) At T of breaking the inclusion solution becomes G (Fig. 23d): $T'<T''<T'''>T_1$, T_0; and $T_1>T_0$ or $T_1<T_0$, depending on the volume added by decrepitated inclusion and its initial filling (isochores d_1 and $_2$).

Inclusions, which under external atmospheric P, decrepitate before homogenization ($T'<T_0$). Similarly as above, the relation may be found between T_0, T_1, T' and T" for inclusions, whose minimum overheating ($T'-T_0$) has a negative value. Under external P of mineral-forming fluids, temperature of break (T', T'") may be higher than T_0 and in such case the earlier presented relations are true.

From analysis of conditions of decrepitation of L inclusions there appears the following:

1. Decrepitation of L inclusions in nature may occur due to T increase (overheating) and also due to rapid decrease of external P of mineral-forming solutions.

2. Th of parent inclusions (T_1) with small haloes of daughter inclu-

sions are close to Th before decrepitation (T_0). Depending on initial filling of inclusions $T_1>T_0$ or $T_1<T_0$.

3. Th of parent inclusions homogenizing in L phase may approach Td or even be higher, however in all cases they are higher than Th of inclusions before decrepitation.

4. Homogenization of parent inclusion in L also proves a similar process before decrepitation, whereas homogenization in G phase not always proves its initial trapping from G.

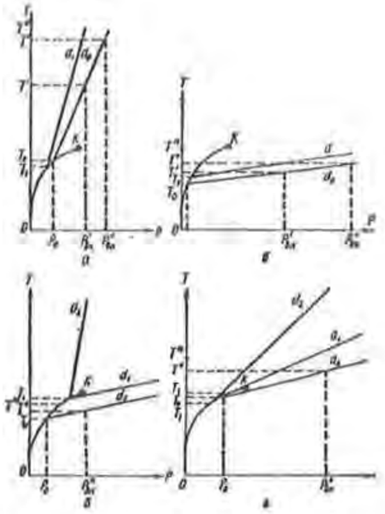
5. Studies of daughter inclusions may provide evidence about the true T of healing of fractures. Moreover, healing of fractures proves the authigenic nature [18] of the solution of decrepitated inclusion with respect to the mineral bearing it. This conclusion has important meaning during studies of decrepitated inclusions of non-aqueous inclusions.

Morphology of inclusions caused to decrepitate is determined mainly by the character of the distribution of the fractures around the inclusion. The vacuoles themselves usually change their habit little. Commonly, the healed fractures are plainly visible due to clusters of microscopic or submicroscopic daughter inclusions. Sometimes healing of fractures is incomplete and hence parent inclusions become ramified on their edges [...]. Unhealed but isolated (from the outside) fractures occur very rarely. Examples are found in the fractures in calcite around large inclusions during freezing of solution in subpolar areas.

Decrepitated inclusions were studied mainly in quartz and occasionally in other minerals (fluorite, calcite, beryl). Oriented and disoriented healed fractures were observed in quartz. The first ones usually are beaded by submicroscopic daughter inclusions and occur in planes parallel to faces of prism $\{11\bar{2}0\}$, and the negative and positive rhombohedrons. They occur around inclusions whose habit is close to that of negative crystals. The second ones are connected with inclusions of irregular habit, formed during healing of uneven surfaces of fractures and made of planes without determined orientation.

Orientation of fractures around L inclusions in quartz is determined not only by mineral structure but also by the habit of inclusions and their distribution. If parent inclusion is a negative prismatic crystal, daughter inclusions occur only in planes parallel to prism faces $\{11\bar{2}0\}$. In projection on (0001) plane these planes have the habit of trigonal bundles and are parallel to edges formed by faces of positive rhombohedron. Trigonal bundle of fractures in one of the vertices of L inclusion is turned over an angle of 60°C with respect to the second vertex (Fig. 24). Habit of such inclusions recalls the negative crystals with "hoods" described by G.G. Lemmlein [116]. Two more healed fractures parallel to face of the negative rhombohedron $(\bar{1}011)$ occur around inclusions of pseudocubic habit formed by faces of the positive rhombohedron, in addition to two trigonal bundles of fractures. Fractures parallel to faces of the positive rhombohedron form in special cases when the inclusions occur close one to another and significant overheating strongly deforms the quartz occurring between them with formation of rhombohedral blocks. Angles between the fractures measured with Fedorov's stage were equal 94 ± 30 and 86° ± 30°[sic, A.K.]. It is interesting that decrepitated inclusions in these fragments also have rhombohedral (pseudocubic) habit. As before, here also trigonal bundles of healed fractures occur. Around inclusions of irregular habit, the fractures usually are uneven surfaces; sometimes the trigonal bundles of fractures are observed around them.

Dimensions and morphology of fracture size of daughter inclusions and habit of the parent inclusions depend on: a) interval of natural overheating [126]; b) dimensions, habits and distribution of inclusions. Moreover, absolute dimensions of daughter inclusions depend on their position



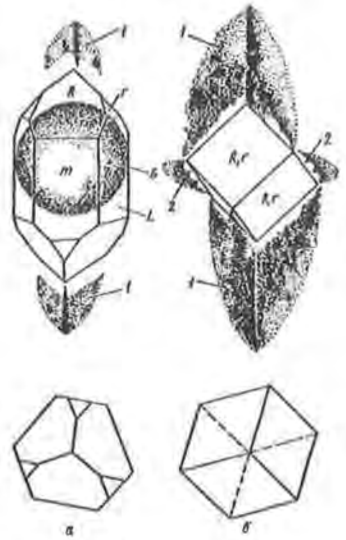


Fig. 23. Relation between T_0, T_1, T', T", T'" of aqueous inclusions in which decrepitation occurred due to short-time T increase (explanations in the text).

Fig. 24. Distribution and shape of healed fractures around negative crystals of prismatic (a) and rhombohedral (b) habits: 1 - submicroscopic daughter inclusions in planes parallel to faces of prism $(11\bar{2}0)$; 2 - same inclusions but distributed parallel to faces of negative rhombohedron $(\bar{1}011)$.

in the fracture.

Sometimes certain inclusions of the healed fracture are weakly decrepitated. This is caused only by differences in habit, size and distribution of inclusions, because external factors causing decrepitation are the same. Solution density in inclusions of the fracture is the same, only Th of the broken inclusions is somewhat higher than that of the others.

Neighboring inclusions often are joined by fractures during decrepitation. On healing inclusions of complicated habit form, sometimes filled in various degree. Inclusions also were found that have only large daughter inclusions and so the characteristic feature as a halo of submicroscope inclusions is absent. Parts of fractures immediately adjacent to the present vacuole of the parent inclusion of size 0.1-0.4 mm frequently bear relatively large daughter inclusions with distinctly varying phase composition. Their amount increases with increase of parent inclusion size. Thermometric studies of such inclusions make possible the determination of true T of fracture healing.

G.G. Lemmlein and M.O. Kliya [126] showed that fractures around inclusions during overheating usually are oriented parallel to cleavage of the crystal or, in general case, perpendicular to the direction of the weakest bond. It is interesting to compare the directions of quartz cleavage occurring most frequently with orientation of daughter inclusion planes.

G.W. Fernberg [vide 197] theoretically considered the possibility of obtaining of the imperfect cleavage in quartz and he arranged the following sequence of its diminution:

$$R(10\bar{1}\bar{1})>r(01\bar{1}1)>m(10\bar{1}0)>c(0001)>a(11\bar{2}0)>s(11\bar{2}1)>X(51\bar{6}1).$$

Cleavage along the prism a is in the fifth place, but most frequent breaks around inclusions are parallel to faces of this prism a$\{11\bar{2}0\}$, more rarely to r or R rhombohedrons, the best cleavage and the weakest bonds in crystal structure. Regular distribution of fractures with submicroscopic inclusions was noted also around P glass inclusions in high-T quartz of effusive rocks [122]. Data about habit of decrepitated inclusions in other minerals are almost lacking, detracting from the quality of reconstruction of history of forming of geological objects.

Aureoles of decrepitation around inclusions provide the possibility of obtaining additional data about the mode of T regime of mineral formation. The fact of decrepitation itself proves the episodes of T increase or sudden P decrease against a background of general gradual evolution of PT parameters. Th of daughter inclusions in decrepitation haloes may show the true T of fracture healing, because formation of such inclusions from homgeneous trapping occurred under conditions of two-phase equilibrium L-G (vapor). Detailed study of decrepitation haloes, growth zones of crystals and genetic types of inclusions makes possible the establishing of the relative age (sequence) of action of high-temperature solutions and [trapping of] inclusions. Also inclusions altered by breaking in certain determined cases may be used for estimation of PT conditions of crystallization [18]. These and other problems are explained also in the chapter about genetic significance of altered inclusions.

Alteration of inclusion morphology (necking-down, precipitation of substance on the vacuole walls, forming of negative crystals)

Thin fissures in minerals formed during crystallization and filled by parent solution, are disequilibrium systems with excess surface energy. Their healing develops due to loss of free energy according to the Curie-Wulf principle [118]. Experiments of G.G. Lemmlein and M.O. Kliya [125] show that due to dendritic growth, the fracture opening is divided into isolated fragments, in which the parent solution is trapped. These inclusions in the crystal are the subject of self-alteration as they obtain a more stable equilibrium habit. Negative crystals, i.e., a faceted cavity with morphology like the crystallographic forms of the host mineral (with its symmetry), that might form under conditions of equilibrium with parent solution, is for these inclusions the ideal habit, with minimum surface energy. If inclusion alteration occurs during T decrease, they may divide (neck down), and the G bubble or dms may remain in one of the isolated parts of inclusion and homogeneous solution in another. Finally, at room T, inclusions in the same healed fracture will have different phase and composition and they yield different Th (Fig. 25). Inclusion habit and composition of inclusion filling may also change due to precipitation from solution the same substance as host mineral on the vacuole walls. The first report about presence of rims of precipitated substance [on the walls of inclusions] were published by G.G. Lemmlein [116] and N.P. Ermakov [63]. G.G. Lemmlein [116] explains wide rims around inclusions in topaz occupying 50-70% of vacuole volume by precipitation from inclusion solution after its trapping and sealing. Such rims, according to N.P. Ermakov [63], formed during the process of inclusion formation before its sealing. He thought that very thin rims visible on the periphery of inclusions in quartz, topaz and other minerals, may dissolve during heating and precipitate again on cooling. Wide rims did not show such changes.

Special experiments made by the author with long heating of inclusions (up to 23 days) at Th or at T a little higher than Th did not reveal any change of either inclusion habit (also those with rims) or Th [88]. However, experiments in autoclaves under high external P of G (300 MPa) and T ~700°C caused melting of inclusion vacuole walls and increase in size of the vacuole [128]. Later the author, with D.K. Voznyak [20, 22], studied the detail inclusions with rims in topaz (Fig. 26). It was found that early S and P inclusions of this type formed from heterogeneous

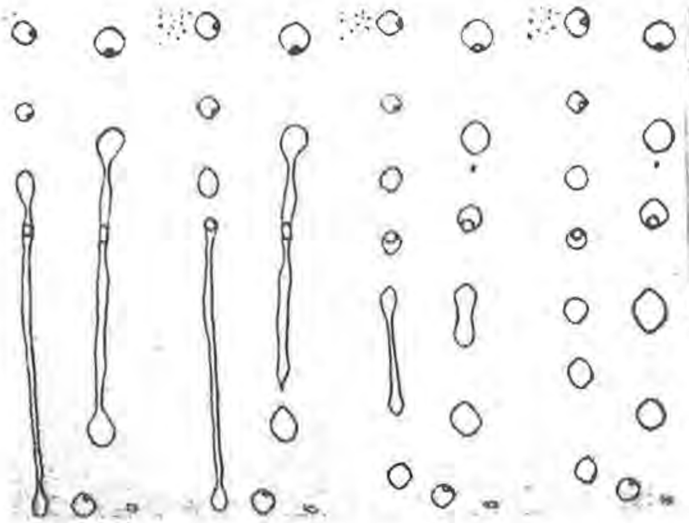
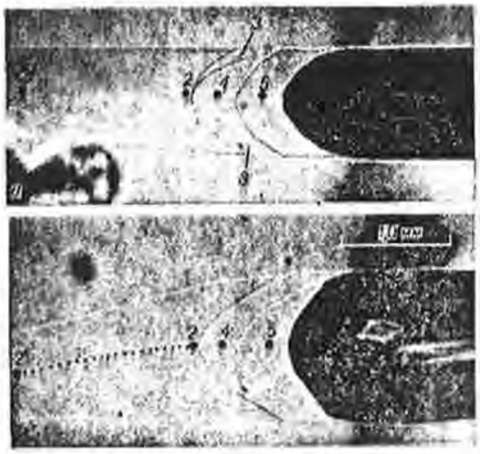


Fig. 25. Epigenetic alteration (necking down) of inclusions in sodium nitrate, x 275; a - immediately after cooling of preparation from 100°C to room T, b - after 3 hours, c - after 8 hours, d - after 21 hours.

Fig. 26. Inclusion in topaz in the plane of the cleavage, lined by a rim. Refractive index of rim is lower than refractive index of main part of crystal, x 300.

(boiling) solution. Hence Th and P of homogenization of homogeneous trapped inclusions (370-415°C, 30-40 MPa) are the true conditions of crystallization and heating of such inclusions to 700°C for reestablishing of initial parameters is not justified. This is confirmed by studies of syngenetic inclusion groups in numerous topaz crystals where solid phases occurring in inclusions were not authigenic but xenogenic substance (see Fig. 3). Moreover, relative topaz volume in rim around inclusions of the same type may range from 0 to 200% of the present volume of inclusion vacuole. There were found also cases of surrounding of two or several P inclusions by one common rim. In preparations cut perpendicularly to cleavage, the present vacuole always extends behind the rim. The face (001) of the vacuole looks like it "penetrated" the essential mass of topaz (Fig. 27, 28). These facts negate the possibility of precipitation of rim substance from an originally oversaturated solution, very concentrated with respect to topaz, sealed at that time. It is doubtful if crystallization occurred in stagnate conditions with the inclusion still not isolated from the surrounding fluid [63]. [sic] The facts prove that crystallization of low-refractive topaz ($n<0.001$), surrounding the inclusion occurred in isolated space of vacuole due to reprecipitation of mineral under action of factors tending toward minimum free energy of a negative crystal. This agrees with the regularities found by G.G. Lemmlein for inclusions in highly-soluble salts.

The author supposes that the process of achieving of negative crystal equilibrium state by the inclusion sealed in a crystal developed gradually and most actively under conditions of high T, and also gradually decreased with T decrease, and commonly did not obtain the ideal habit of a completely faceted vacuole. Of course, dendritic healing of capillary fracture with later formed S inclusions first developed relatively quickly, just as dendrites grew quickly in the wedge-shaped end of fracture in easily soluble salt [125]. This was connected with separation of vug of thin fracture into isolated inclusions, limited by straight parts of adjoining dendrites. The latter formed the regular limitation of vacuole contours, now marked by the external boundary rims. Next substance reprecipitated



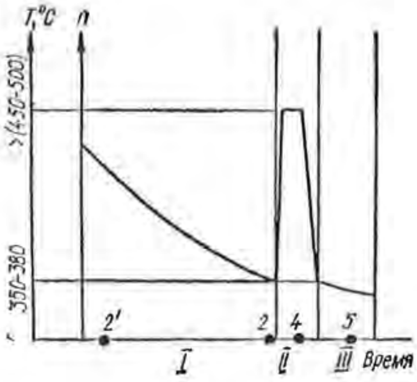


Fig. 27. Relation between form and distribution of topaz substance reprecipitated by solution of P inclusion, and T change and time (see Fig. 28). Only part of inclusion vacuole is shown, its G phase (dark); a - image in plane (001), b - image in plane (010).

Fig. 28. Relation between refractive index n of reprecipitated substance and T and time; 1-5 - zones of topaz with various refractive indices: $n_4 \geqslant n_1 \geqslant n_3 > n_2$; $n_1 > n_5$ (see Fig. 27); zone 4 fixes temporary T increment that is reflected in higher n, 1-111 - periods of topaz reprecipitation.

in the closed space (the second stage). But again the growth centers formed and grew from several points of the flat disequilibrium vacuole, yielding the pattern of "teeth-like" contours. This is proved by "teeth-like" intermediate lines inside the rims (see Fig. 26). The second stage, however, developed against a background of T decrease and increase of inclusions vacuole thickness, sharply diminishing the growth volocity of dendrite-like projections [125]. Their crystallization practically stopped later, without achieving the equilibrium habit of a negative crystal.

Migration of inclusions in a thermogradient field

The unusual phenomenon of migration of L inclusion toward a heat source was first noted in crystals of sodium nitrate by G.G. Lemmlein [122]. Next Ya.Ye. Geguzin [29], using NaCl* and KCl, studied the process of change of inclusion habit and velocity of inclusion migration in a thermogradient field.

Although the velocity of such alteration for natural minerals is much less than for experimentally studied salts, the duration of natural processes makes visible the consequence of this process. Hence, milky-white quartz of the inner core of zanorysh pegmatites of Volyn' in zones

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*Also studied in natural salts by E. Roedder and H. Belkin, 1980, Thermal gradient migration of fluid inclusions in single crystals of salt from the Waste Isolation Pilot Plant site (WIPP), 453-464, in Scientific basis for nuclear waste management, vol. 2, C.J.M. Northrup (Editor), Plenum Press, New York, and same authors, 1980, Migration of fluid inclusions in polycrystalline salt under thermal gradients in the laboratory and Salt Block II (abst.). Proc. 1980 National Waste Storage Program Information Meeting, ONWI-212, 361-363, see also E. Roedder, 1982, Application of studies of fluid inclusions in salt samples to the problems of nuclear waste storage, Acta Geol. Polon., v. 23, no. 1-2, p. 109-133.

of fracturing, when submitted to activity of mineral-forming solutions of T>T of wall rocks, becomes transparent around fractures due to the elimination of G/L inclusions. Similar results are observed during the overlapping high-T processes on semitransparent vein quartz of hydrothermal formations.

Genetic significance of altered inclusions

Certain investigators [66, 67] categorically denied the significance of epigenically altered inclusions for obtaining information about conditions of mineral genesis. Presently, the gradual change of opinions may be observed [70, p. 40-43]. However, in mineral genetic practice the important data about mineral origin and association, that may be derived from studies of inclusions that are decrepitated, refilled, or with altered habit, is still used very rarely. For this reason below the reader may find examples, showing the very interesting and valuable results of properly performed studies of altered inclusions in minerals of Volynian pegmatites; the studies were made by the author with D.K. Voznyak.

The method of determination of relative age of crossing fractures on the basis of inclusions occurring in them, was widely used by the author at the Volyn' and Donbass geological sites [91, 103]. Crystals of quartz and topaz, where the distinct features of groups of S inclusions may be observed, are most useful for reconstruction of the sequence of origin of inclusions of various age. Normally formed large crystals of quartz from Volyn' pegmatites have a zonal structure. From crystal center to its periphery the following quartz zones are visible, 1) icy, smoky and morion or 2) "reticulate" (result of healing of contraction fractures during inversion from high to low quartz), icy, smoky and morion (Fig. 29). Changes to smoky and morion color are gradual, and from "reticulate" to icy and smoky-sharp. Moreover, broken fractures in crystals (and platy chips of blocky quartz) are regenerated by colorless transparent quartz. Colorless quartz forms also a thin external zone on the crystals. Rarely crystal faces have very thin, discontinuous envelope of amethyst.

In certain pegmatite bodies quartz crystals have the normal zoning disturbed. Usually in their central part the large chips of earlier varieties occur - "reticulate," "banded" or icy quartz. Structure of one of such crystals is shown schematically in paper [21], where, moreover, the age relations between main inclusion types are shown, confirmed by respective refillings. Characteristic features of the ten main types of inclusions distinguished in quartz, showing their generalized systematics on the basis of studies of numerous pegmatite bodies of the region, is quoted in the age sequence from earliest to latest in Table 3. The types of inclusions found have their analogs also in other minerals (topaz, beryl, fluorite).

Figure 18 shows the sketches of most interesting and important cases of refilling of inclusions in quartz.

The following inclusions display the most clear connection with growth elements of quartz crystals: 1) early S inclusions of "reticulate" quartz that occurs in the root part of quartz crystals, 2) P, tubular inclusions occurring in the zone of regeneration of crystals by transparent quartz. These groups of inclusions are the starting (fixed points) for determination of the relative age of the other inclusions. "Reticulate" inclusions having the habit of negative crystals, are refilled by solutions which correspond to essentially G faceted inclusions (L 30 to 40%), complex CO_2 inclusions (see Fig. 18a), G/L with L 95 to 97% (Fig. 18b) and one-phase L inclusions. Solutions of all those inclusions were trapped later than fluids that healed "reticulate" fractures in high-T quartz.

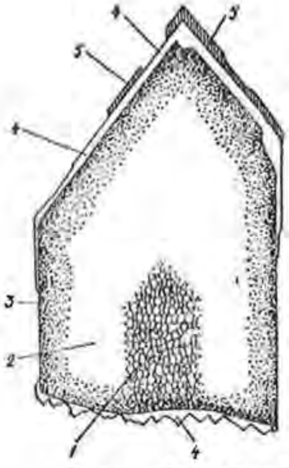

Fig. 29. Scheme of zonal structure of morion crystals from zanorysh pegmatites of Volyn': 1 - "reticulate" quartz, 2 - icy-transparent quartz, 3 - morion, 4 - colorless regeneration quartz, 5 - amethystine quartz.

P complex inclusions of CO_2 formed from heterogeneous (boiling) solution and S inclusion corresponding to the previous ones with their composition, are opened by fractures with G/L (L 70 to 80%, see Fig. 18h), essentially G (L 1 to 2%, see Fig. 18k), G and essentially L (L 95 to 97%, see Fig. 18j) inclusions. They are younger than inclusions with LCO_2. Age relations between the inclusions listed above may be also well established from the refilling phenomena (Fig. 18j, k). Fractures with inclusions of CO_2 refill decrepitated inclusions with haloes of daughter inclusions (L = 40%, see Fig. 18d) and polyphase decrepitated inclusions (see Fig. 18e), i.e., two last groups, intermediate between the "fixed points." Age relations between G>L and polyphase (with dms) inclusions are shown in Fig. 18c, f, g. All S inclusions in quartz crystals are early S, with the exception of, possibly, those which formed after sealing of complicated vacuoles with LCO_2 (late S).

Determination of the phase state of mineral-forming solutions from inclusions homogenizing in G phase, as it was already mentioned, is ambiguous. One may suppose that before formation of polyphase (with dms) inclusions crystallization occurred from dense G solution close to the critical state. After this, as it appears from fracture crossing and traces of healing, hydrothermal L solutions prevailed, almost in all stages being in the state of two-phase equilibrium (boiling). Earlier the author found such state of mineral-forming solutions of zanorysh pegmatites and the presented sketches of refilling confirm this (see Fig. 18c, f-h).

Sequence of inclusions show significant variations of total solution concentration and its individual components, as well as pH of inclusions. Solutions of "reticulate" inclusions are weakly acid (pH 6.3 to 6.9). The relatively low total salt concentration was found in solutions of this type, equal 7.3 ± 0.8%. Earlier concentration of solutions in those inclusions was thought to be several times higher [50]. Relatively low-concentration alkaline solutions (see Fig. 18c, d) were followed by highly-concentrated acid solutions of polyphase inclusions (Fig. 18c, f), which next were replaced by more dilute alkaline solutions with LCO_2 (see Fig. 18e) and filled in various degree G/L inclusions with L 70-80% (Fig. 18c, h). Change of concentration of solutions of inclusions with dms is well recognizable from refilling (see Table 3). Solutions of complex CO_2 inclusions trapped by crystal at final stage of mineral genesis again are replaced by solutions of late S low-T inclusions, more saturated with salt components (Fig. 18i-k).

Crystallization of quartz occurred under conditions of general T decrease and against this background sharp decreases and increases appeared, caused by disturbances of normal evolution of the physico-chemical

Table 3. Characteristic features of different age types of liquid inclusions in quartz, in age sequence [from earliest (top) to latest (bottom)].

Quartz generation, that still contains inclusions of a given type	Type of inclusions	Features and composition of inclusions considered in the age sequence
Blocky quartz	Not detem.	G, G>L, G<L, G+solids etc., hardly are to be systematized in age sequence.
"Reticulate" quartz	1	Early secondary, G/L (LH_2O 25-40%, pH 6.6, Th 380-410°C in G phase).
	2	Early S solid>G and G>solid (trapped minerals: topaz, microcline, etc., up to 90-95% of vacuole), pH 5.2-5.4.
"Banded" quartz	3	Early S, G/L (LH_2O 35-40%, pH 7.8, Th 390-395°C in G phase).
Icy, smoky, morion ("patchy" quartz)	4	Early S and P, G/L (LH_2O 25-40%, pH 7.8-8.2, decrepitated, Th 420-435°C in L phase[sic, A.K.]. Th of daughter inclusions 350-360°C in L phasa; in solution ions Mg, Fe^{2+}, Fe^{3+}, Mn were not found).
	5	Early S, families of polyphase inclusions filled to various degree, bearing 1-2 and more dms (NaCl, KCl, elpasolite, cryolite, $FeCl_2 \cdot 2H_2O$, etc.), relation L:G:solids varies from 80:15:5 to 30:30:40, pH 5.2-5.6, Th 250-500°C in L phase, Fe = 7%, found Mg. Typical in one inclusion family both polyphase L and essentially G inclusions are present. The subtypes of inclusions were distinguished: 5a - L (50 to 65%) + solids (20 to 25%) + G (15 to 20%), sometimes weakly decrepitated, occur together with G>L inclusions L (10 to 30%) + G (70 to 90%), Th 340-350°C; 5b - solids (40 to 45%) + G (30%) + L (20 to 30%), Th 450-500°C and higher. Syngenetic essentially G inclusions + L (2 to 5%) + solids (2 to 3%). 5c - L (90 to 90%) + G (10 to 15%) + solids (5 to 8%), Th 200-250°C in L phase, sometimes decrepitated.
Transparent quartz of zones of crystal regeneration	6	P tubular inclusions with $LCO_2:LH_2O:G$ = 15:5:90 at +15°C, pH 7.4-7.6 to 8.0, Th 260-300°C in G phase. Mg, Fe^{2+} and Fe^{3+} are absent.
	7	P, G/L (L 80 to 85%) Th 230-240°C. Inclusions of types 6 and 7 are coeval one with another and they fix the heterogeneous state of solutions (...), P 23-25 MPa.
	8	S (early S), complex inclusions of CO_2, Th 300-320°C, P ~25 MPa.
	9	S (early S), G/L (L 70 to 30%), pH 7.4-7.8 to 8.1, Fe^{2+} and Fe^{3+} are absent, Mg-traces.
	10	S (late S), G/L (L 90 to 95%), pH 5.5-6.7, Fe^{2+} and Fe^{3+} not found, noticeable amounts of NaCl, Ca, Mg, K, and SO_4, total salt concentration in inclusion solutions about 17%.

system of the pegmatite. Formation of "reticulate" quartz marks the borderline of two stages of precipitation of this mineral: pre- and post-inversion (Fig. 30). T of high-low quartz inversion under normal P is equal 573°C. It may exceed this value under high P or it may vary in certain ranges for reason of presence of admixtures of Al, Li and Ge. Study of quartz shows that inversion T is in ranges 570-620°C. Thus, crystallization of the earlier, blocky quartz occurred at T ~600 to 700°C. Concluding from distribution of syngenetic zones of "reticulate" quartz in root zones of morion cyrstals, essential mass of monomineralic blocky zone formed just in this stage. At T<570-620°C, zanorysh crystals essentially formed (morion, topaz, etc.). From the age sequence of inclusions, T decreased from 570-620°C ("reticulate" inclusions) to 80-100°C (one-phase liquid and G/L inclusions with L 95-97%), with two distinct T increases against a background of general gradual T decrease.

Maxima in the T line (Fig. 30) are connected with important changes of parageneses in pegmatite crystallization and they are detectable not only from Th, but also from the type of decrepitation and alteration of habit of successively formed inclusions.

Inclusions of types 1-4 (see Table 3) bear L and G phase in a similar ratio (about 2:3); they are characterized by similar salt concentration of solutions and narrow Th range (380-435°C) in G phase. This proves the gradual change of PT parameters of mineral-forming fluid. Later mineral-forming solutions differed by heterogeneous state and high salt concentration. Fracture crossing shows that parent solutions of polyphase inclusions of type 5b had higher (>500°C) T (true T are here determined as Th due to solution boiling) than parent solutions of polyphase inclusions of type 5a and G>L inclusions of type 4, taking into account the relatively low P of the crystallization medium. That was the first T maximum. The second maximum was determined from the true T of type 6-9 inclusion trapping from heterogeneous fluid. T of trapping of inclusion types 8 and 9 was 70-80°C higher than T of trapping for earlier inclusion types 6 and 7.

Inclusions with decrepitation haloes show more dramatically time and conditions of episodic T increase. Decrepitated inclusions were observed in all groups, except the P and S complex CO_2 inclusions (types 6 and 8) and inclusions type 10. However, the decrepitation haloes are not the same in size for various inclusions in quartz of a given pegmatitic body or for various pegmatites of this region. This depends first on the presence or absence of inflow of high-T fluids to a given pegmatite and how intensive was that inflow. Decrepitated inclusions were not found in some pegmatites. Sometimes only in inclusions with L = 40% were haloes of daughter inclusions found; notably, these inclusions always are most altered by this process. As a result, the altered inclusions of this type have the following features: a) in family of syngenetic inclusions of the same composition and filling, the cloudy haloes are proportional to inclusion dimension, but in tiny inclusions frequently no such haloes are found (those inclusions resist higher T of overheating); b) syngenetic inclusions of various degrees of filling have haloes of various size, and the haloes even may be absent; c) syngenetic inclusions of the same filling and composition in healed fracture of large dimension do not show differences in decrepitation haloes, even taking into account the various depths of their positions in crystal (with respect to growth zones or faces).

The relative time of the first T increment and respective inclusion decrepitation developed after formation of the type 4 inclusions and before trapping of type 5c inclusions and crystallization of regeneration quartz, bearing in the root parts P complex CO_2 inclusions of type 6. This is confirmed by the following observations. As was mentioned above, inclusions of type 4 are most subject to decrepitation. The earlier inclusions of "reticulate" quartz rarely have decrepitation haloes. The decrepitated type 4 inclusions refilled by solutions of polyphase inclusion type 5 solutions, in one case have decrepitation haloes (see Fig. 18c), in other cases not (Fig. 31). This proves that crossing of them by fractures with inclusions of type 5c occurred later than decrepitation, and by fractures with inclusions of types 5a and 5b - before decrepitation. Although sometimes around inclusions of type 5a also there are fine haloes, but then refilled by this solution inclusions of type 4 are surrounded by very fine cloudy haloes; non-refilled inclusions of type 4 have large decrepitation haloes.

The earlier T increase than crystallization of regeneration quartz is indicated by limitation of decrepitation haloes of inclusions of type 4 in a newly-formed zone of the mineral; on the basis of the latter zone the tubular vacuoles of type 6 inclusions develop frequently from places of its contact with the haloes (Fig. 32). Decrepitated type 4 inclusions, refilled by solution of complex S CO_2 inclusions (type 8), have the same haloes of daughter inclusions as the non-refilled ones (see Fig. 18d). If one takes into account that in inclusions of type 8 the haloes are absent, such crossing undoubtedly proves that decrepitation of G>L inclusions of type 4 (L 40%) occurred before their refilling.

The second T maximum is connected with the activity of solutions

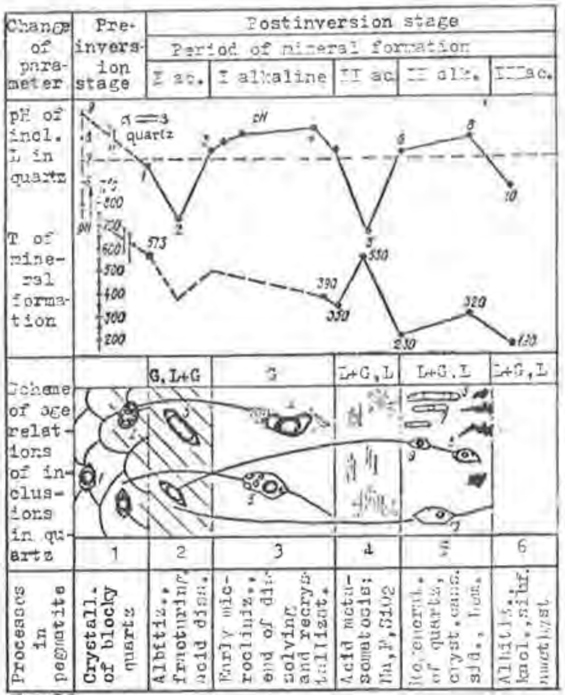

FIG.30
1 - "reticulate" quartz, 2 - "banded" quartz, 3 - icy and smoky quartz, morion 4 - patchy quartz, 5 - colorless quartz, 6 - amethyst, opal; ac = acid

Fig. 30. Scheme of evolution of pH and T during formation of Volyn' pegmatites in the post-inversion stage, from the data of investigation of essential types (1-10) of inclusions in quartz [146]. (Translation not available at press time.)

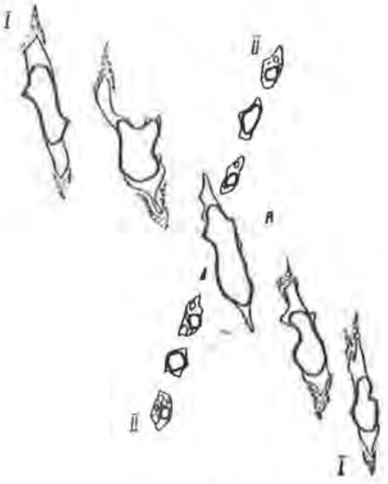

Fig. 31. Crossing of various-age fractures, next healed, with decrepitated (I-I) and polyphase (II-II) inclusions filled to various degrees. Absence of cloudy halo around refilled inclusion A points the earlier refilling than decrepitation.

Fig. 32. Scheme of distribution of early S decrepitated and P tubular inclusions in the contact of morion (G) and later colorless regeneration quartz (D). Numbers refer to inclusion types as in Table 3, L_1 - water solution.

respective to inclusions of types 8 and 9. The solutions caused decrepitation of inclusions of type 7 and possibly 5c.

The convincing fact, confirming the episodic T increment, may be the discussed reprecipitation above of topaz substance around inclusions in that mineral. During careful observation in blended light the rim of low-refraction topaz appears nonhomogeneous. Moreover, in the distribution of inhomogeneous areas and contrast of lines, the regularly determined outer part of the rim (see Figs. 3 and 27) becomes more and more contrasty approaching the inclusions, that proves the gradual change of optical properties of reprecipitated topaz. Closer to the inclusion several more zones of topaz with various refractivity may be seen (see Fig. 28). The [variations of] 2V of reprecipitated topaz in various parts occurs in the ranges of measurement error, thus, difference in the indices of refraction of topaz does not exceed 0.002-0.003.

Because the inclusion alteration occurs in vacuoles isolated from the external medium, the reasons of alteration may be only internal intensive factors plus T. General T decrease led to increase of fluorine ion activity and this way to more intensive (in comparison with OH group) entering the topaz structure, causing the decrease of refractive index of reprecipitated mineral [113]. On the other hand, the origin of rim band of type 4 (see Fig. 27) with higher refractive index indicates the sharp T increase in the crystallization medium of the pegmatite. The insignificant amount of substance disturbing the smooth decrease of refractive indices and its place in the reprecipitated mass of topaz indicate that the T increase was short in time and occurred in the end of pegmatite formation. This T increase is sharply marked against the background of evolution T decrease.

KULIKOV, I.V., DEVIATOV, V.E. and GROMOV, A.V., 1982, A new natural compound - calcium fluoride-chloride: Izvest. Vyssh. Uchebn. Zaved. Geol. Razved., v. 25, no. 7, p. 120-122 (in Russian).

During the study of the solid phase of large (0.1-1, sometimes up to 1.5-3 mm.) multiphase inclusions in fluorite of the Tyrny Auz Mo-W deposit (northern Caucasus), there was found a flattened crystal (0.12 mm. in diameter) of a colorless, birefringent daughter mineral, which proved to be a compound previously unknown in nature, calcium fluoride-chloride (CaFCl).

The studied crystals of fluorite of octahedral habit are rich in primary inclusions of highly concentrated mineral-forming solution-brine, occupying sometimes up to 5% of the volume of the mineral host. Most of the inclusions, besides the gas and liquid phases (not more than 20-30 vol.%) contain many daughter minerals, differing in form and size of deposit, color, indices of refraction, magnitude of birefringence, and other optical properties. During heating, the solid phases dissolve, some up to the moment of the disappearance of the gas phase, other after it. The temperature of complete homogenization of the primary inclusions is 650-800°C and more (1, 2, 3). If all the solid phases are dissolved in the liquid preserved in the inclusions, the concentration of such a brine attains 60-90% ($CaCl_2$+NaCl+KCl+$FeCl_2$), found by a direct method (2); according to indirect methods it is also known that the brines also contain silicon, aluminum, sulfur, and CaF_2.

The largest inclusions were opened, and the solid phases contained in them, together with unavoidable droplets of mother brine, were extracted by means of a steel needle on a microscope slide. From these microcrystals there was prepared a sample by the method of rolling a globule of rubber cement, from which there was obtained a powder pattern by the Debye method. The samples were photographed in the RKD-57.3 X-ray camera, FeK_α radiation in the URS-60 apparatus (current 6MA, voltage 40kV, FeK_α radiation, time 9 hours). As shown by deciphering the x-ray patterns, the usual daughter-minerals in the described inclusions are halite, calcite, magnetite; often occurring are fluorite, sulfides, and graphite. For each of the microminerals there were obtained up to several distinct powder patterns. Sphalerite, cubanite, pyrrhotite, arsenopyrite, sylvite, chlorite, ankerite, tungstenite, and CaFCl were found, according to the identity of powder patterns for each of them (in all, 54 powder patterns were made). Some minerals in the inclusions were found in intergrowths (sphalerite and chalcopyrite, sphalerite and calcite); besides there were recorded two x-ray amorphous minerals of unknown composition. Such data on microminerals of fluid inclusions of fluorite were first obtained in (2).

Table (p. 121)

Interplanar spacings of CaFCl, extracted from fluid inclusions in fluorite, compared with data of ASTM

ASTM no.24-186		Data of authors				ASTM no.24-186		Data of authors			
		First photograph		Repeated photograph after 1.5 months				First photograph		Repeated photograph after 1.5 months	
I/I_1	d/a	I	d/a	I	d,A.	I/I_1	d,A.	I	d,A.	I	d,A.
10	6.81	-	-	-	-	16	1.5621	3	1.565	-	-
9	3.409	1	3.42	-	-	25	1.5502	3	1.550	-	-
6	3.377	2	3.19**	8	3.18**	5	1.4497	0.5	1.465	-	-
-	-	3	2.82*	4	2.83*	8	1.3821	0.5	1.388	-	-
50	2.751	3	2.75	1	2.72	11	1.3757	0.5	1.379	2	1.373**
100	2.564	10	2.57	-	-	9	1.3643	-	-	-	-
2	2.275	-	-	-	-	2	1.2875	-	-	-	-
50	2.142	5	2.14	1	2.14	-	-	1	1.26*	2	1.26*
-	-	2	1.995*	3	1.995*	5	1.2302	1	1.230	-	-
17	1.963	1	1.96	10	1.94**	5	1.2227	1	1.223	-	-
35	1.945	4	1.94	-	-	11	1.2184	1	1.218	-	-
4	1.754	-	-	-	-	8	1.2124	1	1.213	-	-
-	-	1	1.655**	5	1.655**	6	1.1576	1	1.157	1	1.152*
5	1.691	-	-	-	-	12	1.1172	2	1.118	4	1.120**
-	-	1	1.625*	1	1.63*	5	1.0290	1	1.029	2	1.052**

* lines coinciding with lines of halite

** lines coinciding with lines of fluorite

The calcium fluoride-chloride, found by x-ray analysis, occurs in close intergrowth with halite, and probably also with a small amount of fluorite. Together with it in the same vacuole occur halite, fluorite, magnetite, and some other minerals, not identified by us because of their small size. The interplanar spacings for the calcium fluoride-chloride are given in the table, along with standard ASTM data.

As is well-known, calcium, fluorine, and chlorine are widely distributed and often are principal elements of the (operative) mineral-forming medium. Nevertheless, a mineral of this composition has not been reported previously. On the one hand this is connected to the fact that the compound CaFCl is unstable in air (ASTM, no. 24-186). Repeated photographs of our sample of CaFCl after 1.5 months showed that the mineral had decomposed and that on the x-ray pattern there appeared distinct lines of CaF_2. On the other hand, it may be explained by the fact that for the formation of calcium fluoride-chloride it is necessary to have unusually high temperatures for hydrothermal conditions.

The colorless material CaFCl[1] was synthesized in the U.S.A. from equimolar mixtures of CaF_2+CaCl_2, purified and dried at high temperatures (4). The mixture was held at 820° for 16 hours and then cooled to room temperature. In the final product of calcium fluoride-chloride there was present a small admixture of CaF_2 (4, 5). Analysis of the ternary system $CaCl_2-CaF_2-CaO$, studied by (5), showed that the crystallization of the phase CaFCl occurred in the interval 735-625°. The latter temperature is that of the eutectic $CaCl_2-CaFCl-CaO \cdot 2CaCl_2$. In this system, studied experimentally, water, which lowers the temperature of crystallization, was absent. Judging from the character of the inclusions of fluorite, in one of which the solid phase CaFCl was found, the medium of crystallization was a brine, similar in properties to a melt with low viscosity, containing not more than 10-20% H_2O. Nonetheless, the relatively high concentration of silicon, aluminium, and iron in this brine permit one to state that the finding in inclusions in fluorite of the compound CaFCl, previously unknown in nature, confirms the high temperature of formation of these inclusions

(650-800°). The unusually high temperatures of formation of this fluorite are confirmed by other data, for example by the sharp, extreme impoverishment of the Tyrny Auz fluorite in rare-earth elements (1), and also the complete similarity of the gas-salt composition of the inclusions of fluorite with the chemical composition of some high-temperature metal-bearing subsurface brines of many geothermal regions, the temperature of which sometimes already at depths of 2-3 km. are about 400° (2). Besides, brine with concentration up to 60-90% cannot exist in homogeneous liquid form at lower temperatures (2). Consequently, the new natural compound CaFCl can, probably, be used as a mineral thermometer.

Literature

1. Vasil'kova, N.N. and others, Fluorite, an indicator of conditions of formation and zoning of scheelite-fluorite mineralization of Tyrny-Auz. Mineral. Zhurnal. V. 2, no. 6 (1980).
2. Kulikov, I.V., Mineralogy and genesis of scheelite-sulfide-mineralization of Tryny-Auz deposit. Abstract of dissertation for degree of candidate geol.-mineralog. science, Moscow: MGRI, 1981.
3. Mel'nikov, F.P., Kulikov, I.V., and Gromov, A.V., Multiphase inclusions in fluorite of Tryny-Auz deposit, Deposited in V.I.N.I.G.I., no. 3965-79, Moscow 1979.
4. United States National Bureau of Standards. Monograph 25, Section 10, Nov. 1972.
5. Wenz, D.A., Johnson, I., Wolson, R.D. $CaCl_2$-CaF_2-CaO System. J. Chem. Eng. Data 14, 250, 1969.

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1/ Handbook data of calcium fluoride-chloride (4). Structure: tetragonal, $\bar{P}4/nmm$ (129), Z = 2, isostructural with matlockite; the structure of matlockite (PbClF) was determined by Nieurenkamp and Bijvoet (1932) (4). Density 3.039 g/cu.cm. (calcd.) Unit cell parameters, a 3.8911, c 6.8228A.

(Translation courtesy Dr. M. Fleischer)

SHUGUROVA, N.A. and SHOKHONOVA, L.A., 1982, Methodology recommendations for gas phase analysis of individual inclusions in minerals, in N.P. Ermakov, ed., Thermobarogeochemistry in Geology - Materials of the Sixth All-Union Symposium on Thermobarogeochemistry: Vladivostok, Far East Sci. Center, Acad. Sci. USSR Pub. House, p. 151-156 (in Russian).

Until now the analysis of gases in inclusions is performed most precisely for gas bubbles of diameter >0.06 mm. So large inclusions are typical mostly for hydrothermal minerals. However, dimensions of the majority of inclusions from magmatic and metamorphic minerals are smaller than 0.06 mm. This feature complicates the gas analysis. Additional complications appear in the observation of gas sorption and measurements of bubble dimensions, that decrease the accuracy of the volume percent values for individual components. The most important problem is the precise measurement of initial bubble size (>0.06 mm), especially for rapidly absorbed gases (H_2S, SO_2, HCl, HF, NH_3) and their various mixtures. Such measurements have to be made not in moment of inclusion opening, because this is practically impossible, but after certain time (10-15 sec.).

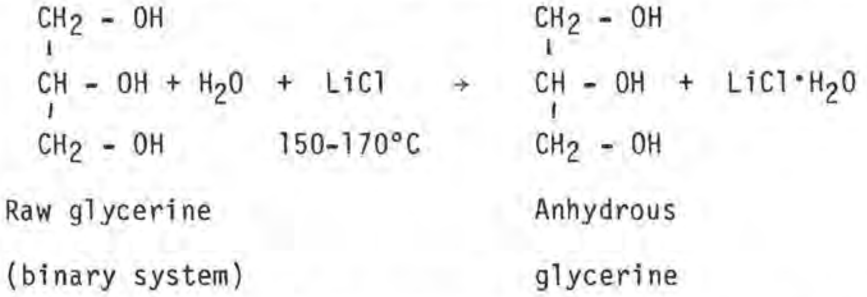
The essential principle for the choice of an inert liquid is not known presently. Physical nature of absorption process is explained by so-called film theory. Separation surface between L and G should be imagined not as geometric boundary but as thin layer (few molecular diameters).

Gravitation tends to separate G from L, forcing the bubble movement toward the surface, and L from the bubble walls - to flow down to the essential mass of L. Surface tension causes coalescence and bubble disappearance. All this finally causes interruption of L layer.

The higher the viscosity, the lower the velocity of decrease in bubble size and the process becomes self-inhibiting. Frequently viscosity of L layers is higher than the viscosity of the main mass of L, sometimes due to the fact that the layer has lower T (because of evaporation from its surface, sometimes due to influence of solution concentration (floating or dissolved particles move toward the phase boundary and cause usual or anomalous increment of viscosity). However, in most cases the viscosity increase cannot be explained.

Selecting the inert liquid for gas analysis, the authors studied the properties of 21 liquids and 15 compositions of glycerine mixtures. Most appropriate is a glycerine solution bearing 25 g of dried LiCl per 150 g of glycerine (Louri 1943). Admixture of LiCl is necessary to increase the aggregate stability of glycerine[sic].

During saturation of glycerine with LiCl, according to opinion of chemists, the crystalhydrate $LiCl \cdot H_2O$ forms and glycerine loses its water:



$$\begin{array}{lll} CH_2-OH & & CH_2-OH \\ | & & | \\ CH-OH + H_2O + LiCl & \rightarrow & CH-OH + LiCl \cdot H_2O \\ | & & | \\ CH_2-OH \quad 150\text{-}170°C & & CH_2-OH \end{array}$$

Process of glycerine dehydration goes gradually, without change of its structure. Forming of crystalhydrates during dehydration stabilizes glycerine and thus increases its viscosity. Crystalhydrate of LiCl also improves stability and decreases fluidity of glycerine at elevated T. Viscosity changes but gradually, not abruptly. Addition of LiCl precludes the sorption of moisture from air by glycerine (Rebinder 1936, Rebinder, Trapeznikov 1938). An opinion exists that with T increase, viscosity of glycerine saturated with LiCl strongly decreases and this affects results of measurements of gas bubble volumes. For evaluation of this condition the authors determined viscosity of glycerine and LiCl-saturated glycerine with use of viscosimeter VPZh-1. During T increase from 24°C to 30°C viscosity of glycerine saturated with LiCl decreased insignificantly, from 1250 to 1240 mPa x sec (Fig. 1).

In a series of experiments with small bubbles, the velocity of absorption was measured for CO_2, H_2S (Fig. 2) and HF, HCl, NH_3, SO_2, $H_2S+CO_2+SO_2$, H_2S+CO_2 (Fig. 3), and plots of absorption were made. Solubility of O_2, N_2, CO, H_2 and CH_4 in glycerine is minute in the authors' opinion and it cannot disturb the analytical determinations.

The analysis sequence remains as before with certain modifications. For gas extraction the mineral specimen with the studied inclusion is put on the lower lens with 2-3 drops of LiCl-saturated glycerine. Next inclusion is opened and immediately timer is started. Results are arranged in the table (p. 337)

Initial diameter of gas bubble is determined either graphically (from values D_1, D_2, D_3, D_4 - method of smooth curves) or mathematically (external value of argument):

Table

min.:	1	2	3	4
D_0 (diameter*)	96.5	83.5	74.0	64.0
$\sqrt[3]{D_0(y)}$**	4.57	4.37	4.2	4.0

*Most probably diameter, but not explained in the paper;
**Expression not explained directly in the paper, probably should be $\sqrt[3]{D_0}=y$. (A.K.)

$$\sqrt[3]{D_0} = \frac{2y_1+y_2-y_4}{2} = \frac{2\cdot 4.57+4.37-4.0}{2} = 4.75$$

The obtained calculation and graphic data should agree within the measurement error limits. Thus, the possibility exists for calculation of percent content of individual gas components with sufficeint accuracy. Deviations from [a smooth] experimental curve on a time plot indicate the presence of gas mixtures.

Gas components SO_2, HCl, HF, H_2S and NH_3 are given as a total value (Fig. 3). Separate quantitative determination from a small bubble is not now possible, only qualitative determination is possible.

For qualitative analysis of gas components the authors used a ultramicrochemical method. During crushing of the studied plate it is necessry to check initially the absorption of the above (acid) gases. If their content is significant, the bubble is sorbed quickly. If such gases are absent, bubble volume does not change and it may be analyzed by the usual methods.

For determination of gas content by the usual methods, the series of experiments was performed for definition of possibility of separation of H_2S from CO_2 in gas mixture. For practical determination of percent content of H_2S and CO_2 separately, a nomogram was plotted (Fig. 4). Smoothing of empirical values of H_2S and CO_2 contents was made by the method of a simple sliding average (Plokhinskiy 1961). The obtained relation was complex non-linear, because practically it is impossible to prepare gas bubbles with exactly needed diameters from various mixture of H_2S and CO_2. Absorption of CO_2 in cadmium acetate depends on quantitative relation of H_2S and H_2O. The new data obtained agree exactly with points found earlier (1968). Absorption of CO_2 for gas bubbles of dia. 70 μm in $Cd(CH_3COO)_2$ does not exceed 25% of gas bubble volume. For small bubbles (57 to 10 μm) absorption in glycerine equals 75-84% and during the placing of the bubble in $Cd(CH_3COO)_2$ is 15% for bubble dia. 10 μm, 21.8% for bubble dia. 100-280 μm and 25% for bubble dia. 70 μm[sic].

Nomogram is plotted for 23 gas mixtures prepared in laboratory.

Considering the results of studies for improvement and checking of the method, we conclude the following:

1. The inert liquid: LiCl-saturated glycerine, is used correctly. Principle of the method for analytical determination remains as before.
2. The improved method of analysis of gas phase of inclusions in minerals needs special preparation of sample, proper inclusion opening and time of complete absorption of the determined component.
3. Sorbent reagent for gases are appropriate; they were checked with use of pure gases and gas mixtures.

Inclusion gas mixtures may be analyzed using an exact regime of operation sequence and time of analysis.

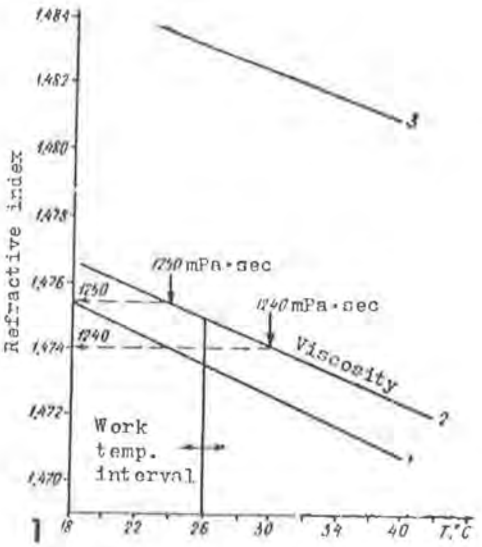
Literature

Adam, N.K. Physics and chemistry of surface. Moscow, Leningrad, 1947.
Louri [Lowry?], Dzh. Glycerine and glycols. Leningrad, 1943.
Plokhinskiy, N.A. Biometry. Novosibirsk, 1961.

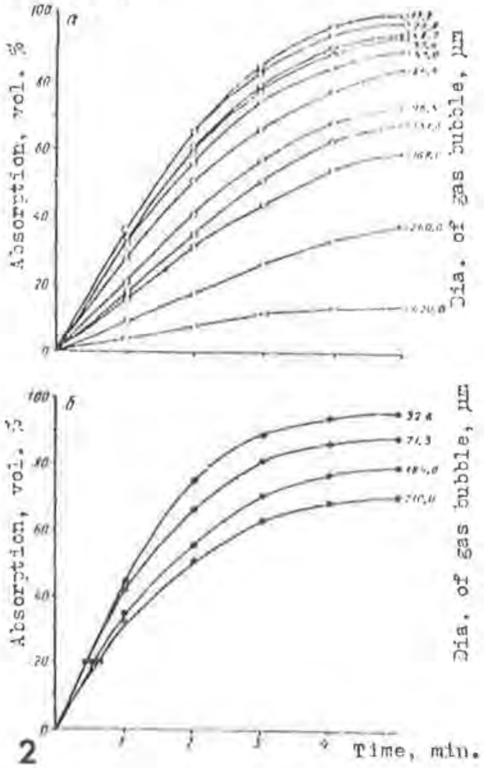
Rebinder, P.A. Absorbing layers and their influence on properties of dispersion systems. Izv. AN SSSR, Otd. matemat. i estestv. nauk, ser. khim., 1936, no. 5.

Rebinder, P.A., Trapeznikov, A.A. Mechanical properties and stabilizing action of absorption layers in dependence of degree of their saturation. Zhurn. Fizicheskoy Khimii, 1938, v. 12, no. 5-6.

(Translated by A. Kozlowski, Zawoja, 28.I.1985)



1



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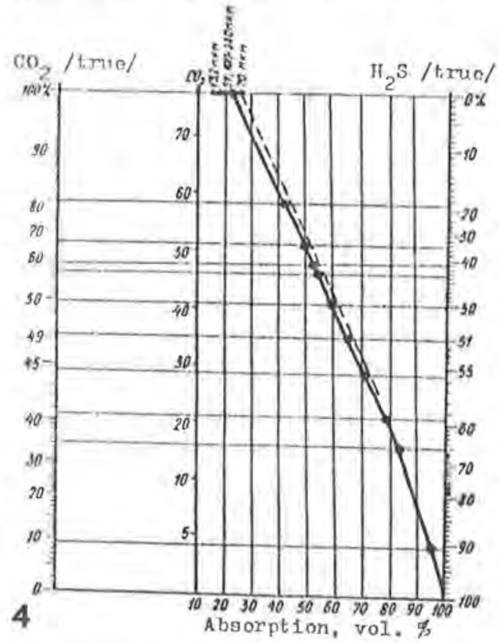

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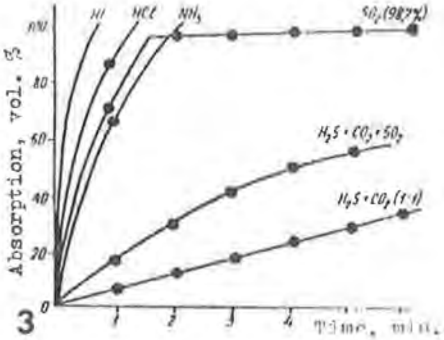

3

Fig. 1. Relation between viscosity of glycerine liquids and T. 1 - usual glycerine, 2 - LiCl-saturated glycerine, good for determinations, 3 - LiCl-saturated glycerine not suitable for determinations.

Fig. 2. Plots of absorption of CO_2 (a) and H_2S (b) in LiCl-saturated glycerine.

Fig. 3. Plot of absorption of gases in LiCl-saturated glycerine.

Fig. 4. Nomogram for separation of H_2S and O_2 (absorption in cadmium acetate).

Indices

The user should keep in mind the following features of these indices. The indexing procedures and entries are evolving and hence are not uniform from one volume of COFFI to the next, and even within a given volume consistency cannot be claimed, so caveat emptor. Where several different items in the given category occur on the same page, the number of such items is put in parentheses after the page reference. Some items may continue on to following pages. Transliteration of Cyrillic has not been uniform in the various sources used, and hence the user must look under the several possible spellings, e.g., Ye and E, ...iy and ...ii, etc. As all entries in the Translation section are also cited in the Abstracts section in alphabetical order, no Author index is needed.

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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