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FLUID INCLUSION RESEARCH

Proceedings of COFFI

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

Volume 12

1979

Fluid Inclusion Research

Volume 12

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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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Preface

In 1968 the publication of Fluid Inclusion Research - Proceedings of COFFI was started as an offshoot of the Commission on Ore-Forming Fluids in Inclusions (COFFI) of the International Association on the Genesis of Ore Deposits (IAGOD). Although closely connected with COFFI and IAGOD, 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 mostly repaid, from the International Union of Geological Sciences.

The purpose of the publication is to provide entree to the literature with English abstracts or annotated bibliographic citations of all items from the world literature published during the volume year 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 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. We also publish notices of meetings and symposia. 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. Thus this volume includes a complete translation of a rare Ukrainian book (only 350 copies printed), that summarizes Soviet work in fluid inclusions in evaporite deposits.

Most of the 327 items from Russian sources in this volume were translated or abstracted by the associate editor. A major part of these are the abstracts from several meetings in the Soviet Union, for which proceedings volumes have yet to be published. There are 476 items from other foreign language sources and English language literature for a total of 803 abstracts, citations, or annotated citations, plus subject and locality indices. A few non-pertinent items are cited, by title only, when they were presented as part of a symposium dealing with fluid inclusions. Some items from previous years that were missed in previous volumes are included, as are items for which a full English translation has become available, even if the item was previously abstracted from the original Russian.

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 the indexing of data bases. Numerous persons and recent articles have suggested that with the rapid development of computerized data retrieval systems, bibliographical publications such as Fluid Inclusion Research--Proceedings of COFFI 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, I have some serious reservations. First, it is necessary that the desired items be in the data base, and although there are several extensive geological literature computer data bases, and these have been consulted in assembling 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 later indexers. One needs only to ask for various subject searches that should pull out items from his own 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, in particular, Dr. M. Fleischer, of the U.S. Geological Survey, who provided considerable help. Chemical Abstracts, of Columbus, Ohio, has most graciously permitted the use of a limited number of their copyrighted abstracts, as indicated in the abstract citations. Help has also been received from Drs. H.A. Stalder (Bern, Switz.); P. Lattanzi (Firenze, Italy); and A.P. Berzina (Novosibirsk, USSR). Many other individuals, too numerous to list here, have helped by sending books, reprints, references, individual translated abstracts, and copies of abstracts. I am also indebted to Professor Ermakov, Chairman Emeritus of COFFI, for copies of Russian books; and to Prof. J. Guha (Chicoutimi, Quebec); and to H.E. Belkin (U.S.G.S.) for literature searches. I thank Constance Conte, Patricia Dick, Barbara Herring, and Nancy Teed (U.S.G.S.) for the extensive 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 has been the excessive lag time between the close of the literature year and publication. This lag time has been cut a little with this volume, and we hope for considerably more improvement with future issues, particularly with the help of numerous inclusion workers throughout the world.

We will 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.

December 25, 1982

Edwin Roedder, Editor
Andrzej Kozlowski, Associate Editor

Contents

Notices of Meetings and Symposia

Past Meetings

The Sixth All-Union Conference on Thermobarochemistry was held 15-18 September, 1978, in Vladivostok, USSR, with 410 registered attendees. Two volumes of abstracts were printed: I - "Thermobarogeochemistry in geology," and II - "Thermobarogeochemistry and Ore Genesis;" part of these abstracts will be found in volume 11, and the remainder will be found in this volume.

The Sixth Symposium of the International Association on the Genesis of Ore Deposits (IAGOD) was held in Tbilishi, August 30 - September 17, 1982. It included a meeting of the Commission on Ore-Forming Fluids in Inclusions (COFFI); abstracts will appear in a later volume.

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; the seventh meeting will be in Orleans (see below). The symposium was a very stimulating meeting; 65 participants from 14 countries were registered and 34 papers were presented. Part of the papers presented were published in a special issue of Chemical Geology (v. 37, 1982), others have been published elsewhere.

A meeting on the Geological Significance of Fluid and Melt Inclusions in Minerals was convened by Drs. A.H. Rankin and T. Shepherd, in connection with the 4th meeting of the Geological Societies of G.B. in Sheffield, September 21, 1979. Abstracts of the eight papers presented are given in this volume.

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 involving fluid inclusion studies.

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 will be given in vol. 15 of COFFI.

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 will be abstracted in the 1982 volume.

Future Meetings

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

The Seventh All-Union Conference on Thermobarogeochemistry is tentatively scheduled for L'vov, in 1983.

The next Quadrennial meeting of IAGOD will be held in conjunction with the International Geological Congress in Moscow in 1984. At this meeting fluid inclusion papers will be handled as regular IGC papers, according to Acad. V.S. Sobolev.

A meeting on European Current Research on Fluid Inclusions, sponsored by the Soc. fr. Minéral. Cristallogr., will be held at Univ. Orléans, 6-8 April, 1983.

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* are converted to abcdef. The numerous abbreviations used in earlier volumes have not been used here. Other than the normal scientific and reference abbreviations, we use only 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 (usually of ice).*
P	primary	Tn	temperature of nucleation.*
PS	pseudo secondary	Tt	temperature of trapping.*
S	secondary	(...)	part of author's abstract omitted.

*For explanation, please see the following item, reprinted from Volume 10.

Suggested terminology and abbreviations for future inclusion work.

The literature on fluid inclusion is expanding rapidly, and currently many different terms and abbreviations are in use for the temperatures at which various specific events occur within inclusions. The terminology, and hence also the abbreviations, in use in languages other than English obviously must differ, but the time has come for English-speaking inclusion workers to come to a consensus on terminology. After consultation with numerous inclusion laboratories, a consensus was reached on the following terminology, and it is suggested that if this terminology is used consistently in future papers, considerable ambiguity will be avoided. The overlap between the temperature ranges involved, and the similarities of the phase changes noted in gas-rich inclusions at very low temperatures, in "ordinary" aqueous inclusions below and above zero, in highly saline multiphase inclusions at ~300-600°C, and in melt inclusions at ~600-1200°C make it desirable to have the terminology and abbreviations compatible throughout. No terminology can cover all situations, but the recommended terms should be adequate to cover normal usage.

The lowest temperature normally recorded for aqueous inclusions is the temperature at which an inclusion first freezes on dropping the temperature. This usually occurs only after considerable (metastable) supercooling, and hence the temperature represents not a stable phase change but only the fortuitous event of nucleation of ice and salts. It will vary with inclusion size and with the time-temperature procedure used, but has some significance as a measure of either the freedom of the system from foreign nuclei (for heterogeneous nucleation) or the ease of homogeneous nucleation, without spurious nuclei. When used, it has been called, quite logically, the *freezing temperature* (i.e., "Tf"). This is the same term that I introduced in 1962 for a different temperature, that of stable, reversible ice-solution equilibria, in allusion to the temperature at which ice (or other phases) *should* form on cooling, under stable equilibrium (and subsequently abbreviated T_f, T_F, or T_{Frz}). My usage was not well chosen, however, and I believe it should be dropped, and the term *temperature of nucleation* (Tn) used. This covers *any* nucleation event, and *can be further identified* as Tn ice, etc.

The next higher temperature is normally that at which some liquid is first seen to be present on warming a formerly all-crystalline inclusion. I have used the term *first melting temperature* here, but for simplicity and consistency, I suggest changing to "Te" for *eutectic temperature*, since that is, in effect, what is being determined.

On further warming, specific solid phases may melt (i.e., dissolve) at recognizable temperatures. Several papers have used "Tm" as the general term for such melting temperatures, with a designation appended to indicate which phase melted (when identifiable), such as "Tm NaCl" or "Tm CO_2". I suggest we follow this usage, as it is descriptive and hence effective. (I realize that "melting" is not necessarily always a good descriptor, but the other term that has been used here, "solution" (i.e., Ts) is equally invalid in other cases, e.g., for the disappearance of pure solid CO_2 at its triple point of -56°C). My original usage of "freezing temperature" thus becomes "Tm ice", or where there is no chance of ambiguity, "Tm". Temperatures for unidentified daughter minerals would then become "Tm dms".

The usage of "homogenization temperature" has also been the source of considerable ambiguity, in that sometimes it is used to refer *only* to liquid and vapor phases, and other times to *total* homogenization. I thus suggest that whenever ambiguity may exist, the usage be clarified by adding the designation of *which* phases homogenize. Thus in low-temperature phase equilibria one could use "Th CH_4 L-V" or "Th CO_2 L-V", and for inclusions with a daughter mineral, "Th L-V" would refer to the homogenization of these two fluids without reference to the behavior of the daughter mineral, the behavior of which is independent, of course. "Th" without other designation should be reserved for actual *homogenization*, i.e., complete homogenization. As such it would follow most current usage.

The temperature at which an inclusion was trapped is sometimes abbreviated "T_F", for temperature of formation. This causes confusion with the temperature of freezing, so I suggest "Tt" be used, for temperature of trapping. Thus inclusions were formed at Tt and Pt.

The temperature of decrepitation has usually been abbreviated Td, and this seems adequate. Specific details on how such a temperature is determined, e.g., the start of decrepitation, the most rapid rise of decrepitation rate, or the maximum number of impulses per unit increase in temperature, will vary with the technique used and will have to be specified in each paper.

Tentative summary of recommended designations (for ease of typewriting and typesetting, I suggest not using subscripts.)

Th - temperature of total homogenization. The phase into which homogenization occurs should also be stated as well (e.g., Th L or Th V).

Th L-V, Th CO_2 L-V, etc. - temperature of homogenization of the stated pair of phases only. The phase into which homogenization occurs should also be stated as well (e.g., Th CO_2 L-V (V), or Th CO_2-H_2O (CO_2)).

Tt - temperature of trapping.

Td - temperature of decrepitation.

Tm - temperature of melting (or dissolving).

Tm NaCl, Tm dms, Tm ice, etc. - temperature of melting (pure phase) or of solution (mixed system) of specific phases indicated.

Te - temperature of eutectic, i.e., first recognized formation of liquid on warming a completely crystalline inclusion; this 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 - temperature of nucleation in fluid, generally on cooling (i.e., in a normally supercooled, metastable fluid). Thus Tn for an aqueous inclusion "freezing temperature" would be Tn ice; the heterogenization of a previously homogenized inclusion would be Tn V, Tn NaCl, Tn CO_2 V, etc.

E. Roedder, Editor

Abstracts, Translated Abstracts, or Annotated Citations to World Literature, 1979

Note - This section also includes some earlier items that were missed or were not available in time for inclusion in the previous volume.

ABDULLAEV, M.Yu. and RAKHMANOV, A.M., 1978, Stages and formation conditions of the skarn-rare-metal deposit Sarymat (Central Tadzhikistan) (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 73-74 (in Russian). First author at Geol. Office of the Ministry Board of Tadzhik SSR, Dushanbe.

Skarn tungsten deposit Sarymat is connected with Upper Carboniferous granodiorite/Upper Silurian limestone contact and it may be included to the skarn-pneumohydrothermal type. The following stages were distinguished: 1) pyroxene-garnet Th 660-380°C, 2) quartz-rare-metal Th 410-330°C, 3) quartz-sulfide Th 320-220°C, 4) quartz-carbonate 240-160°C. Solutions changed from gaseous (skarn stage) through pneumatolytic to liquid water ones. Water leachates made from pyroxene, quartz, pyrrhotite and late calcite suggested that in the first stage pH was 8.2 and solution composition SO_4-Cl-HCO_3-Na-K-Mg-Ca, in the second stage, pH 8.5 of solution bearing Cl-SO_4-HCO_3-CO_2-Ca-Na-K-Mg, in the third stage pH was 8.2 and solution composition CO_2-SO_4-Cl-HCO_3; in the fourth stage pH was 7.8, with ions in solutions as follows: HCO_3-Ca. Most of the solutions bear also traces of Ti, Al, Si, Fe. (From the authors' abstract, transl. by A.K.)

ABE, Kikuo, SHIGENO, Hiroshi, IKEDA, Kiyoji, ANDO, Naoyuki, and GOTO, Junji, 1979, Chemical composition, hydrogen and oxygen isotope ratios and tritium content of hot waters and steam condensates from the Oyasu-Doroyu-Akinomiya geothermal area in Akita prefecture, Japan: Bull. Geol. Surv. Japan, v. 30, p. 177-197.

The chemical characteristics of the hot spring waters and their zonal distribution in this area are interpreted as the result of the reaction of the high temperature acidic volcanic gases ascending from the deeper part of the earth with the underground waters of meteoric origin and rocks at various temperatures, depths and degrees. (From the authors' abstract)

AGAR, R.A., 1979, Copper mineralization and the Linga super-unit of the Coastal Batholith: Anales del IV Congreso Peruano de Geologia; Parte III, Soc. Geol. Peru, Bol., v. 62, p. 45-62 (in Spanish).

Indexed under fluid inclusions. (E.R.)

AHMAD, MASOOD, 1979, Fluid-inclusions and geochemical studies at the Emperor gold mine, Fiji. PhD dissertation, Univ. Tasmania, 211pp.

The gold-silver telluride deposits of the Emperor mine (Vatukoula, Fiji) are fairly typical of the epithermal deposits found in association with Tertiary volcanic activity in the circum-pacific belt. The bulk of the mineralization was probably associated with the first of several periods of igneous activity (10 to 7.5 m.y.).

Initial hydrothermal activity resulted in widespread propylitization and carbonatization of basalt, and this was followed by limited K-silicate alteration and mineralization. The lodes are essentially fracture fillings with well-developed crustification textures and vugs. Ore-mineral, sulfide and carbonate precipitation appears to have been intermittent, whereas quartz precipitation was essentially uninterrupted, and continued after the cessation of ore-mineral precipitation. The ore-minerals are native gold, native tellurium and gold-silver tellurides. Paragenetic studies suggest ten stages of ore and gangue mineral precipitation, viz. stage IA: widespread propylitic alteration with the development of carbonate, chlorite, actinolite, epidote etc.; stage IB: fringe K-silicate alteration which includes K-feldspar, sericite, dolomite and sulfides; stage IIA: barren vein quartz deposition; stage IIB: vein quartz, dolomite, K-feldspar, sericite, roscoelite, native tellurium and gold-rich tellurides; stage IIIA: barren vein-quartz deposition; stage IIIB: vein quartz, dolomite, K-feldspar, sericite, roscoelite, native gold and silver-rich tellurides; stage IVA: white barren vein quartz; stage IVB: amber barren vein quartz; stage IVC: white barren quartz; and stage V: calcite deposition. The bulk of mineralization (stage IIB tellurides) is restricted to 12 level and above while stage IIIB tellurides and native gold are distributed throughout.

Fluid-inclusion studies on quartz indicate a temperature range from 205 to 317°C during stage IIA and from 170 to 230°C during stage IIIA. Temperatures during stage IVA, IVB and IVC ranged from 160-240°C and peaked around 180°C. Fluid inclusions in stage V calcite are rare and very small, and generally lack a visible vapor phase; no temperature determinations were possible. Temperatures during stage IIA show an apparent increase with depth but no such changes are apparent during other stages. A number of inclusions from near the top of the mine show evidence that the fluids were boiling and it is possible to reconstruct dramatic variations in the water table during the vein formation which apparently overlapped caldera formation.

Freezing temperatures of fluid inclusions indicate about 5.5 wt% eq. NaCl and there is no apparent variation in salinity with time. Leaching studies of fluid inclusions indicate that the fluid averaged 0.1 molal K, 0.35 molal Na, 0.26 molal Ca and 0.005 molal Mg.

The δD values of fluid-inclusion water from vein quartz (stages IIA to IVC) range from -26 to -58 per mil and there is no apparent variation in these values with time. The $\delta^{18}O$ values of water (stages IIA to IVC) calculated from the oxygen isotopic composition of quartz range from +3 to +9 per mil and it appears that the solutions were progressively depleted in the lighter isotope with time. The $\delta^{18}O$ values of fresh rocks range from +5.5 to +7 per mil. The $\delta^{18}O$ values of propylitized rocks range from +9 to +12.5 per mil and K-silicate rocks range from +15.5 to +17 per mil. The $\delta^{18}O$ values of vein quartz (stages IIA to IVC) range from +16 to +21 per mil. It is suggested that the hydrothermal fluids were largely meteoric waters which underwent extensive oxygen-isotope exchange with the country rocks. The δD values of inclusion water in stage V calcite range from -60 to -80 per mil suggesting a magmatic source at this stage.

The $\delta^{13}C$ values of carbonates in the propylitic rocks range from -1.1 to -1.4 per mil. The $\delta^{13}C$ values of early vein carbonates (stages IIB and IIIB) range from +0.3 to -1 per mil. The $\delta^{13}C$ values of calcite in the supposedly underlying sedimentary rocks range from -0.8 to -4 per mil. It is suggested that the hydrothermal carbon (stages IA to IIIB) was derived from the underlying sedimentary rocks. The $\delta^{13}C$ values of stage V calcite range from -4 to -8.6 per mil suggesting a magmatic parentage. It is suggested that intrusion of minor plugs and dikes during the second period of igneous activity (5 to 4.3 m.y.) probably resulted in the formation of shallow convection cells and the stage V carbon was either directly derived from these intrusions or was leached from the surrounding volcanic rocks.

The $\delta^{34}S$ values of pyrite (stages IA to IIIB) range from -5.5 to -15.3 per mil. When considered in conjunction with f_{O_2}-T-pH conditions these values are compatible with a magmatic source.

Chemical analyses of fresh and altered rocks indicate that SiO_2 was depleted from the propylitic rocks but was added to the K-silicate rocks. MgO, CaO, Al_2O_3, Na_2O and TiO_2 show progressive depletion with the intensity of alteration.

Physicochemical conditions of ore deposition have been approximated from mineral stability and other data. They are: T = 200 to 250°C; pH = 5.5±0.5; $M_{Cl} = 1$; I = 1; $M_{\Sigma S} = 10^{-3}$; $m_{\Sigma C} = 10^{-2}$; $m_{\Sigma S_r}/m_{\Sigma S_o} = 1$ and $f_{O_2} = 10^{-35}$ to 10^{-40}. Metal solubility calculations suggest that under these conditions the solutions may carry 10 to 1 ppm Zn, 100 to 10 ppm Fe, 0.05 to 0.02 ppm Au and 0.1 to 0.01 ppm Pb, Ag and Cu each.

Stability fields of several tellurides have been constructed and the existing thermodynamic data indicate that the tellurium concentrations as low as 10^{-11} molal will result in stabilizing a number of tellurides. Apparently the thermodynamic data on the aqueous tellurium species need revision.

A fluid convection model is proposed in which meteoric water circulated for most of the history of the system through basalt and the underlying sediments. The probable cauldron geometry requires only one major discharge zone for the convective system. Though this limits the potential for further deposits related to the Tauva caldera it emphasizes the ore potential of other similar structures in Fiji. It is estimated from the settling properties of pyrite grains that the fluid velocity in the vein was about 4 cm/sec. This with other assumptions regarding metal solubility and the length and width of the feeder channel suggest that deposits of the size of Emperor could form in about 10^3 years.

A model is envisaged in which the circulating meteoric waters reacted with the underlying calcareous sediments and volcanics and picked up sedimentary carbon and heavy oxygen. The ore and gangue mineral constituents were also probably leached from these rocks. These solutions were channeled upwards through existing fractures and boiled at the site of deposition. A decrease in temperature together with a drop in $m_{\Sigma S}$ and increase in pH due to boiling were probably the main causes of ore and gangue mineral precipitation. (From the author's abstract)

ALBINSON, Tawn, 1978, Fluid inclusion studies of the Tayoltita mine and related areas, Durango, Mexico: MS thesis, Univ. Minnesota.

The three areas described in this study (Tayoltita, Ventanas and La Libertad mining districts) are located approximately 100 kilometers northeast of Mazatlán, Sinaloa, along the axis of the Sierra Madre Occidental. Tayoltita is one of the major precious-metal producers in the world; its total output through 1974 is larger than 9,713,587 kg of silver and 191,203 kg of gold.

Mineralization occurs in steeply dipping quartz veins hosted in two distinct volcanic sequences, spatially and temporally associated with two diorite stocks of Eogene age, which are apophysis of a large batholith at depth. Mineralization at Tayoltita is confined to an "ore horizon" 350-600 meters thick which is presently inclined about 30° to the east-northeast but was originally horizontal at the time of formation. Likewise in the Ventanas district an ore horizon 1000 meters thick was identified along the Mala Noche vein and also exhibits post-mineral tilting 40° to the southeast.

Fluid inclusion data at Tayoltita indicate deposition of three stages of vein formation occurred at approximately the same temperature range between 250°C and 310°C within the ore horizon. The salinities of the solutions ranged between 2-10 wt% NaCl and exhibit no strong fluctuations throughout the paragenesis. Fluid inclusion gas analysis indicate the fluids were dilute water solutions ($>99.5\%$ H_2O) with very small amounts of CO_2, CO and nitrogen oxide gases, plus minute amounts of sulfur gases, hydrogen, nitrogen, argon and organic gases.

The Mala Noche vein on the other hand formed from non-boiling higher salinity fluids (9-12 wt% NaCl) rising under a recognizable thermal gradient within a vertical interval 2000 to 1000 meters below the surface. Uneconomic base metal sulfides were deposited in the lower parts of the system at 265°C and silver-gold mineralization occurred higher up at 200°C.

At La Libertad vein formation and mineralization took place within 300 meters of the surface by high temperature (237°C-285°C) boiling fluids with salinities between 3.9 to 10 wt% NaCl.

The calculated $\delta^{18}H_2O$ of the brines that deposited vein quartz at Tayoltita ranged from -3.7‰ to -2.86‰, indicating meteoric waters played the dominant role in vein formation. δS^{34} values obtained from Tayoltita sulfides ranged between -3.94‰ to -6.10‰. Since changing physical-chemical parameters can account for the observed negative shift from the meteoritic standard, it is likely the sulfur was derived either from an igneous source at depth or from pyrite disseminated in the country rocks.

The precious metal vein deposits studied are related to hydrothermal systems composed almost entirely of meteoric waters. Ore deposition occurs within subhorizontal masses of hot water more commonly in the upper kilometer of the crust. A magmatic origin for the metals and possibly for the sulfur is favored and their inferred sources are the same intrusive bodies that power the convecting hydrothermal systems. (Author's abstract, modified.)

ALDERTON, D., 1979, Scanning electron microscopy of daughter minerals in inclusions in quartz from the elvans of S.W. England (abst.): Program of Fourth Meeting of the Geological Societies of the British Isles, Univ. Sheffield, Sept., 1979 (unpaginated). Author at University of Keele.

The late-magmatic microgranite dykes ('elvans') of S.W. England typically contain euhedral phenocrysts of quartz and K-feldspar. Many of the quartz crystals contain a variety of fluid inclusions. These inclusions appear to have formed over a wide range of temperatures and pressures. Melt inclusions have also been observed. One particular elvan (from Praa Sands) has been studied in detail, as inclusions from this locality contain a complex assemblage of daughter minerals. Some inclusions contain at least seven daughter minerals, and nine different species have so far been identified. Most of these daughter minerals have been identified by scanning electron microscopy - using a combination of their crystallographic characteristics and qualitative chemical analyses. The most common phases are sodium aluminosilicates and chlorides of sodium, potassium, iron, and manganese.

The exact significance of these highly saline fluids is at present unclear. One possibility is that their high contents of potassium and iron have been generated by the assimilation of local country rocks. These could thus be the fluids responsible for the late-magmatic, metasomatic activity which has affected many of the granitic rocks of the region. (Author's abstract)

ALDOUS, R.T.H., and RANKIN, A.H., 1979, Melt inclusions in olivine from the Palabora carbonatite complex; implications for the origin of phoscorite and copper mineralization at Palabora (abst.): Program of Fourth Meeting of the Geological Societies of the British Isles, Univ. Sheffield, Sept., 1979 (unpaginated). Authors at Imperial College, London SW7.

Olivine from the earliest carbonatite facies (phoscorite) of the Palabora complex of S. Africa (one of the top ten copper producers in the World) contain a complex assemblage of multisolid melt inclusions composed essentially of calcite, dolomite, phlogopite, magnetite and sulfides of copper and iron with traces of nickel. The presence of significant amounts of copper and sulfur in these inclusions, which represent portions of the earliest carbonatite magmas evolved at Palabora, demonstrated conclusively that the extensive copper mineralization within the complex was an integral part of the carbonatite process and was not introduced from an extraneous source during late stage hydrothermal/metasomatic activity.

The presence of primary inclusions of carbonatitic composition in the phoscorite olivines further demonstrates that these olivines are direct precipitates from a true carbonatitic magma. (Authors' abstract)

ALEKSANDROVA, E.S., IGNAT'YEVA, I.B. and PASHKOV, Yu.N., 1978, Methods of study of the composition of gas-fluid inclusions in minerals, in Theory and Practice of Thermobarogeochemistry, N.P. Ermakov, ed., Izd. Nauka, p. 214-227 (in Russian).

ALEKSANDROVA, E.S. and MIRONOVA, O.F., 1978, Gas-chromatographic analysis of gases typical for inclusions in natural minerals: Zh. Anal. Khim, v. 33, p. 981-984 (in Russian; translated in J. Anal. Chem. USSR, v. 33, p. 756-758).

ALLMAN-WARD, P., and RANKIN, A.H., 1979, Phase ratio calculations and the prediction of fluid inclusion homogenization temperatures (abst.): Program of Fourth Meeting of the Geological Societies of the British Isles, Univ. Sheffield, Sept., 1979 (unpaginated). Authors at Imperial College, London SW 7.

Previous workers have used phase ratios (i.e. the ratios of gas, liquid and solid phases) in fluid inclusions to distinguish between different inclusion populations. Their calculations were often tedious and made use of unproven assumptions. The object of this study was to improve methods of phase ratio calculation.

The assumption that fluid inclusions can be closely modelled by ellipsoids especially in quartz permits the use of various hypothetical models to establish the relationship between the three dimensional fluid inclusion and its two dimensional projection. The models emphasize the importance of orientation of the fluid inclusion and show how apparent phase ratios can be misleading if orientation effects are ignored. They also indicate that the apparent phase ratios (of two dimensional projections) can be used to determine the true phase ratios under certain conditions, provided that the major axis of the fluid inclusion is parallel to the plan of viewing and that the phase ratios are calculated for groups of inclusions. The method only requires the measurement of phase areas and the largest dimension of the fluid inclusion. The equations used are derived from equations of area and volume of ellipsoids and cubes. The method lends itself to statistical analysis and so to improving the resolution between different populations of fluid inclusions.

Data relating the homogenization temperature to the degree of filling (ratio of liquid phase to the total) has already been published for pure NaCl brines. The increase in accuracy in determining phase ratios enables the use of this data to predict theoretical homogenization temperatures for two-phase inclusions. The relationship between homogenization temperature and degree of filling is dependent upon salinity. Salinities for fluid inclusions containing halite can be derived directly from phase ratios, though salinities have to be assumed or measured for two-phase inclusions.

In application the method is quick and easy to use and appears to be accurate. It is suggested that it is particularly useful in the study of thin sections and it is hoped that it will encourage and enable fluid inclusion studies to become a routine part of petrological investigations. (Authors' abstract)

AL'MUKHAMEDOV, A.I. and MEDVEDEV, A.Ya, 1979, An experimental investigation of the interaction of a basic silicate melt with sulfur-containing phases: Geokhimiya, 1979, no. 1, p. 18-29 (in Russian; translated in Geochem. Internat., v. 16, no. 1, p. 6-16, 1979).

AMANNIYAZOV, K.N. and NAZAROVA, A.L., 1978, Studies of detrital quartz from rocks of Middle-Jurassic deposits of Bol'shoi Balkhan for elucidation of their origin (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 42-43 (in Russian). Authors at Territorial Geol. Office, Ashkhabad, USSR.

The abstract bears short description of inclusions in quartz grains. (A.K.)

AMBLER, E.P., ASHLEY, P.M., BOTH, R.A. and DONNELLY, T.H., 1979, Stable isotope and fluid inclusion studies on the Mount Black lead-zinc deposit, southern New South Wales: Journal of the Geological Society of Australia, v. 26, p. 399-409. First author at Hooker Industrial Sands, 175 Pitt Street, Sydney, N.S.W. 2000.

The Mount Black Pb-Zn deposit is a quartz-galena-sphalerite replacement body in the Silurian Cooleman Limestone. Fluid inclusion Th ranges from 120° to 170°C for paragenetically early sphalerite, to 210° to 315°C for late quartz, and 245° to 320°C for calcite from contiguous recrystallized limestone. Fluid salinities increased with rising temperature, during deposition of the minerals, and the fluid composition changed from NaCl-rich to possibly $CaCl_2$-NaCl (-?$MgCl_2$)-rich brines.

$\delta^{34}S$ values of sphalerite and galena range from -8.1 to -2.7 per mil, and -13.5 to -4.4 per mil respectively. Although a magmatic source for sulphur is not excluded, it is suggested that most probably the sulphur was derived by biogenic reduction of sea-water sulphate during diagenesis. Carbon and oxygen isotope data for the Cooleman Limestone range from compositions typical of Silurian marine carbonate in samples distant from the deposit, to fluctuating, but ^{12}C- and ^{16}O-enriched in recrystallized material adjacent to the quartz-sulphide rocks. ^{12}C-enrichment probably reflects organic carbon oxidation during karst formation, continuing later during limestone recrystallization and accompanied by ^{16}O-enrichment during the action of saline formation waters.

The process of formation of the Mount Black deposit may have been analogous to that of Mississippi Valley-type deposits, but modified by and/or resulting from, an increasing geothermal gradient caused by nearby synchronous intrusions. (Authors' abstract)

ANDERSON, A.T., Jr., 1979, Water in some hypersthenic magmas: J. Geol., v. 87, p. 509-531. Author at Dept. Geophy. Sci., Univ. Chic., Chicago, Illinois 60637.

The concentrations of H_2O in inclusions of glass in phenocrysts are estimated indirectly by summation difference using electron probe microanalysis. The method probably is valid if inclusions are glassy (not devitrified) and larger than about 30 µm diameter and if more than about 2 wt. % of H_2O is present. Inclusions of melt may lose H_2O by diffusion and/or oxidation after initial entrapment. The concentrations of H_2O quenched in basaltic and andesitic glasses in olivine phenocrysts are mostly between 2 and 4 wt. % for Pavlof Volcano, Alaska; Asama Volcano, Japan; Fuego Volcano, Guatemala; and Mt. Shasta, California. The revised estimate of the rate of igneous outgassing of H_2O in subduction zones is twice that for fresh submarine ridge basalts and suggests that most of the H_2O added to oceanic crust during alteration and weathering either is recycled by some means other than magmatism or is stored deep in the earth. The Cl/K_2O ratios of associated silicic glasses commonly are less than for the low-silica glasses. Silicic glasses commonly have equal or lesser concentrations of H_2O compared to associated less silicic glasses. Probably many silicic hypersthenic magmas develop in vapor saturated bodies of magma within a few kilometers of the surface. Some silicic hypersthenic magmas appear to have about 7 wt. % of H_2O and probably developed at greater depths either by differentiation from hydrous basaltic parents or by contamination with H_2O-rich dacitic melts derived from partial fusion of hydrous peridotites within the crust. (Author's abstract)

ANDERSON, G.M., 1979, Experimental data on the solubility of sphalerite and galena in brines (abst.): Program, 108th AIME Annual Meeting, New Orleans, Feb. 18-22, 1979, p. 19.

A review is presented of sphalerite and galena solubility data, including recent unpublished results. Despite some disagreements, it is possible to conclude that chloride complexes alone will not allow ore-forming amounts of metal and reduced sulfur to be transported together in brines at temperatures below 150°C and reasonable pH values. Geological evidence as to whether this has occurred is rarely conclusive. It is important to know whether this is physically possible, and under what conditions, because of the implications it has in deducing the nature of the ore depositing environment. The possibility that organic complexing is significant is considered. (Author's abstract)

ANDRAWES, F.F., and GIBSON, E.K. Jr., 1979, Release and analysis of gases from geological samples: Amer. Min. v. 64, p. 453-463. First author at Lockheed Electronics Company, Inc., 1830 Nasa Road I, Houston, Texas 77058.

A system has been developed for the qualitative and quantitative analysis of gases released from geologic samples upon crushing. The system includes a hydraulically-operated stainless-steel crusher through which helium flows. The released gases are fed directly into a gas chromatograph equipped with dual columns and helium ionization detectors. The chromatographic system is capable of separating and detecting H_2, Ar, O_2. N_2, CO, CO_2, light hydrocarbons, and water. Samples ranging in size from 5mg to 1000mg can be crushed and released trapped gases analyzed. The crushing pressure (up to 32 kbar) allows efficient release of trapped gases. Depending on the nature of the sample, 85 to 100 percent of the trapped gases in the crushed sample are released. The newly-developed crushing technique eliminates previously identified problems associated with gases generated by the crusher and adsorption of the released gases by the newly generated surfaces of the crushed sample. The analytical system has a wide range of potential uses. To date meteorites, lunar rocks and soils, basalts, glasses, and minerals with both fluid and gas phase inclusions have been analyzed. Selected examples of experimental results are presented. (Authors' abstract)

ANDREEVA, I.P., ROSSMAN, G.I., VASIL'KOVA, N.N., KOPLUS, A.V., ZAYTSEV, Ye.I, KHITAROV, D.N., KHARLAMOV, Ye.S., 1979, Importance of some typomorphic features of fluorite during prospecting for hydrothermal uranium ore mineralization associated with continental formations: Geol. Rudnikh. Mestor., v. 21, no. 1, p. 97-102 (in Russian) Institution employing the authors not specified.

Fluorite varieties from U-Mo deposits yielded the following Th in °C: green 215-155 (P), 170-140 (S), 3 samples, 21 measurements; dark violet 207-180(?), 1 sample, 3 measurements; violet 187-165 (P), 177-110 (S), 3 samples, 16 measurements; colorless 180-152 (P), 4 samples, 11 measurements. Oral communications of A.A. Nikitin (1974, 1975) suggested that the extended Th range for fluorite of U-Mo ore field was 240-80°C; Th range for fluorite of the fluorite deposits was estimated by Doroshenko (1965-1968, oral communication) as equal 265-100°C (no deposit names are given).(Abst. by A.K.)

ANDREEVA, T.A. and MOLCHANOV, V.I., 1978, Hydrogen and hydrocarbon gases in the composition of the gaseous inclusions in rocks: Sov. Geol. Geophys., v. 19, no. 10, p. 24-29.

See Fluid Inclusion Research--Proceedings of COFFI, v. 11, p. 7. (E.R.)

ANDREYEV, G.V. and SHVADUS, M.I., 1977, Pressures and temperatures of crystallization of alkalic rocks of the Synnyr complex, as inferred from first finds of inclusions of melt: Akad. Nauk SSSR, Doklady, v. 235, no. 4, p. 910-913 (in Russian; translated in Dokl. Acad. Sci. USSR Earth Sci. Sect., v. 235, p. 150-152, 1979).

Abstract in Fluid Inclusion Research--Proceedings of COFFI, v. 10, p. 5-6, 1977. (E.R.)

ANDRUSENKO, N.I., 1978, Temperature zoning of gold-silver deposits: Sov. Geol., v. 6, p. 48-59.

See Fluid Inclusion Research--Proceedings of COFFI, v. 10, p. 6. (E.R.)

ANDRYANOVA, S.I. and ZAREMBO, Yu.G., 1978, Zonalty of tungsten-gold ore mineralization (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 82-83 (in Russian). Authors at Central Sci.-Research Geol.-Prosp. Inst., Moscow, USSR.

Tungsten-gold ores (deposit name not given, A.K.) form a complex stockwork of quartz and quartz-sulfide veins and veinlets of several stages. G/L inclusions were studied in samples taken from the depth 0-1000 m. Two essential types of inclusions were found: 1) water-salt solution, Th (in L phase) 80-340°C; 2) water-carbon dioxide (G up to 95%) Th (sometimes with critical phenomena and decrepitation) 360-700°C (sic. A.K.), rarely 240-280°C. The amount of H_2O-CO_2 inclusions with Th 500-700°C increases with the depth; at the lowest levels the amount of pure-gas one-phase inclusions sharply increases. Dms are frequent in all types of inclusions. (From the authors' abstract, transl. by A.K.)

ANTHONY, T.R. and CLINE, H.E., 1978, Stresses generated by the thermomigration of liquid inclusions in silicon: J. Appl. Phys., v. 49, no. 12, p. 5774-5782.

APLONOV, V.S. and MOSKALYUK, A.A., 1978, Evolution of the chemistry of mineral-forming solutions; formation of the Noril'sk copper-nickel ores, in Theory and Practice of Thermobarogeochemistry, N.P. Ermakov, ed., Izd. Nauka, p. 119-122 (in Russian).

APLONOV, V.S., SUKHANOVA, Ye.N. and DEL'NIK, G.P., 1978, Exploration for high-grade copper-nickel ores in the Talnakh Deposit with the help of decrepitation analysis, in Theory and Practice of Thermobarogeochemistry, N.P. Ermakov, ed., Izd. Nauka, p. 197-201 (in Russian).

AREHART, G.B., 1978, Geology and geochemistry of the Black Cloud PS3 Zn-Pb-Ag replacement orebody, Leadville District, Lake County, Colorado: Master's thesis, Colorado State Univ., Fort Collins, CO.

Indexed under fluid inclusions. (E.R.)

AREVADZE, D.V., 1978, Ceramic microstage for homogenization of inclusions in the temperature ranges 25-700°C and 25-1400°C (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, v. 1, Thermobarogeochemistry in geology: Vladivostok, Acad. Sc. USSR,

p. 204 (in Russian). Author at the Caucasian Inst. of Mineral Raw Materials, Tbilisi, Georgian USSR.

Heating element is made of nichrome in the low-temperature stage and of Pt-Rh alloy in the high-temperature stage. Thermocouples were of chromel-copel or Pt-P+Rh wires. Stage body was made of porous alumina (70%) plus 30% of Chasovyarkoe Kaolinite. The stage is very convenient due to small size, stable working conditions, small distance from objective to preparation, good illumination, low heat inertia, significant duration of working time and simple preparation of the microstage. (Author's abstract, transl. by A.K.)

AREVADZE, D.V., KAVILADZE, M.Sh., SUKHISHVILI, A.I. and YAROSHEVICH, V.Z., 1979, Fluid inclusions and stable isotopes of hydrogen and sulfur in pyrite-polymetallic ores of the Bolnisskii region: Tr. Kavkaz. In-t Mineral'n. Syr'ya, v. 21, no. 14, p. 84-97 (in Russian).

ARIMA, M., and EDGAR, A.D., 1979, Compositions of analcites in the system analcite-H_2O at 1 kbP_{H_2O} and their petrogenetic implications (abst.): Geol. Assoc. Can.- Min. Assoc. Canada Program with Abstracts, v. 4, p. 37.

Most experimental studies on the stability of analcite have been done in the presence of an excess water vapor phase and few attempts have been made to determine the compositions of the resulting analcites, even when this mineral coexists with albite as reported by many investigators. A series of experiments with a synthetic analcite and two natural analcites (from a blairmorite of the Crowsnest Formation, Alberta and from a basalt from Cape d'Or, Nova Scotia) of known compositions have been run at 1 kbP_{H_2O} between 400 and 500°C. Under these conditions albite (estimated between 5-20 percent) almost inevitably occurs together with analcite. Compositions of the analcites are generally less SiO_2-rich than the original specimens. With increasing run time and decreasing amounts of H_2O added (ranging from zero to 25 weight percent H_2O - excluding the H_2O inherent in the analcites) the analcites are progressively poorer in SiO_2. Temperature appears to have a minimal effect in changing the compositions of the analcites and in all runs an excess vapor phase was present. From a knowledge of the original analcite composition, the composition of the analcite after the experiment and assuming the albite is stoichiometric, calculations indicate that vapor phase may contain appreciable SiO_2 or $NaAlO_2$. The variable analcite compositions and the presence of albite may cast doubt on the validity of the previously determined stability relations of analcite. In nature the presence of alkalies and/or silica may be important in metasomatic alteration processes.

ARNOLD, Michel, GUILLOU, J.-J. and ZIMMERMANN, J.-L., 1979, Fundamental differences between the chemistry of visible and micromosaic inclusions in quartz, and their significance: C.R. Acad. Sc. Paris, v. 288, Ser. D, p. 1111-1113 (in French).

Optical and chemical study of a low temperature quartz rich in visible fluid inclusions (Gour Nègre, Gard, France) shows that organic matter is concentrated in the micromosaic blocks of the crystal. These blocks appear to be devoid of visible inclusions but contain inframicropores where organic matter is stored. Hence, conclusions concerning the medium of crystal growth drawn from data revealed only by the visible inclusions may be misleading. (Authors' abstract)

ARNONE, G., 1979, A study on the thermal springs in northern Latium: Soc. Ital. Mineral. Petrol. Rendconti, v. 35, p. 647-666 (In Italian).

Results obtained using both the SiO_2 and Na-K-Ca geothermometers for the study of the temperatures of hot waters in depth show very little differences in the determined temperatures. (From the author's abstract)

ARSAMAKOV, Kh.I,; GRANOVSKII, A.G.: KOBILEV, G.A., and TRUFANOV, V.N., 1979, Mineralogical-geochemical and thermobarometric characteristics of polymetallic mineralization of Gornaya Chechen-Ingushetia: Izv. Sev.-Kavk. Nauchn. Tsentra Vyssh. Skh., Estestv. Nauki 1979, v. 7, no. 1, p. 49-53. Authors at Rostov. Gos. Univ., Rostov, USSR.

Two groups of mineral aggregates, mainly quartz and carbonates, are distinguished in the ore-bearing veins of polymetallic deposits (Caucasus) Formation of the ore deposits was pulsative, with 2 distinct maxs. of pptn. from the ore-forming solns. The quartz and calcite have 2 genetic groups of fluid inclusions, indicating formation of the quartz-calcite-pyrite-pyrrhotite aggregate at 350-440 and the galena-sphalerite with quartz aggregate at 160-210°. Formation of the most productive mineral aggregates was accompanied by a pressure drop of 40-100 atm (from 300-440 atm) and formation of less productive associations occurred during periods of pressure increase. (C.A. 91:110354e, 1979)

ASHIMINA, N.A., BOGATIKOV, O.A., GORSHKOV, A.I., MOKHOV, A.V., OBRONOV, V.G., and FRIKH-KHAR, D.I., 1979, First finding of particles of metallic aluminum in lunar soil. Akad. Nauk SSSR Doklady, v. 246, no. 4, p. 958-961 (in Russian). Authors at Inst. of Geol. of Ore Deposits, Petrography, Mineralogy and Geochemistry of Acad. Sci. SSSR, Moscow.

Sylvite and halite were determined by electron microprobe in Lunar soil (see Ashimina et al., Proceedings of COFFI v. 11, 1978) (A.K.)

AUGUSTITHIS, S.S., 1979, Atlas of the textural patterns of basalts and their genetic significance: Amsterdam, Elsevier Sci. Pub. Co., 323 pp.

Contains 604 figures, mostly photomicrographs, some of which show various types of silicate (and CO_2?) inclusions in minerals of basalts, along with the author's sometimes very special, ad hoc interpretations. (ER)

AVDONIN, V.V., DOROGOVIN, B.A. and MURADYAN, K.M., 1979, Melt inclusions of liquation type in volcanogenic rocks of acid composition: Akad. Nauk. SSSR Doklady, v. 245, no. 2, p. 428-430 (in Russian; translated in Dokl. Acad. Sci. USSR, v. 245, p. 137-138, 1981). Authors at Moscow State Univ. USSR.

P melt inclusions in quartz from liparite porphyries of Rudnyi Altai consist of light and brown glass phases plus G bubble. Th of brown glass is much lower than Th of the light one: 1050° and 1170-1205°C, respectively, in Leninogorskiy region and 910-1000 and 980-1250°C in Kamyshinskiy ore field. Inclusions are azonal and both varieties are mixed randomly in quartz crystals. In Armenian region Shamshada similar P azonal inclusions are filled by a) glass + 15% G by vol., Th 960-950°C, b) semitransparent solid phase + nebulous G bubble, Th 1360°C and c) rare inclusions filled by transparent glass 30% + opaque glass 55% + G bubble 15% (all by vol.), Th 1310°C, with disappearance of phase boundary between melts. Since quartz grains bear various inclusions, they have been trapped at T $<$Th (i.e $<$1310°C). Similar inclusions were found by Roedder and Weiblen in lunar rocks. Liquation was also observed in inclusions during homogenization runs. In certain inclusions filled by glass, tabular dxl ~ 20% and G bubble ~ 20%, after dxl melted it forms droplet of melt immiscible with main inclusion filling up to 1360°C (Th). Similar immiscibility was observed on heating in inclusions bearing several dxls. (Abst. by A.K.)

AYORA, C., 1978, Fluid inclusions in vein material from the Ribes Valley, eastern Pyrenees, Spain: Ata Geol. Hisp., v. 13, no. 5, p. 163-169 (in Spanish).

AYZDERDZIS, D.Ya, MELENT'YEV, G.B., ARGAMAKOVA, B.A. and AKELIN, N.A., 1978, The morphostructures and petrogeochemical zoning of rare-metal pegmatite fields; criteria fo the prediction of uncovered cesium-tantalum mineralization, in Problems in the geology of rare elements, M.V. Kuz'menko, ed., Izd. Nauka, p. 96-119 (in Russian).

Indexed under fluid inclusions. (E.R.)

BACHINSKI, S.W., and SCOTT, R.B., 1979, Rare-earth and other trace element contents and the origin of minettes (mica-lamprophyres): Geochim. Cosmo. Acta, v. 43, p. 93-100. First author at Dept. Geol., Univ. New Brunswick, Fredericton, New Brunswick, E3B 5A3 Canada.

Based on instrumental neutron activation and X-ray fluorescence analyses of minettes, the authors tentatively propose that the process best able to account for the unique geochemistry of ultrapotassic rocks, kimberlites, and, to a lesser extent, carbonatites is limited partial melting of the subcontinental mantle following and dependent on the metasomatic introduction of K, Ti, Fe, REE, halogens, P, and other elements as well as H_2O and/or CO_2. If the enriched mantle is H_2O-rich, minette magma is produced; if it is CO_2-rich or has an intermediate CO_2/H_2O ratio, carbonatitic-kimberlitic and/or ultrapotassic magmas result. (From the authors' abstract)

BAILEY, D.K., 1979, Geotherms, volatile flux, and the generation of the kimberlite-carbonatite spectrum (abst.): Mineralog. Soc. (London) Bull., no. 45, p. 4. Author at Dept. of Geology, University of Reading.

Kimberlite 'pyroxene geotherms' closely approach vapor-present peridotite solidi in the depth range 150-200 km, and if melting were initiated the key attributes of kimberlite eruption would follow. Decompression melting in a rising mantle diapir does not provide for either the prerequisite source conditions, or other alkaline magmatism. Open-system melting induced by a rising vapor phase does. Moreover, the whole gamut of alkaline and carbonatite magmatology becomes explicable by fluxing and metasomatism along different geotherms. It follows that lithosphere sections sampled by kimberlite nodule suites are not random, but are those where the geotherm lay in the narrow range specific to kimberlite generation. (Author's abstract)

BAKUMENKO, I.T. and KOSUKHIN, O.N., 1977, Water in inclusions of silicic silicate melt: Dokl. Akad. Nauk SSSR, v. 234, p. 114-117 (in Russian; translation Doklady Akad. Sci. USSR, v. 234, p. 173-175, 1979).

Abstract in Fluid Inclusion Research--Proceedings of COFFI, v. 10, p. 13 (1977).

BAKUMENKO, I.T., KOSUKHIN, O.N., PAVLISHIN, V.I., and CHUPIN, V.P., 1979, On the magmatic stage in the formation of chamber pegmatites from Volyn: Dokl. Akad. Sci. SSR, v. 248, p. 1194-1197 (in Russian).

BALCE, G.R., 1979, Geology and ore genesis of the porphyry copper deposits in Baguio district, Luzon Island, Philippines: Jour. of the Geol. Soc. of the Philippines v. 33, no. 2, p. 1-43.

Fluid inclusion studies reveal that the bulk of mineralization in Santo Tomas II Mine was formed at about 525°C, 500 bars and at 2 kilometers depth from the surface. The average salinity of ore solutions is about 54 wt. % NaCl equivalent. Those of Santo Niño Mine were formed at about 516°C, 475 bars, 1.900 meters depth from the surface and 52 wt. % salinity of ore solutions. Lobo ore body in Western Minolco Mine was formed at about 497°C, 410 bars, 1,640 meters depth and 49 wt. % NaCl equivalent salinity of ore solutions. Boneng ore body, also of Western Minolco Mine, was formed at about 505°C, 430 bars, 1,720 meters depth and 53 wt. % NaCl equivalent salinity of ore solutions.

The BMI ore body of Kennon Mine was formed under much different conditions. The temperature was about 433°C; pressure, about 275 bars; depth, about 1,100 meters, and salinity of ore solutions, about 42 wt. % NaCl equivalent. (From the author's paper).

Evidence of boiling was found in all deposits examined. In plagioclase of the host porphyries, and in phenocrystic quartz and calcite and anhydrite in sulfide-bearing veinlets, polyphase inclusions Tm are rare. KCl ranges from ∼100-200°C, Tm NaCl generally ∼500; complete homogenization >600°C in many, and even >700°C. Salinities ranged up to 60 wt. % in all, and over 80% at Santo Tomas II. Other daughter minerals include hematite (?), sulfides, anhydrite (?), and calcite. The author makes use of the relative abundance of Th data points to infer specific populations at Santo Tomas II: >650°C, 350-650°C, and 100-350°C (the last being low salinity). The above is a combination of data from the cited reference and from 25 pages of the author's PhD dissertation, 1978, from Tohoka Univ., Sendai, supplied by Dr. Balce. (ER)

BALLURKAK, Ashok, 1979, Temperature of formation of barite based on fluid inclusion data: Curr. Sci, v. 48, p. 621-622. Author at Centre of Expl. Geophys., Osmania University, Hyderabad 500 007.

Tf of barite has been determined from Th and Td of the fluid inclusions. Both primary and secondary inclusions were noticed belonging to mono-and two-phase (liquid-gas) types. Tf is estimated = 125°C which is in agreement with the approximations made on the basis of other features of barite mineralization. The investigations also revealed some interesting information regarding the physico-chemical nature of mineralizing solutions. (Author's abstract)

BANASZAK, K.J., 1979, A coherent basinal-brine model of the genesis of Mississippi Valley Pb-Zn ores based on part upon absent phases (abst.): Program, 108th AIME Annual Meeting, New Orleans, Feb. 18-22, 1979, p. 18.

Basinal brines heated to about 200° destroy some enclosing silicate minerals and become 1) acid (pH = 4-5), 2) richer in sodium over potassium, and 3) as dense as fresh water at 25°C. These brines then rise into carbonate host rocks, dissolving them but changing little in pH, because of the brine's high calcium (up to 0.5 molal). Cooling the brine results in further solution of the host, but pH changes little and ore and gangue minerals are precipitated. Part of the evidence for an acid ore-forming fluid is the absence of some expected layered silicates, especially sepiolite. (Author's abstract)

BARABAS, A.H., 1979, (Factors controlling nickel sulfide mineralization). Late fluids of mafic intrusive complexes of the Lynn Lake region (Manitoba, Canada): Mem. BRGM, v. 97, p. 219-237 (in French).

Indexed under fluid inclusions. (E.R.)

BARANOVA, N.N., KOZERENKO, S.V., BANNIKOVA, L.A. and BARSUKOV, V.L., 1979, Gold in hydrothermal processes: transportation and deposition behavior (abst.): Pacific Science Congress, 14th, Khabarovsk, 1979, Abstracts of Papers, Section BVI, p. 38-39 (in English).

The study of genetically different gold deposits has shown gold mineralization to be formed in both oxydizing and reducing conditions. In the former instance gold is associated with manganese oxides, hematite, magnetite, gypsum, and anhydrite and in the latter - with pyrrhotite, pyrite, and graphite. Deposition of gold is commonly accompanied and followed by the reduction processes.

Au, Ag, and H_2O content in natural hydrothermal solutions was estimated. Extracts from liquid inclusions in quartz of typical mineral assemblages have been analyzed for Au and Ag using inverse-amperometric method with carbon paste electrode. The gold content in extracts ranges from 10^{-6} to 10^{-4}M and that of silver from 10^{-5} to 10^{-2}M. Experimental data on gold content in hydrothermal solutions are in good agreement with calculated values based on proposed model of complexing of gold.

Sulfide-ion content was measured using the potentiometric technique. These values range from 10^{-5} to 10^{-3} M H_2S.

Physico-chemical parameters indicating the range of formation conditions for investigated ore deposits are revealed. The data available for dissociation constants of Au(I) and Au(III) complexes for these conditions were used in computer calculations. Quantitative relations of various complexing reactions in solutions have been confirmed for the temperature interval 25-300°C.

Quantitative evaluation of gold deposition parameters was carried out. The existence of gold in such different valence states as Au(I), and Au(III), as well as high values of standard potentials in Au^+/Au^{3+} = 1.52V and Au/Au^+ = 1.83V pairs results in the large role of the variation of the system redox potential as the main factor of gold deposition from ore-forming hydrothermal solutions.

The number of observations of natural systems leads to assumption that reactions of a solution with organic matter could affect the redox conditions of hydrothermal system and serve as the stimulator of gold and sulfide deposition from the ore-forming solutions. At the same time the role of temperature, pH values and electrochemical and sorbtion processes are considered. The validity of this assumption is confirmed by investigation of carbon isotopes of hydrothermal carbonates from gold deposits. Low values of ^{13}C appear to be the indicators of the important role of biogenic CO_2 in the total balance of CO_2 in hydrothermal system. The correlation between the carbon isotopic ratios and gold contents in ore bodies is found. (Authors' abstract)

BARANOVA, N.N., RYZHENKO, B.N. and DAR'INA, T.G., 1978, Concentrations and species of gold and silver in solutions of inclusions in quartz of some gold ore deposits, (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 1, Thermobarogeochemistry in geology: Vladivostok, Acad. Sci. USSR, p. 197-198 (in Russian). Authors at GEOKHI of Acad. Sci. of the USSR, Moscow.

Thoroughly separated quartz samples came from various stages of formation of gold ore deposits in Yakutia, Priamur'ye and Armenia. By reverse voltamperometry with use of carbon-paste electrode, gold and silver concentrations in water leachates from quartz were determined. Samples were leached by 0.5n HCl, to prevent hydrolysis and sorption by quartz powder. The Au concentrations found range from 0.5×10^{-10} to 50×10^{-10} gram-ion per liter of leachate and Ag concentration 0.5×10^{-8} to 2×10^{-8} gram-ion per liter of leachate, i.e. when recalculated to inclusion solution concentrations, 5×10^{-8} to 5×10^{-6} gram-ion of Au per liter and 5×10^{-6} to 2×10^{-5} gram-ion of Ag per liter. The method used permits distinguishing total ionic forms versus neutral Au°. In solutions in inclusions 40% or more of Au occurs as Au°. The anion composition of the solutions is ordinary, total salt concentration relatively low, pH almost neutral. When Au in solution is in equilibrium with metallic Au, and Ag in solution is in equilibrium with Ag_2S, total Cl concentration 1 mole per liter, total S concentration 0.01 mole per liter, P_{H_2} 10^{-10} to 10 atm, P_{H_2S} 10^{-10} to 1 atm, and T about 250°C, the hydrothermal solutions may contain Au and Ag in amounts sufficient to precipitate ore as monovalent Au complexes: $Au(HS)_2^-$, $AuOH^\circ$, $AuOHCl^-$ and Au°, and Ag as $Ag(HS)_2^-$, $AgOH^\circ$, $AgOHCl^-$. (From the authors' abst., transl. by A.K.)

BARBIER, E., (ed.), 1979, - Cerro Prieto Geothermal Field. Proceedings of the 1st Symposium, San Diego, CA, Sept. 1978 - Part I. Geothermics v. 8, Spec. Issue.

A collection of 17 papers covering various aspects of the geothermal field. The more relevant papers are abstracted in this issue. (ER)

BARKER, Colin, 1978, Pyrolysis of naturally occurring organic matter: a review, (abst.): Geol. Soc. Amer. Abstracts with Programs, v. 10, no. 7, p. 363.

Pyrolysis is the thermally-induced breakup of large molecules to give simpler products which are more easily analyzed by routine procedures. Pyrolytic methods are particularly well suited to the study of complex, polymeric materials and are being used increasingly in the study of geopolymers, such as kerogen. A wide variety of time-temperature combinations is used, but in general the higher the temperature the shorter the heating time. Although isothermal heating is often useful much current research employs a steadily increasing temperature (in the range 10-40°C/min) and the release of products is monitored as a function of temperature. In most pyrolysis experiments the sediment, rock or organic matter sample is heated in an inert environment whose main function is to exclude oxygen, though it is usually selected to be compatible with the analytical procedure (e.g., vacuum for mass spectrometry). Gas chromatography is particularly well suited for the analysis of the small quantities of complex mixtures formed by pyrolysis and the carrier gas can be routed to provide the inert atmosphere in the pyrolysis cell as well as transferring material to the chromatographic column. Pyrolysis has been applied in studying the structure of geopolymers and has been used widely in evaluating the past thermal history of rock samples, and in simulating the reactions which accompany increasing depth of burial in nature. Pyrolysis techniques are generally quick, relatively inexpensive, use small samples, require minimal sample preparation and provide significant information. Their use seems certain to expand. (Author's abstract)

BARKER, C., WENZEL, K.A. and KUENHOLD, K.A., 1978, Analysis of gases in individual fluid inclusions (abst.): Geol. Soc. Am., Abstr. Programs, v. 10, p. 1.

BARKER, C.E., 1979, Vitrinite reflectance geothermometry in the Cerro Prieto geothermal field, Baja California, Mexico (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 68.

Author considers the method superior to fluid inclusions. (E.R.)

BARNES, Ivan and McCOY, G.A., 1979, Possible role of mantle-derived CO_2 in causing two "phreatic" explosions in Alaska: Geology, v. 7, p. 434-435. First author at U.S. Geol. Survey, Menlo Park, California 94025.

Two "phreatic" maars in Alaska may have been created by the explosive release of carbon dioxide from a basaltic melt. Both the basalt of the maars and the observed CO_2 ($\delta^{13}C = -6.36\%$) are inferred to have come from the mantle. (Authors' abstract)

BARNES, S.J., 1979, The Katiniq nickel deposit, Quebec - a Proterozoic nickel sulphide - komatiite association (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 384.

Immiscible sulphide liquid droplets were introduced and segregated into topographic irregularities in the footwall during emplacement. The silicate magma portion of the suspension had an MgO content between 15 and 18%, and the mean Cu/Cu+Ni ratio of the sulphides is 0.19, suggesting equilibrium between silicate and sulphide liquids. (From the author's abstract)

BARR, S.M., RATANASATHIEN, B., BREEN, D., RAMINGWONG, T. and SERTSRIVANIT, S., 1979, Hot springs and geothermal gradients in northern Thailand: Geothermics v. 8, p. 85-95. First author at Dept. of Geol., Acadia Univ., Wolfville, N.S., Canada.

Chemical geothermometry of hot springs in northern Thailand indicates that many have reservoir temperatures in excess of 150°C and some in excess of 180°C. Measurements of temperatures in abandoned oil wells in Fang Basin indicate geothermal gradients of 70-130 mK/m. The high geothermal gradient may be the result of extensional tectonics in northern Thailand, caused indirectly by sea-floor spreading in the Andaman Sea. Relatively high reservoir temperatures and shallow reservoir depths suggest that hot spring areas in northern Thailand may be potential sources of geothermal energy. (Authors' abstract)

BARSIKOV, V.L., KOGARKO, L.N., POLYAKOV, A.I., IGNATENKO, K.I. and ZINOVEYEV, A.I., 1979, Differentiation of basaltoid melts and formation of the volcanic rock series of the South Atlantic Islands: Geokhimiya, 1979, no. 11, p. 1587-1600 (in Russian; translated in Geochem. Internat., v. 16, no. 6, p. 1-12, 1979). Authors at Vernadskiy Inst. Geochem. Anal. Chem., Acad. Sci. USSR, Moscow.

In connection with a study of phenocrysts and megacrysts of olivine, clinopyroxene, hornblende, plagioclase, and titanomagnetite from the volcanic rocks of the South Atlantic islands (Grand Canary, St. Helena, and Tristan da Cunha), reports CO_2 inclusions in olivine and pyroxene ankaramites from all the islands. The CO_2 pressure was 5 kbar at 1330° for the ankaramites on Grand Canary island, as against 3.6 kbar at 1280° for the ankaramite-basalts on St. Helena, or 3.3 kbar at 1280° for Tristan da Cunha. These results indicate intermediate magmatic hearths at depths of about 10-18 km. (E.R.)

BARTON, P.B., RYE, R.O. and BETHKE, P.M., 1979, [Sulfur isotope studies at Creede, Colorado] (abst.): U.S. Geol. Survey Prof. Paper 1150, p. 191.

A sulfur isotope study of the ores at Creede, Colo. Analyses of 67 sulfides and 26 barites show a narrow range of $\delta^{34}S$ values for individual sulfide minerals (-1.2 ± 2.2 per mil for sphalerite) but a very large range of values for barite (19.8 to 33.8 per mil). Systematic sampling of two samples of growth-banded sphalerite from widely spaced localities respresenting only a small percentage of the paragenesis shows small, but systematic variations that correlate with variations in temperature and salinity of associated fluid inclusions. Late-stage pyrite is significantly heavier than earlier stage pyrite. No gross changes with location within the district are evident. Two pyrites from different localities yielded very anomalous and puzzling $\delta^{34}S$ values of about 41 and 47 per mil.

Except for short-lived perturbations, the chemistry of the hydrothermal system responsible for the ore deposits was sufficiently oxidizing that sulfate was probably 100 times as abundant as sulfide in the ore fluid, yet the ores themselves contain equal amounts of sulfide and sulfate. Sulfate-sulfide sulfur isotope relationships and detailed sulfur isotope data on sphalerite indicate that the sulfur isotope systematics of the hydrothermal system were not governed by equilibrium exchange reactions; rather, they were governed by mixing of reduced and oxidized fluids in an oxidizing environment. Consideration of possible sources and bulk sulfur isotopic composition for the district as a whole favor strongly, but do not prove, a magmaticlike sulfur near 0 per mil derived from either local volcanic rocks or magmatic emanations. (Authors' abstract)

BATCHELDER, J.N., O'NEIL, J.R. and MORRIS, H.T., 1979, [Light-stable isotope and fluid-inclusion studies of the East Tintic district in Utah] (abst.): U.S. Geol. Survey Prof. Paper 1150, p. 190-191.

A light-stable isotope and fluid-inclusion study of quartz, barite, and galena from the East Tintic mining district in Utah. Fluid inclusions in barite have homogenization temperatures of 300°C to 390°C. No salinities could be obtained. Fluid inclusions in quartz have temperatures of homogenization from 185°C to 325°C and salinities generally less than 1 percent but locally up to 3.5 equivalent weight percent NaCl. The calculated $\delta^{18}O$ values of water in equilibrium with quartz range from -10.0 to $+1.5$ per mil. The δD values of water in fluid inclusions in quartz range from -131 to -98 per mil.

Fluid-inclusion water in galena has $\delta^{18}O$ values of -16.6 to -5.4 per mil and δD values of -121 to -84 per mil. Values of $\delta^{34}S$ for the galenas range from -3.5 to $+0.6$ per mil.

A technique was developed to scrutinize inclusion fluids in cleaved galena. Upon cleaving, the fluids from the inclusions "blew out" leaving behind evaporite halos on the surface around the cavity. Quantitative analyses were performed using an X-ray energy dispersive analyzer and halite and sylvite were identified in the halos but not in the cavities. However, daughter minerals of tetrahedrite, chalcopyrite, argentiferous tetrahedrite, and a silver-antimonide were identified in the cavities.

These data indicate that galena was likely deposited from a saline-brine (<23 equivalent weight percent NaCl) composed of approximately equal proportions of magmatic and meteoric waters. Quartz, on the other hand, although intimately related to galena texturally, was deposited entirely by fluids of meteoric origin that were enriched in ^{18}O through exchange with the wall rock.

BAUBRON, J.-C., BOSCH, Bernard, DEGRANGES, Philippe, LELEU, Michel, MARCÉ, Adrien, RISSLER, J.-J. and SARCIA, Claudine, 1979, Geochemical studies on the thermal waters of the west border of the French Limagne: Bull. Minéral., v. 102, p. 676-683 (in French). First author at Dept. Min., Geoch., Anal., B.P. 60009, 45060 Orleans Cedex, France.

From studies of 22 springs located on the west border of the French Limagne, chemical measurements at the sampling sites for pH, t, SiO_2, Rb, and chemical and isotopical measurements in laboratory on the waters and on the free gases for $\delta^{34}S_{SO4}$, ^3H, δD, $\delta^{18}O$, $\delta^{13}C_{HCO3}$, $\delta^{13}C_{CO2}$, $\delta^{13}C_{CH4}$, lead to the following conclusions:

The thermal waters are of meteoritic origin and are heated in depth; on the basis of the isotopic data, the carbon dioxide and the argon of the free gases associated to these waters, could have a deep supply.

The important chemical heterogeneity of the waters, noticeable for both major and trace elements, could be related with local geological features at the sampling sites and with the possible rock nature in depth.

The temperature reached by the waters was determined using the classical SiO_2, Na-K, Na-K-Ca geothermometers, as follows:

- confirms a mixing model for certain waters, between hot deep mineralized waters and cold non-mineralized superficial waters;
- shows that, for some waters, the silica content is controlled by the precipitation of a silica solid phase;
- leads to hypothesis on the nature of plagioclase in depth.

The use of the $\delta^{13}C$ compositions for CO_2 and CH_4 lead to their equilibration temperature: these temperatures are systematically higher than those coming from the chemical thermometers.

The whole results are compared with the data on the thermal gradient of this area. (Authors' abstract)

BAUM, W. and GOEBEL, V., 1978, Ore paragenesis and geochemical aspects of polymetallic gold-quartz mineralizations, Cordillera Occidental, south-western Columbia, S.A. (abst.): Geol. Soc. Am., Abstract Programs, v. 10, p. 1.

Indexed under fluid inclusions. (E.R.)

BAZAROV, L.Sh., CHEPUROV, A.I., ORLOVA, L.M. and MIKHAILOV, M.Yu., 1978, Some aspects of the genesis of spodumene pegmatites: Tr. Inst. Geol. Geofiz., Akad. Nauk SSSR, Sib. Otd., 78, v. 403, p. 260-265.

Indexed under fluid inclusions. (E.R.)

BEALES, F.W. and HARDY, J.L., 1979, Criteria for recognition of diverse dolostone types from host rocks for Mississipi valley-type ore deposits (abst.): Am. Assoc. Pet. Geol., Bull. v. 63, p. 416.

Indexed under fluid inclusions. (E.R.)

BEALES, F.W. and SIVENAS, P.,1979, Electrochemistry applied to the study of Mississippi Valley-Type ore deposits (abst.): Program, 108th AIME Annual Meeting, New Orleans, Feb. 18-22, 1979, p. 19.

Explanations for Mississippi Valley-Type ore precipitation are not completely satisfactory. The emplacement of disseminated ore bodies, the absence of ore in some places, and its concentration in apparently similar host rocks nearby; differences in mineralogy and zoning, "snow on the roof" sphalerite, and its absence elsewhere; and sulfide stalactites and stalagmites are problematical. Substantial natural voltage gradients may provide an explanation of some of these field observations. Potential differences, e.g., those initiated within the transportation/precipitation sites of the formational and basinal brines, must be considered in conjunction with the potential gradients of the depositing ores. Presently meager but increasing data and numerous possible indications for electro-chemical involvement in ore precipitation already exist. (Authors' abstract)

BEANE, R.E., 1979, Studies of mineralization and alteration at the Sierrita porphyry copper deposit, Arizona: II. Wallrock influence on alteration and mineral deposition (abst.): Program, 108th AIME Annual Meeting, New Orleans, Feb. 18-22, 1979, p. 27.

The occurrence of quartz monzonite and quartz diorite as host rocks to metallization has resulted in formation of minerals characteristic of both potassic and propylitic alteration types in the central portion of this deposit. These early assemblages accompany Cu mineralization, and are overprinted by minor amounts of later phyllic alteration. Use of information derived from fluid inclusion studies in conjunction with mineral stability data indicate that the central propylitic assemblage represents an analogue to potassic alteration in calcic rocks. This conclusion is further substantiated by computer-simulated reactions between a hydrothermal fluid and each of the two rock types present at the deposit, which provide reasonable approximations to observed paragenetic sequences and mass abundance data for alteration phases. These results reveal several mineralogic and paragenetic modifications to classical interpretations of zoned porphyry copper alteration which must be taken into account in exploration. (Author's abstract)

BEANE, R.E., 1979, Genesis of metalliferous ore deposits: U.S. National Report, 17th General Assembly, IUGG, Canberra, Australia, Dec. 1979, Papers in volcanology, geochemistry, and petrology: Reviews of Geophysics and Space Physics, v. 17, no. 4, p. 903-911.

BECK, B.F., 1978, Color differentiation in "fried egg" stalagmites: J. Sediment. Petrol., v. 48, no. 3, p. 821-824.

Indexed under fluid inclusions. (E.R.)

BEHAR, Francoise and PINEAU, Francoise, 1979, Analysis of CO_2, H_2O, and CH_4 of inclusion fluids by gas chromatography of the gas phase: application to Alpine fissures and metamorphic rocks: Bull. Minéral, v. 102, p. 611-621. Authors at Dépt. Sci. de la Terre, Univ. Paris VII, 2 place Jussieu, 75230 Paris Cedex 05, France.

Gas chromatographic techniques have now been developed for the quantitative analysis of H_2O, CO_2 and CH_4 in the vapor phase of fluid inclusions. The problem resulting from the presence of water in the inclusions has been resolved by optimizing the various parameters of the chromatography experiment (length, diameter and temperature of the column and the gas flow) and by the development of an appropriate injection system.

The application of these techniques to inclusions in automorphic quartz from Camperio (Switzerland) and the Terres Noires (France) as well as inclusions in catazonal enclaves from Bournac (France) give results which are in good agreement with direct observations made using heating-freezing stage techniques. (Authors' abstract)

BEHR, H.J., HESS, H., OEHLSCHLEGEL, G., and LINDENBERG, H.G., 1979, Quartz mineralization of the "Suttrop"-type on the northern margin of the eastern Rhenish Slaty Mountains. Aufschluss, Sonderband, v. 29, (Warstein), p. 205-231 (in German).

Some fluid inclusion measurements in quartz. (E. Horn)

BELEVANTSEV, V.I., VASILYEVA, N.G., KOLONIN, G.R., PESHCHEVITSKII, B.I., SHAMOVSKAYA, G.I., and SHIRONOSOVA, G.P., 1979, Thermodynamic analysis and experimantal testing of some gold behavior peculiarities under hydrothermal conditions (abst.): Pacific Science Congress, 14th, Khabarovsk, 1979, Abstracts of Papers, Section BVI, p. 39-40 (in English).

Selection of the most reliable thermodynamic constants, characterizing the stability of dissolved gold forms under standard conditions and at higher temperatures, was made on the basis of the critical analysis of literature data.

Calculations reflecting the influence of various solution parameters (temperature, acidity, reducing-oxidizing potential, concentrations of chloride-ion and sulfur in form of sulfide) on distribution of the dissolved gold between such complex forms as $AuCl_2^-$ and $AuCl_4^-$, mixed hydroxychlorocomplexes, hydrosulfide ones and mixed forms with participation of hydrosulfide ion, were made.

The results of calculation of chiefly dissolved gold forms during the ore formation were used for thermodynamic estimation of the most probable conditions and the reasons of its accumulation from hydrothermal solutions.

Experimental investigations, confirming the basic conclusions of the thermodynamic analysis, are listed. In particular it is ascertained with the help of spectrophotometric and other methods, that rise of temperature promotes gold (III) reduction to the univalent state and to metal. High gold solubility and mobility in hydrothermal solutions in presence of sulfides, having various composition, was shown experimentally.

The data received must be taken into account while developing physical-chemical models of hydrothermal gold deposits formation of the Pacific ore zone. (Authors' abstract)

BELEVTSEV, Ya.N., and TERESHCHENKO, S.I., 1979, Thermobaric conditions for the formation of the Ukrainian Shield iron formation in: Osnovn. Parametry Prir. Protsessov Endog. Rudoobraz., (Dokl. Vses Sovestch) 1977

(Pub. 1979).v.1, 166-171, Kuznetsov, V.A., ed. Izd. Nauka. Sib. Otd.: Novosibirsk, USSR (in Russian).

The thermobarometric conditions of formation of the metamorphic facies in the Precambrian Fe ore deposits of the Ukrainian Shield are interpreted from geol. observations and data from inclusions in minerals. Metamorphism of greenschist facies occurred at 320-400° and 1.5-2.5 kilobars, from aq. solns. low in CO_2. Metamorphism of epidote amphibolite and amphibolite facies occurred at 340-470° and 2-2.5 kilobars from solns. with an H_2O-CO_2 compn. Metamorphism of granulite facies occurred at 460-730° and 4.2-4.4 kilobars from carbonated solns. with CO_2 d. 0.796-0.851 g/cm^3. (C.A. 92: 61977v, 1980)

BENCINI, A., and MARTINI, M., 1979, Variation of silica content in phreatic waters from Vulcano: Soc. Ital. Mineral. Petrol. Rendiconti v. 35, p. 639-646 (In Italian). Authors at Ist. di Min. Petrog. Geoch., via La Pira 4, 50121 Firenze, Italy.

Increasing concentrations of silica observed since February 1978 seem due to gradual heating of the whole volcanic system (E.R.)

BENEŠOVÁ, Zdenka, and ČADEK, Josef, 1979, Conditions of the origin of the Moldava fluorite deposit: Vestnik Ustredniho ustavu geologickeho (Bull. Geol. Survey, Prague) v. 54, p. 151-161 (in English). Authors at Ustredni ustav geologicky, 110 15 Praha 1, Hradebni 9, ĆSSR.

The temperature conditions of the origin of fluorite mineralization were studied using thermometric and cryometric measurements of fluid inclusions in fluorite and exceptionally in quartz. The total temperature interval determined using the homogenization method varied within 60-170°C. The cryometry and study of the inclusions fluids indicated that they belong to the NaCl type and are highly concentrated (10-23%). No essential change in the temperature interval of fluorite crystallization was recorded during the development of the deposit, but the concentration of the fluids varied to a considerable degree. (Authors' abstract)

BENSON, B.B., KRAUSE, Daniel, Jr. and PETERSON, M.A., 1979, The solubility and isotopic fractionation of gases in dilute aqueous solution: Jour. Sol. Chem., v. 8, no. 9, p. 655-690.

BERGER, E, 1979, The role in partial melting of mantle diapirism, CO_2, and H_2O from the study of lherzolite nodules of intracontinental alkali basalts: Example of the French Massif Central, <u>in</u> Origin and distribution of the elements, Proc. of the Second Symposium, Paris, May 1977, L. H. Ahrens, ed.: Oxford, Pergamon Press, p. 619-629. Author at Ecole Nationale Superierue des Mines, 60, boulevard Saint-Michel, 75272 Paris Cedex 06.

The origin of ultrabasic xenoliths of intracontinental alkali basalts may be illuminated by the study of several parameters such as major, minor and trace elements and nature of fluid inclusions. Ultrabasic xenoliths may originate from either depleted or undepleted mantle which in turn may or may not be metasomatized, or by crystallization from magmatic liquids.

Paleogeotherms may be obtained from the temperatures and pressures deduced from lherzolites' ortho- and clinopyroxene compositions. Two end-types of pyroxene-geotherms are observed: a lower temperature ("continental") South African type, and an upper temperature ("oceanic") French Massif Central type.

In the case of the French Massif Central mantle diapirism may be inferred from available paleogeotherms. This interpretation is in good agreement with geophysical records and with the distensive crustal evolution of the area during Tertiary times. The lowering of pressure induced by diapirism of upper mantle would favor decarbonization reactions which in turn would facilitate the genesis of alkali basalts. A hot-oceanic" type paleogeotherm would allow the formation of alkali basalts (Massif Central type) whereas a "continental" paleogeotherm (South African Shield) would favor the production, among other magmas, of kimberlitic or carbonatitic magmas. (Author's abstract)

BETHKE, P.M., and RYE, R.O., 1979, Environment of ore deposition in the Creede mining district, San Juan mountains, Colorado: Part IV. Source of fluids from oxygen, hydrogen, and carbon isotope studies: Economic Geol. v. 74, p. 1832-1851.

The hydrogen isotopic composition of fluids responsible for formation of the near-surface silver-base metal vein deposits at Creede was measured by direct analysis of inclusion fluids in sphalerite, quartz, and rhodochrosite and was estimated from analyses of illite and chlorite. The oxygen isotopic composition was determined directly in inclusion fluids in sphalerite and was estimated from analyses of quartz, illite, rhodochrosite, siderite, and adularia. The carbon isotopic composition was estimated from analyses of rhodochrosite and siderite. The ranges in isotopic composition for water and CO_2 in the fluids associated with the formation of each of the minerals is given below (number of dererminations given in parentheses):

Mineral	D_{H_2O}‰	$^{18}O_{H_2O}$‰	$^{13}C_{CO_2}$‰
Sphalerite	-81 to -54 (4)	-10.1 to -4.5 (4)	
Quartz	-97 to -86 (4)	-5.9 to 1.8 (18)	
Illite	-62 to -50 (8)	-1.6 to 1.2 (7)	
Chlorite	-64 to -55 (10)	-2.2 to 0.8 (10)	
Adularia		4.2 (1)	
Rhodochrosite	-82 to -78 (2)	4.2 to 9.4 (9)	-5.7 to -4.2 (9)
Siderite		4.9 to 9.9 (6)	-6.9 to -2.7 (6)

The δD_{H_2O} and $\delta^{18}O_{H_2O}$ values of fluids associated with the formation of quartz illite/chlorite, and carbonate minerals differ substantially from one another, and these differences appear to have been maintained throughout the depositional history, regardless of the positions of the minerals in the paragenetic sequence.

The data suggest that waters from three coexisting reservoirs fed the vein system alternately and episodically during vein formation, and apparently there was little mixing of the fluids from the different reservoirs. The hydrogen, oxygen, and carbon isotope data suggest that the carbonate waters were deep seated, probably dominantly magmatic, in origin. The sphalerite and illite/chlorite waters must have been dominantly meteoric in origin and substantially oxygen shifted by exchange with the volcanic country rocks. The quartz waters were also oxygen shifted meteoric waters but were some 40 per mil lower in deuterium content than the sphalerite and illite/chlorite waters.

We propose that the quartz fluids entered the vein system from the reservoirs beneath the mountainous areas to the north in the vicinity of the present Continental Divide, but that the sphalerite and illite/chlorite fluids entered the vein system from a topographically low area to the south along the structural moat of the Creede caldera. The difference in δD between the two meteoric waters may reflect differences in altitude of the recharge areas for the two reservoirs or may be due to isotopic evolution of the closed-basin lake and interstitial waters in the moat surrounding the Creede caldera. (Authors' abstract)

BIBBY, D.M., FESQ, H.W. and SELLSCHOP, J.P.F., 1978, Trace elements in diamonds of different types: Nature, v. 276, p. 379-381.

BIGGAR, G.M., 1979, Immiscibility in tholeiites, Mineral. Mag., v. 43, p. 543-544.

Proposes that immiscibility in natural tholeiites is metastable immiscibility of supercooled melts. (ER)

BILENKO, Yu.M., 1979, Nitrogen contents in the diamonds of the Yakutian deposits: Geologiya i Geofizika, v. 20, p. 132-135 (in Russian; translated in Soviet Geol. and Geoph. v. 20, no. 7, p. 113-115, 1979)

Compares the nitrogen contents in natural diamonds from bedrock and placer deposits in different areas of Yakutia. (Author's abstract)

BLAKE, D.W., THEODORE, T.G., BATCHELDER, J.N. and KRETSCHMER, E.L., 1979, Structural relations of igneous rocks and mineralization in the Battle Mountain mining district, Lander County, Nevada; Nevada Bur. Mines and Geology Rept. 33, IAGOD 5th Symp. Proc. Vol. 2, p. 87-99. First author at Duval Corporation, Battle Mountain, NV 89820.

Numerous base- and precious-metal deposits in the Battle Mountain mining district are related to bodies of upper Cretaceous and middle Tertiary granodiorite to quartz monzonite emplaced into thick sequences of Paleozoic sedimentary rocks. Molybdenum mineralization occurs sporadically throughout the district, but is especially concentrated in an elongate stockwork system near Copper Basin. This system is related to numerous small Tertiary(?) quartz monzonite intrusions. Near Copper Basin, the emplacement of most intrusive rocks was controlled by two prominent fracture sets, one striking N70°W and the other north-south. The molybdenite mineralization, including very minor chalcopyrite, is related mostly to the N70°W set. In addition, other mineralized fractures striking approximately N45°W and N45°E acted as important conduits for mineralizing fluids. Many of the molybdenite-stockwork veins and their selvages reflect locally intense potassic alteration, and the veins typically contain potassium feldspar-biotite-calcite-molybdenite, and quartz-molybdenite-calcite±potassium feldspar±white mica assemblages. The molybdenite-bearing veins contain abundant liquid plus minor-vapor fluid inclusions. Preliminary fluid-inclusion studies of these veins suggest the bulk of the molybdenite mineralization occurred during circulation of nonboiling to slightly boiling, moderately saline fluids that range mostly between 4 to 12 wt. % NaCl equivalent and that include appreciable amounts of CO_2. Temperatures were approximately 300° to 400°C. The values of $\delta^{18}O$ of the water calculated to be in equilibrium with hydrothermal quartz from molybdenite-bearing veins are +5.8 to +8.6.* δ D values for water liberated from fluid inclusions ranged from -118 to -77.* These isotopic data suggest the fluids contain a mixture of magmatic and meteoric waters of various proportions. Last the molybdenite-stockwork system has been intruded extensively by a series of late north-south-striking west-dipping quartz latite porphyry dikes associated with minor lead and zinc mineralization. (Authors' abstract) (* ‰?)

BLEČIĆ, Novak, 1976, Gaseous-liquid inclusions as a source of information on the genesis of the ore deposits and the nature of the ore solutions: Proceedings Fifth Jugoslavian Geological Congress, 1976, Ljubljana, Jugoslavia, p. 5-17 (in Serbian with English abstract).

A review with 12 references. May be same material as in <u>Fluid Inclusion Research--Proceedings of COFFI</u>, v. 7, p. 24. (E.R.)

BLOOM, M.S., 1979, Evidence for magmatic-hydrothermal processes from fluid inclusion studies of stockwork molybdenum deposits (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 390.

Fluid inclusion study of stockwork molybdenum orebodies permits assessment of evolving fracture-controlled mineralization/alteration and related fluids. Homogenization temperatures range from 600+ °C in pre-molybdenite assemblages to less than 150°C in post-mineralization affiliations. Mineralization occurred at 380± °C. Further decrease in temperature was associated with late-stage base-metal sulfide and tungsten mineralization.

Salinities range between 2 and 20 wt. % NaCl equivalent during ore deposition. Earlier high-temperature F-biotite alteration was associated with hypersaline brines (40-70 Wt. % NaCl equivalent) in which homogenization occurs by NaCl dissolution. The bulk of the molybdenite deposition coincides with quartz-sericite-pyrite alteration at moderate salinities. Evidence of boiling is abundant in early high temperature mineralization and sporadic in post-molybdenite assemblages.

The data are interpreted as recording the evolution from late magmatic to hydrothermal conditions. Episodic release of magmatic-hydrothermal fluids was accompanied by extensive brecciation and changes from lithostatic to hydrostatic confining pressure. Adiabatic temperature reduction in concert with the rapid pressure release and aided by consequent boiling, dilution and fluid-rock interaction enhanced the ore-forming process. (Author's abstract)

BOCTOR, N.Z., POPP, R.K. and FRANTZ, J.D., 1979, Solubility of hematite in chloride-bearing hydrothermal fluids (abst.): Eos, v. 60, p. 974.

The solubility of hematite in chloride-bearing hydrothermal fluids was determined in the temperature range 400°-600°C and at 1 and 2 kbar. (From the authors' abstract)

BOGOLEPOV, V.G., 1979, The ontogeny of mineral formation during the greisenization process of the Akchatau granite deposit, central Kazakhstan, <u>in</u> Metasomatic mineral formation, Bagdasarov, E.A. <u>et al.</u>, eds., Vses. Nauchno-Issled. Geol. Inst., Tr., v. 287, p. 36-43 (in Russian).

Indexed under fluid inclusions. (E.R.)

BOGOLEPOV, V.G., BULAKH, A.G., NAYDENOV, B.M., POLYVYANNYI, E.Ya. and ANASTASENKO, G.F., 1978, Isotopic composition of argon in carbonatite-generating fluids and in their genesis (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 1, Thermobarogeochemistry in geology: Vladivostok, Acad. Sc. USSR, p. 205 (in Russian). Authors at Kazakh Inst. of Mineral Raw Materials, Alma-Ata, USSR.

During carbonatite formation an important role is played by H_2O, CO_2, O_2, CH_4 and other hydrocarbons, F_2, N_2, Ar etc. One of the newest hypotheses suggests a juvenile source of CH_4 due to the mantle degassing and then formation of CO_2 and H_2O. Isotopic composition of Ar in G/L in inclusions was studied in calcite of carbonatites from Paleozoic alkaline-ultrabasic massifs Central Tur'ia and Sebl'yavrskiy (E. Baltic shield). Samples were taken from phlogopite-calcite carbonatites formed at 2-3 km. Ar derived from the P inclusions that decrepitated in the T interval 200-600°C is radiogenic, involved in the process of metamorphism of a granitic crust. Admixture of ^{36}Ar is probably from a mantle origin. Ar from S inclusions was assimilated mostly in the subsurface layer of the Earth's crust. Maybe, like Ar, also fluids forming carbonatites are heterogeneous. (Authors' abstract, transl. by A.K.)

BOGOLEPOV, V.G.: POLYVYANNY, E.Ya.; NAYDENOV, B.M., and BOLOTO, V.B.M., 1978, The nature of silica gangue-forming solutions in deposits at Karatas and Gulshad in northwestern Balkhash: in Thermobarogeochemistry of the earth's crust and ore formation, N.P. Ermakov, ed.: Moscow, Nauka Press, p. 173-176 (in Russian).

Indexed under "Fluid inclusions."

BOGUSH, I.A., 1979, Complex ores of the sulfide deposits in the Northern Caucasus: Geol. Rudnikh Mestor. v. 21, no. 6, p. 23-43 (in Russian). Author at the Novocherkassk Polytechnical Inst., USSR.

Td 240-300°C is reported to be typical of pyrite of footwall of the ore body and very weak decrepitation at 45-70°C of finely-dispersed volcanogenic-sedimentary pyrite. Td of several more varieties of pyrite are given. (A.K.)

BOLOKHONTSEVA et al., 1978 (See p. 209)

BORISENKO, A.S., 1977, Study of the salt composition of solutions of gas-liquid inclusions in minerals by the cryometric method: Geologiya i. Geofizika, v. 18, no. 8, p. 16-27 (in Russian; translated in Soviet Geology and Geophysics, v. 18, no. 8, p. 11-19, 1978).

Although abstracted from the Russian original in Fluid Inclusion Research—Proceedings of COFFI, v. 10, p. 31, 1977, this full translation makes available the various phase equilibrium data and diagrams for various ternary systems of interest to inclusion study such as (all with H_2O): NaCl-KCl; $NaCl-MgCl_2$; $NaCl-CaCl_2$; $NaCl-NaHCO_3$; $NaCl-Na_2CO_3$; $NaHCO_3-Na_2CO_3$. (E.R.)

BORISENKO, A.S.: LEBEDEV, V.I.: OBOLENSKII, A.A.: ZAIKOV, V.V., and TYUL'KIN, V.G., 1979, Physicochemical conditions for the formation of hydrothermal deposits in Western Tuva: Osnovn. Parametry Prir. Profsessov Endog. Rudoobraz., (Dokl. Vses. Soveshch.) 1977 (Pub. 1979). v.2, 226-235 (in Russian). Kuznetsov. V.A., ed. Izd. Nauka. Sib. Otd.: Novosibirsk, USSR.

The formation conditions of the hydrothermal Au, Ni, Co, Bi, fluorite, barite and other ore deposits in the title region are interpreted largely from fluid inclusion compns. and Th and the S isotope compn. of cinnabar and barite. The ore mineralization resulted from the mixing of exogenic Cl waters of Devonian evaporite basin with juvenile metal-bearing hydrothermal solns. The brine-bearing Devonian rocks acted as a geochem. barrier in the path of the juvenile solns. (C.A., 92:62005p)

BORSHCHEVSKIY, Yu.A. and POKALOV, V.T., 1978, Isotopic composition of oxygen from quartz as an indicator of the genesis and the stages in formation of ores: Sov. Geol., v. 7, p. 144-147 (in Russian).

Indexed under fluid inclusions. (E.R.)

BOTH, R.A., 1978, Remobilization of mineralization during retrograde metamorphism, Broken Hill, New South Wales, Australia, in Mineralization in metamorphic terranes, W.J. Verwoerd, ed.: Pretoria, J.L. van Schaik Ltd., Pretoria, p. 481-489.

Silver-lead-zinc mineralization in the Proterozoic Willyama Complex, New South Wales, has undergone multiple metamorphism and deformation, thus providing the opportunity for studying the effects on the ores of both prograde (amphibolite to granulite facies) metamorphism and retrograde metamorphism.

Two types of silver-lead-zinc deposits are recognized in the Willyama Complex, viz. stratiform bodies known as the "Broken Hill type" and veins known as the "Thackaringa type". These exhibit differences in both mineralogy and textural relationships of the minerals. Electron microprobe analyses have also demonstrated differences in the composition of sphalerite from the two types of deposits.

Isotopic studies of lead and sulfur provide evidence of a genetic relationship between the Broken Hill and Thackaringa types. On the basis of a close spatial relationship between retrograde rocks and Thackaringa type deposits, it is proposed that these veins were derived from the Broken Hill type by partial remobilization during retrograde metamorphism. (Author's abstract)

Fluid inclusion Th range from 187 to 204°C, and Tm ice shows salinity of 23% (p. 487-488). (ER)

BOTKUNOV, A.I., GARANIN, V.K., GOTOVTZEV, V.V., and KUDRAIVTSEVA, G.P., 1979, Sulfide inclusions in olivine from the kimberlite pipe "Udachnaia": Dokl. Akad. Nauk SSSR, v. 247, p. 929-933 (in Russian; translated in Dokl. Acad. Sci. USSR, v. 247, p. 113-117, 1981).

BOTKUNOV, A.I., KOVAL'SKIY, V.V., NIKISHOV, K.N., MAKHOTKO, V.F. and BULANOVA, G.P., 1978, New data on the composition of inclusions in diamond: Akad. Nauk SSSR, Doklady, v. 240, p. 1202-1205 (in Russian).

Microprobe analyses of solid inclusions. (E.R.)

BOYLE, R.W., 1979, The goechemistry of gold and its deposits; Geol. Survey of Canada, Bull. 280, 584 pp.

A thorough study of the chemistry, mineralogy, geology, geochemistry, and exploration of gold. The index has no "inclusion" entry, but pages 410-415 include considerable discussion of inclusion data. (ER)

BRADY, J.B., and FRANTZ, J.D., 1979, A microanalytical technique for determination of aluminum in aqueous solutions: Carnegie Inst. Wash. Yearbook 78 (1978-1979), p. 676-679.

BRAME, S., 1979, Mineralization near the northeast margin of the Nelson Batholith, Southeast British Columbia: Master's thesis, Univ. of Alberta, Edmonton, AB, CAN.

BRATUS', M.D., DEYCHAKOVSKAYA, K.A., PLATONOVA, E.L., SASIN, G.G. and TERLETSKIY, A.V., 1979, Mineralogy of the deep horizons of the Beregovo Deposit: Mineral. Sb. (L'vov. Gos. Univ.), v. 33, pt. 2, p. 44-53 (in Russian; English abstract).

The chemical composition, optical properties, density and lattice parameters of skarn hedenbergite, andradite and ilvaite were determined. These minerals crystallized at 310-260°C from 10-12 vol. % (sic) solutions. Calcareous skarn of Beregovo deposits is a highly ferriferous, low-temperature formation. (Authors' abstract)

BRECKE, E.A., 1979, A hydrothermal system in the midcontinent region: Econ. Geol., v. 74, p. 1327-1335.

Pertinent to the interpretation of fluid inclusion data from Mississippi Valley deposits. (E.R.)

BROWN, F.J., 1978, Geologic thermometers: Earth Sci., v. 32, no. 1, p. 34.

Indexed under fluid inclusions. (E.R.)

BROWN, P.E. and BOWMAN, J.R., 1979, Physical-chemical conditions of tungsten skarn formation at Pine Creek, California (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 395.

Phase equilibrium studies applied to the multi-stage Pine Creek, California, tungsten deposit have tightly constrained its conditions of formation. The formation sequence involves: (1) initial isochemical metamorphism of a variable dolomitic siliceous carbonate parent by early Sierra Nevada intrusives yielding assemblages such as Calcite (Cc)-Dolomite (Dol)-Forsterite-Brucite-(Periclase) and Cc-Clinopyroxene (Cpx)-Kfeldspar (Kfs)-Pyrrhotite-Graphite; (2) metasomatism associated with the mineralizing Tungsten Hills Quartz Monzonite initially formed an endoskarn (Cpx-Kfs-Qz-Plagioclase-Scapolite), exoskarn (Wollastonite-Grossular (Gr)-Vesuvianite-Fluorite) pair at the contact. Infiltrating aqueous solutions (initially Si-Al rich, followed by Fe-Mg enrichment) produced a massive garnet ($Gr_{80-50}And_{20-50}$)-pyroxene ($Di_{70-20}Hd_{30-80}$)$\pm$Qz skarn. Geometrical and structural factors played an important role in determining the final shape and extent of the skarn at any one location. Scheelite is nearly restricted to the skarn. Cordierite and andalusite in associated metapelites, Cc-Dol thermometry and T-X equilibria allow initial P-T-X values to be set at $P=1.5\pm.5$kb, $T=550\pm50$°C and $X(CO_2)=.2-.03$. Application of $T-X_f$ equilibria to observed skarn assemblages, corrected for solid solution effects, restrict skarn formation to $X(CO_2)$ $\leqslant .2$ at T=500±50°C. Use of calculated fO_2-fF_2 and fO_2-FS_2 diagrams (for these P-T) with the Pine Creek assemblages give values of $fO_2=10^{-23}$, $fF_2=10^{-41}$ and $fS_2=10^{-5}$. Garnet-clinopyroxene solid solutions shift the values generally less than 2 log units. Retrograde changes in the primary skarn assemblages produced Amph-Cc-Qz from pyroxenes and Ep-Chl-Cc from garnets. Fluid inclusion and stable isotope studies are in progress to further constrain temperatures and fluid flow parameters. (Author's abstract)

BRYNDZIA, L. T., 1979, Mineralogy, geochemistry, and mineral chemistry of siliceous ore and altered footwall rocks in the Uwamuki no. 4 deposit, Hokuroku district, Japan: M.S. thesis, Univ. Toronto.

The Uwamuki #4 deposit is a unique Kuroko deposit in that it has a distinctly Zn + Pb rich stockwork (Black Siliceous Ore; BSO), in addition to the more common Cu + pyrite stockwork (Yellow Siliceous Ore; YSO). The stockworks underlie a Cu-rich BSO, but without a massive YSO. Textural data are presented which suggest that the two stockwork zones formed separately in space and time, with the YSO forming prior to the BSO, and that the Cu-rich nature of the BSO is due to incorporation of a "pre-existing" yellow ore genetically related to the YSO zone.

Alteration trends as depicted by ternary Al_2O_3-MgO-($CaO+Na_2O+K_2O$) plots show that the Uwamuki #4 deposit is characterized by a trend of MgO and CaO + Na_2O + minor K_2O depletion at a constant K/Al ratio similar to that found in stoichiometric sericite. Consequently, sericite (± illite) + quartz are the only silicate materials found in the Uwamuki #4 footwall rocks.

In the BSO, mole % FeS in sphalerite coexisting with pyrite decreases from 0.30 ± 0.04 in the stockwork siliceous ore to 0.11 ± 0.01 in the bedded siliceous ore. The decrease of FeS in sphalerite reflects a decrease in the formation temperature of sphalerite (262°-230°C, from literature fluid inclusion data) at a nearly constant f_{S_2} value of $10^{-9.0}$ atm. On the -100 m level, the area of highest f_{S_2} coincides with the area of maximum Zn + Pb deposition while barite was deposited under the lowest f_{S_2} conditions.

The mineral paragenesis observed on the scale of a thin section reflects in large scale the geochemical zonation in the stockwork, i.e. Cu-Zn+Pb-Ba zones, and is the same mineral zonation that characterized stratiform Kuroko deposits. Sulfur isotopic data show that the $\delta^{34}S$ values of pyrite in the BSO and YSO zones are significantly different, indicating that the YSO and BSO zones were formed under different physical and chemical conditions, and possibly involved two unique fluid phases. However, there is a paragenetically controlled decrease in the $\delta^{34}S$ values of pyrite from the YSO to the BSO, which can best be explained if only a single fluid phase was involved, and the physical and chemical nature of this fluid phase changed with time.

The evolution of the ore fluid with time has been deduced by combining sulfur isotopic data with mineralogical information. The changes in the ore fluid with time are an increase in f_{O_2} and $m_{\Sigma S}$ with decreasing temperature and pH at a nearly constant sulfur fugacity. These changes in the fluid phase with time can be explained by a simple model involving the evolution of a sea water dominated ore-forming fluid. Sea water was the source of sulfate sulfur in the Uwamuki #4 deposit, as well as the cause of a decrease in temperature and increase in f_{O_2} which probably controlled the deposition of sulfides. An increase in the integrated sea water: rock ratio most likely influenced the deposition of barite. (Author's abstract)

BUCHANAN, D.L., and NOLAN, J., 1979, Solubility of sulfur and sulfide immiscibility in synthetic tholeiitic melts and their relevance to Bushveld-complex rocks: Canad. Min.. v. 17, p. 483-494.

Three synthetic tholeiitic melts have been examined experimentally at 1200°C under controlled oxygen and sulfur fugacities at one atmosphere total pressure. Runs were carried out over an oxygen fugacity range of -log 8.50 to -log 11.50 and a sulfur fugacity range of -log 1.00 to -log 4.00. In sulfur-undersaturated silicate melts the amount of dissolved sulfur increases with increasing sulfur fugacity and decreasing oxygen fugacity. Results obtained on starting composition DB/3 (SiO_2 47.6, Al_2O_3 14.8, CaO 8.1, MgO 11.1, total iron as FeO 17.8 wt.%) establish sulfur saturation in the silicate melt along the oxygen fugacity isobars of -log 10.50 and -log 11.50: sulfur fugacities are greater than -log 1.75 and -log 3.75 respectively. By running two additional compositions DB/8 and PAL-685, with FeO contents of 22.75 and 15.65 wt.% respectively, in the field of saturation, sulfur solubility as a function of oxygen fugacity and iron could be established. From Fick's 2nd law of diffusion and the determined sulfur profile a value of 5.6 x 10^{-8} was obtained for the apparent inter-diffusion coefficient of sulfur in starting composition DB/3. The experimental results suggest that in the iron-rich melts present at the top of the Bushveld sequence where values of oxygen fugacity were probably close to the QFM buffer curve, values of sulfur fugacity greater than -log 1.00 would be required before an immiscible sulfide phase could be formed at temperatures of 1200°C. The large field over which the melt is saturated with sulfur at low oxygen fugacity, however, enables an immiscible sulfide to form at very much lower values of sulfur fugacity. This may be an important factor in the formation of sulfide concentrations in the magnesium-rich melts that were present at the base of the Bushveld sequence. (Authors' abstract)

BUKATY, M.B., and VOZHOV, V.I., 1979, Carbon monoxide in the gases dissolved in ground waters in the southwest of the Siberian platform: Geologiya i Geofizika, v. 20, no. 7, p. 37-40 (in Russian; translated in Soviet Geol. & Geophys., v. 20, p. 31-34, 1979).

Discusses the discovery, in the Upper Precambrian and Lower Cambrian deposits of the Kuyumba area, of ground waters saturated with gases containing large amounts of CO and H_2. Their analysis, in the light of similar gases known among platform regions only on the Siberian platform, has led to the conclusion that they were formed through the escape of gases from the basement rocks in zones of deep subsurface faults, suggesting the possible oil and gas exploration significance of CO-containing gases. (Authors' abstract)

BULAKH, A.G., ANASTENKO, G.F., and APOLONOV, V.S., 1979, Methods and results of thermometry of the process of carbonatite formation in alkalic-ultrabasic massifs: Mineralogiya i Geokhimiya, v. 6, p. 39-57 (in Russian).

Calcite, magnetite, and apatite samples from the Turi Peninsula were examined for Th and Td. Pre-carbonatite rocks crystallized at 1080-600; carbonatites, 750-100°, and post-carbonatite rocks, 380-80°C (ER)

BULANOVA, G.P., VARSHAVSKIY, A.V., LESKOVA, N.V. and NIKISHOVA, L.V., 1979, Problem of the "central" inclusions in natural diamonds: Akad. Nauk SSSR Doklady, v. 244, no. 3, p. 704-706 (in Russian). Authors in Geol. Inst. of Yakutian Division of Siberian Branch of Acad. Sci. USSR, Yakutsk, USSR.

Most natural diamond crystals bear "central" inclusions defined as crystallization nuclei and that are different than most other solid inclusions in diamonds. The studied "central" inclusions are taenite, pyrrhotite, troilite and graphite, defined by x-ray studies and electron microprobe analysis. (A.K.)

BULAU, J.R. and WAFF, H.S., 1979, Equilibrium fluid distributions in olivine-basalt assemblages at high pressures and temperatures (abst.): Eos, v. 60, p. 966.

BURIAK, V.A., 1979, Results of the correlation between the evolution of gross chemical composition of quartz-vein mineral associations and gas-liquid inclusions in quartz of these associations (exemplified by the gold-bearing veins of low-sulfide formation). Dokl. Akad. Nauk SSSR, v. 248, p. 436-439 (in Russian; translated in Dokl. Acad. Sci. USSR, v. 248, p. 121-124, 1981).

As Th (and P) decrease with evolution, K contents increase and Na/K decreases. (ER)

BURKE, R.A., Jr., BROOKS, J.M. and SACKETT, W.M., 1979, Light hydrocarbon geochemistry of Red Sea brines and sediments (abst.): Eos, v. 60, p. 845.

BURNHAM, C.W., 1979, The importance of volatile constituents, in The evolution of the Igneous Rocks, H.S. Yoder, ed.,: Princeton, N.J., Princeton Univ. Press, p. 439-482.

BURRUSS, R.C. and HOLLISTER, L.S., 1979, Evidence from fluid inclusions for a paleogeothermal gradient at the geothermal test wells sites, Los Alamos, New Mexico: J. Volcan. and Geother. Res., v. 5, p. 163-177. Authors at Dept. Geol. Geophys. Sci., Princeton Univ., Princeton, NJ 08540, U.S.A.

Homogenization temperatures of individual fluid inclusions from the geothermal test well sites near Los Alamos, New Mexico, systematically change as a function of depth in the cores. Inclusions in samples from depths between 1.5 and 3.0 km have reequilibrated to thermal gradients higher than the present gradient of 50-60°C/km. The loci of maximum temperatures attained has a slope of about 70°C/km; the deepest sample has cooled to 200°C from a maximum of 230°C. The wide range of salinities (0.0 wt. % equivalent NaCl to more than 25 wt. % equivalent NaCl) observed in each sample indicates a large amount of pervasive fluid circulation had not occurred at the time of reequilibration of these inclusions. The results are relevant to calculations for the thermal history of the test site. (Authors' abstract)

BURYAK, V.A., 1979, Results of a comparison of the evolution of the bulk chemical composition of quartz-bearing vein mineral associations and gas-liquid inclusions of quartz of these associations (as exemplified by gold-bearing veins of a low-sulfide formation): Dokl. Akad. Nauk SSSR, v. 248, no. 2, p. 436-439 (in Russian). Duplicated from Buriak (1973) above.

BUSH, P.R., 1979, Carbonate coastal sabkhas; the precursor of Mississippi Valley-Type lead-zinc deposits? (abst.): Program, 108th AIME Annual Meeting, New Orleans, Feb. 18-22, 1979, p. 18.

The modification of marine and non-marine groundwaters in arid coastal plain sediments (sabkhas) as the result of precipitation of salts and the reactions between the brines and earlier formed carbonate minerals produces a solution similar to that found in fluid inclusions associated with Mississippi Valley-type deposits. The carbonate minerals found in the sabkha deposits are capable of producing the first phase of enrichment for some heavy metals. These metals are released during later diagenesis to become involved in further benefication processes. (Author's abstract)

BYCHKOV, A.S., PAVLOVA, G.Yu. and STASHCHUK, M.F., 1978, Limits of use of ion-selective electrodes for studies of liquid phase in inclusions in evaporite minerals, (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 1, Thermobarogeochemistry in geology: Vladivostok, Acad. Sci. USSR, p. 187-188 (in Russian). Authors at Far-East Sci. Center of Acad. Sci. of the USSR, Vladivostok.

Ion-selective electrodes were used for determination of pH, Na, K, Ca, Mg, halogens and carbonates. Although the method is rapid, it cannot be used for determination of complete composition of liquid phase in inclusions, because: 1. Ion-selective electrodes are difficult to calibrate since ionic strength of solutions varies widely, 2. Other ions disturb the determination, 3. Complexing of ions occurs in many solutions, 4. Deviations (are) caused by high ion concentrations. (Authors' abst., transl. by A.K.)

BYDTAYEVA, N.G., 1978, Temperature conditions for the formation of accessory minerals in quartzites from the Aldan Shield, in Thermobarogeochemistry of the Earth's Crust and Ore Formation, N.P. Ermakov, ed., Izd. Nauka, p. 96-98 (in Russian).

Indexed under fluid inclusions. (E.R.)

CALAS, Georges, HUC, A.-Y. and PAJOT, Bernard, 1976, Utilization of infrared spectrometry for fluid inclusion studies in minerals: feasibility and limits: Soc. fr. Mineral. Cristallogr., Bull., v. 99, p. 153-161 (in French with English abstract). First author at Lab. de Min. Crist., C.N.R.S., Univ. Pierre et Marie-Curie, 75230 Paris Cedex 05, France.

It is possible to detect in situ the main components of fluid inclusions in a short time by infrared spectrometry: water, carbon dioxide and organic matter, and their relative proportions. It is also possible to estimate the volumetric importance of those inclusions in the mineral. The interest for crystal growth studies is pointed out, and also the limits of the method, principally related to mineral absorption in the majority of the cases (with the exception of natural halogenides), which can make the fluid inclusion spectra more difficult to study. (Authors' abstract)

CARIGNAN, J., KHEANG, L., BROWN, A. and GELINAS, L., 1979, A preliminary microthermometric study of fluid inclusions associated with the volcanic deposit of Millenbach: Geol. Assoc. Can.-Mineral. Assoc. Can., Jt. Annu. Meet., Program Abstr., v. 4, p. 42 (in French).

CARLSON, S., 1979, Fluid inclusion studies of the tourmaline copper-molybdenum bearing breccia pipe, northern Peru: MS thesis, Univ. Minnesota.

CARPENTER, A.B., GARBARINI, M.J., and FRANK, J.R., 1979, Diagenetic changes in the Lamotte and Bonneterre Formations in response to metal-rich solutions (abst.): Program, 108th AIME annual meeting, New Orleans, Feb. 18-22, 1979, p. 19.

Samples of the Lamotte Sandstone and Bonneterre Formation containing disseminated sulfides from the Viburnum Trend, Missouri, have been examined with an electron microscope and a luminoscope. The sequence of authigenic minerals in the sandstone is potash feldspar, galena, quartz, chalcopyrite, and kaolinite plus illite. A high percentage of the galena has been precipitated on grains of detrital apatite. Some of the authigenic carbonates in the Bonneterre Formation have distinctive patterns of cathodoluminescence. Zones of intense red luminescence in dolomite appear to indicate episodes of sulfide deposition. (Authors' abstract)

CARPENTER and GRETHEN, 1979 (See p. 209)

CARSTENS, H., 1979, Liquid immiscibility in basic alkaline magmas: Chem. Geol., v. 27, p. 297-308.

CAWTHORN, R.G., and FRASER, D.G., 1979, Element partitioning in immiscible volcanic liquids: a statistical model: Chem. Geol., v. 27, p. 99-114.

CAWTHORN, R.G., MCIVER, J.R., McCARTHY, T.S., WYATT, B.A., FERGUSON, J., and BARNES, S.J., 1979, Possible liquid immiscibility textures in high-magnesia basalts from the Ventersdorp Supergroup, South Africa: Jour. Geol., v. 87, p. 105-113.

CELICO, P., DE GENNARO, M., GHIARA, M.R., and STANZIONE, D., 1979, Structural, hydrogeological and geochemical investigations on thermal springs in the Valle del Sele, Salerno: Soc. Ital. Mineral. Petrol. v. 35, p. 389-409 (In Italian). First author at Ist. Geol. appl., Univ. Napoli, Napoli, Italy.

On the basis of geochemical results Contursi waters seem to have two main circuits: the first, shallower, with low salinity and low temperature calcium-bicarbonate waters, the second deeper, with high TDS, Cl, SO_4, Li, Sr, Rb and NH_4 thermal waters, and intermediates on a mixing line. (ER)

CHARLES, R.W., 1979, Reaction of Sentinel Gap basalt in an experimentally controlled temperature gradient (abst.): Eos, v. 60, p. 973.

CHAROY, B., 1979a, Definition and importance of deuteric phenomena and associated fluids in granites. Metallogenetic consequences: Sciences de la Terre, Mémoire no. 37, 364 p., 119 fig., 76 tables, 7 plates. Author at CRPG, BP20, 54501 Vandoeuvre les Nancy Cedex, France.

The present memoir is an attempt to understand as precisely as possible several types of late to post magmatic alterations (deuteric stricto lato). These phenomena were studied in several, a priori representative, examples in Cornwall and Brittany. The study is developed along four principal themes:

The character of the magmatism in Cornwall, the determination of the thermobarometric conditions of anatexis and source possibilities of the granitophile elements (B, Li, F, Sn and W).

The early processes corresponding to the development of a "vapor" enriched in boron and potassium which unmixed from a magma at the end of crystallization and which was in equilibrium with a magmatic brine, the character of which has been defined in the present study. This early tourmalinization is at the origin of certain specific facies (tourmalinites) and of certain "hydrothermal" breccias.

Greisenization of the wall rocks of the quartz veins mineralized in tin, tungsten and copper and including the petrographic aspects and geochemical characterization of this alteration and a detailed study of the fluid inclusions representative of the contemporaneous hydrothermal fluids. These fluids were acid (pH ~3 to 4.5) aqueous chloride solutions, rich in sodium (K/Na at.: 0.06 to 0.15) and having a low salinity (5 to 10 wt.% equiv. NaCl) the deposition of the principal mineralizations was for the most part synchronous with the greisenization. The nature of the complexes responsible for transporting the metals remains open to question but there appear to have been several types of boron and fluor complexes which succeeded each other in time.

Kaolinization with affirmation of the existence of a phase of hydrothermal argillization developed by fluids of very low salinity (2 to 3 weight % eq. NaCl) at between 100 to 200°C and in an acid environment having K/Na (at.) from 0.200 to 0.300. Aluminium, commonly considered to be a relatively immobile element, must have been present in solution in the form of colloidal complexes which led to the direct precipitation of kaolinite in the veins that cut the deposit. This hydrothermal alteration appears to have facilitated the development of a later supergene kaolinization.

The results and conclusions presented in this memoir cannot be used to establish a generalized model for deposits of this type termed "depart acide" but rather their significance is restricted to the specific deposits studied, The results obtained in the present work indicate the major importance of the tectonic and structural factors in the development of such phenomena (alterations and associated mineralizations). (Author's abstract)

(Editor's note - although not so stated, most of the above data came from study of the fluid inclusions.)

CHAROY, Bernard, 1979b, Greisenization, mineralization, and associated fluids at Cligga Head, Cornwall (Southwest England): Bull. Minéral, v. 102, p. 633-641 (in French).

The nature and characteristics of the hydrothermal solutions contemporaneous with (i.e., responsible for) the greisenization and Sn-W mineralization of Cligga Head have been approximated from the study of fluid inclusions. The mineralization occurs in a stockwork of quartz veins with strongly greisenized wall-rocks. In spite of the evidence of telescoping and superposition of different phenomena (successive sequences of fracturing, circulation, precipitation and fracture healing), it has been possible to unravel the hydrothermal evolution:

1) The total salinity decreases with decreasing temperature from 10% wt. eq. NaCl at 400°C to 2-3% wt. eq. NaCl around 100-200°C (kaolinization phase); the pressure, while in the subvolcanic environment of the intrusive never being excessive, is always sufficient to prevent boiling of the solutions.

2) The greisenization of the wall-rocks, the mineralization and the formation of the quartz veins are seen to be synchronous and appear to be complementary expressions of a single process.

3) The solutions are rich in sodium and chloride and, depending on the temperature, have an estimated pH between 3 and 4.8; CO_2 is notably absent. The K/Na atomic ratio is related to the hydrolysis of each of the feldspathic phases and increases progressively from 0.08 to 0.30.

The conclusions, while accounting for the results presented in this study, cannot be generalized to a larger genetic model for "depart acide" deposits. (Author's abstract)

CHEKHMIR, A.S., EPEL'BAUM, M.B. and LYUTOV, V.S., 1979, Migration characteristics of some components of fluid in magmatic melts at elevated pressures and temperatures: Akad. Nauk SSSR Doklady, v. 246, no. 3, p. 698-701 (in Russian). Authors at Inst. of Experimental Mineralogy of Acad. Sci. of the USSR, Chernogolovka near Moscow.

Diffusion of HF, HCl, P_2O_5, H_2O, CaO, SiO_2 in melts at 1000-1100°C and 500 bars, are characterized. Pertinent to melt inclusion studies. (A.K.)

CHERNOSKY, J.V.,JR., 1979, Experimental metamorphic petrology: U.S. National Report, 17th General Assembly, IUGG, Canberra, Australia, Dec. 1979, Papers in volcanology, geochemistry, and petrology: Reviews of Geophysics and Space Physics, v. 17, no. 4, p. 860-871.

CHEUNG, H: FULLER, M.E. and GAFFNEY, E.S., 1979, Modeling of brine migration in halite (abst.): Program, Materials Research. Soc. Symp. on Scientific Basis for Nuclear Waste Management, Cambridge, Mass. Nov., 1979, p. 114.

An evaluation of four different theoretical models for the migration of brine (i.e., inclusions) in halite (ER)

CHOU and WILLIAMS, 1979 (See p. 209)

CHRISTOPHERSON, K.R., 1979, A geophysical study of the Steamboat Springs, Colorado, geothermal systems: Master's thesis, Univ. of Colorado, Boulder, CO, USA.

CHUPIN, V.P., BAKUMENKO, I.T., and SOBOLEV, V.S., 1979, Crystallized inclusions of melts in quartz of rapakivi granites: Dokl. Akad. Nauk SSSR, v. 248, p. 1200-1204 (in Russian; tranlated in Dokl. Acad. Sci. USSR, v. 248, p. 109-111, 1981).

Th values range from ~ 590 to 830°C. (E.R.)

CLOCCHIATTI, R., 1979, Immiscible droplets of high titanium and phosphorous glass in the ground-mass of strange andesitic rocks (Mont-Arci, Western Sardinia): Extension of immiscibility field: C.R. Acad. Sci. Paris, v. 289, Ser. D, p. 607-610 (in French). Author at Lab. Petrog., Bat. 504, Univ. Paris Sud, 91405 Orsay Cedex, France.

The groundmass of the andesitic lavas is made of a granitic matrix glass which contains small spherules of a dark red colored glass. Titanium (TiO_2 17%) and phosphorous (P_2O_5 6.7%) contents are very high, SiO_2 (30%) and Al_2O_3 (1.2%) - very low. Spherules are also highly enriched in manganese, nickel and sulphur. Both melts are similar to some glasses found in terrestrial basalts and in lunar rocks. Their composition implies a considerable extension of the immiscibility field as inferred from experimental studies. (Author's abstract, modified by J. Touret)

CLOCCHIATTI, Robert, HAVETTE, Andree and NATIVEL, Pierre, 1979, Petrogenetic relations between transitional basalts and oceanites from trapped melts in olivine and chromospinels phenocrysts of Piton de la Fournaise (Reunion island, Indian ocean): Bull. Minéral, v. 102, p. 511-525 (in French). First author at E.R. 45 du C.N.R.S. - Lab. Petrog.-Volc., Univ. Paris XI, 91405 Orsay, France.

The phenocrysts of olivine and chrome spinel of recently erupted oceanites (1966 and 1977) from Piton de la Fournaise contain a not insignificant quantity of monophase and polyphase glass inclusions. The inclusions in the spinel contain glass or glass with gas bubbles; those in the olivine are most frequently glass with gas bubbles and daughter spinel crystals. In a few crystals of olivine some crystals of pyroxene and sulfides of Fe, Cu and Ni globules have been observed and analyzed. The sulfides have separated at high temperatures ($>$ 1,200°C) on initial liquid saturated in sulphur. The melt inclusions of the olivines and spinels have a transitional basalt composition. The enriched contents of MgO and Cr_2O_3 in the melt trapped in spinel show that these minerals began to crystallize before the olivine. The comparison between petrographic and geochemical data of transitional basalt and oceanite shows a cumulative character of the oceanite. This is also suggested by a comparison between chemical composition of melt inclusions on one hand, and melt adhered to the crystals and whole rock on the other hand. The sulphur contents in the melt inclusions (1,800 ppm) are clearly greater than those measured in the whole rocks and they provide a good approximation of the sulphur content of the parental basaltic magma. (Authors' abstract)

CLOCCHIATTI, Robert and KRASOV, Nikolai, 1979, Fractional crystallization and immiscibilities in calc-alkaline melts trapped by feldspar phenocrysts of Karimski Volcano lavas (Kamtchatka, U.S.S.R.): C.R. Acad. Sc. Paris, v. 289, Ser. D, p. 1-4 (in French).

During the magma ascent and slow cooling down, fledspar phenocrysts keep on crystallizing from the andesitic melts trapped in melt inclusions. According to the composition of phases which crystallize on the cavity walls, the formation of either basic or acid residual melts, or even immiscibility between both can be noticed. The most evolved terms of the series are becoming richer in volatile elements: this is shown by the appearance inside the inclusions of hydrous phases (amphiboles, biotites) and of magnetite, postassic feldspar and quartz crystallization. The description of the glass inclusion evolution is typical of many calc-alkaline series and shows physical and chemical conditions of crystallization identical in the lavas generated in subduction regions. Optical, thermometrical and chemical studies of the inclusion filling and more particularly, the important immiscibility phenomena, are discussed. (Authors' abstract)

CLOKE, P.L., 1979, Application of the concepts of the halite trend to the Granisle and Bell porphyry copper deposits, British Columbia (abst.): Geol. Assoc. Can.-Min. Assoc. Canada Program with Abstracts, v. 4, p. 43.

Consideration of prior data on high salinity inclusions at Granisle and Bell and of $NaCl-KCl-H_2O$ equilibria provides new insights into porphyry copper mineralization and alteration. Many inclusions homogenize during heating by disappearance of halite after both sylvite and vapor have vanished. These temperatures permit estimating compositions in respect to the $NaCl-KCl-H_2O$ system. These compositions plot along a line (the halite trend) pointing toward a slightly potassic halite.

We interpret these data in view of known and extrapolated phase equilibria in this ternary and the Na/K/Ca geothermometer as follows:

1) potassic ore and alteration at Granisle formed at 400° to possibly 800° from solutions with salinities up to 70% and K/Na atomic ratios ≥0.2. These solutions probably came directly from magma, and changed composition by crystallization of halite but not by boiling or mixing with meteoric water.

2) sericitic ore and alteration at Bell formed at temperatures of 400° to 600°C from solutions with K/Na atomic ratios ≤0.2 and salinities like those at Granisle. They probably arose from equilibration of meteoric water with host intrusions at ca. 500°C and enhancement of salinity by boiling.

3) most crystallization at Granisle took place at high pressure whereas that at Bell occurred at lower pressure.

Comparison with fluid inclusion data on other porphyry copper deposits suggests that deposits with undisturbed potassic zones are similar to Granisle and deposits with sericitic and phyllic overprints to Bell. (Author's abstract)

CLOKE, P.L. and KESLER, S.E., 1979, The halite trend in hydrothermal solutions: Econ. Geol., v. 74, p. 1823-1831. Authors at Dept. Geol. and Min., Univ. Mich., Ann Arbor, MI 48109.

Observations of halite and sylvite disappearance temperatures in fluid inclusions from high-temperature deposits indicate that the trapped solutions have compositions lying on linear trends in the $NaCl-KCl-H_2O$ system. These trends were formed by crystallization of KCl-bearing halite from the hydrothermal solutions before the liquid was trapped in fluid inclusions. Consideration of phase equilibria in the $NaCl-KCl-H_2O$ system indicates that the required pre-trapping, halite-liquid equilibria could be caused by reaction paths such as: (1) the EL path, in which halite separates from liquids under sufficient pressure to avoid the presence of vapor, i.e., if pressure decreases sufficiently prior to trapping, a vapor phase will form subsequently and the inclusions will homogenize by vapor disappearance but fall on the halite trend; (2) the EV path, in which a vapor phase crystallizes halite and then separates from it and partially condenses to liquid, which in turn becomes separated and trapped in inclusions without further compositional change; (3) the DL path, in which a decrease in pressure places the system into the vapor + halite field, thus causing the liquid to boil and deposit halite; and (4) the SC path, in which liquids are trapped while on the solubility surface in the $NaCl-KCl-H_2O$ system (in equilibrium with halite and vapor) or after cooling (with little pressure drop) to yield the assemblage liquid + halite.

Solutions trapped while undergoing each of these processes will yield a specific, and in some cases distinctive, assemblage of inclusion types, thus permitting designation of the probable path that formed the observed halite trend. This, in turn, permits limits to be put on the pressures and temperatures of mineralization. Experimental data on Na, K, and Ca contents of fluids in equilibrium with granitic rocks as well as data on the partitioning of Cl between magma and aqueous phases support the interpretation that solutions at the high-temperature end of the halite trend originated by exsolution from a granitic magma. (Authors' abstract)

CLOKE, P.L., WILSON, J.W.J., KESLER, S.E., and KELLY, W.C., 1979, Application of the concepts of the halite trend to the Granisle and Bell porphyry copper deposits, British Columbia (abst.): Geol. Assoc. Canada-Min. Assoc. Canada Program with Abstracts, v. 4, p. 43.

(See Cloke, 1979, above.)

COBB, J.C., STEELE, J.D. and ASHBY, J.F. 1979, Sphalerite-bearing coals in the central region of the United States (abst.): Abstracts of papers, Ninth Internatl. Cong. of Carboniferous Stratigraphy and Geology, Univ. Ill. at Urbana, p. 40. Authors at Illinois State Geological Survey, Urbana, IL 61801, U.S.A.

Some coals of the Desmoinesian Series in the central region of the United states are enriched in zinc and cadmium. The zinc and cadmium enrichment of these coals is restricted to certain areas in Illinois, Iowa, Missouri, and Kansas and is attributed to the presence of sphalerite, which is an epigenetic mineral in these coals. In those enriched areas, a strong positive correlation exists between high concentrations of zinc and cadmium and the degree of disturbance in the seams. Disturbances of coal seams include clastic dikes, faults, and fractures, all of which may or may not contain sphalerite.

In the sphalerite-bearing coals in Illinois, Iowa, Missouri, and Kansas, paragenetic sequences of kaolinite, pyrite, multibanded sphalerite, pyrite, and multibanded calcite occur. The sphalerite bands are colorless containing purple lamellae, yellow, and orange. Fluid inclusions in sphalerite suggest that the mineral was precipitated from moderately hot (80° to 100°C) saline formation waters.

An area of sphalerite-bearing coals in the northwestern part of the Illinois Basin Coal Field (Fulton, Knox, Peoria, and Stark Counties), which has about 7.2 x 10^9 metric tons of mapped resources in the ground, was sampled in detail to assess the zinc and cadmium enrichment. The arithmetic mean concentrations on a whole coal basis were 750 µg/g for zinc and 7.4 µg/g for cadmium. The confidence intervals for these means at the 90 percent significance lever are 490 to 1010 µg/g for zinc and 4.6 to 10.2 µg/g for cadmium. Because the zinc and cadmium data are distributed lognormally, a special statistical estimator (Sichel's t) has been used to assess their geochemical abundance. These abundance estimates are 1026 µg/g for zinc and 8.1 µg/g for cadmium. (Authors' abstract) (See adjacent abstract in same volume for details of occurrence of geol. veins containing sphalerite (ER))

COCKER, M.D. and PRIDE, D.E., 1979, Hydrothermal alteration-mineralization of a subvolcanic-volcanic complex, Breckenridge Mining District, Colorado (U.S.A.), in Papers on mineral deposits of western North America, IAGOD Fifth Quadrennial Symposium Proc., v. 2, J.D. Ridge, ed.; Nevada Bur. Mines and Geology Report 33, p. 141-149.

Early Zn-Pb-Ag-Au veins in the district are temporally related to development of the phyllic-propylitic alteration. An episode of Zn-Ag-Au-Cu-Bi mineralization also was identified and is associated with the development of the explosion breccias. Molybdenum and tin ranging up to 300 ppm, and tungsten to 1000 ppm, may represent "leakage" from underlying molybdenum mineralization up along fractures and by inclusion in intrusion breccias. Halite-bearing and gas-rich fluid inclusions further suggest highly saline and boiling conditions during part of the evolution of the igneous complex. (From the authors' abstract)

COHEN, L.H. and ROSENFELD, J.L., 1979, Diamond: depth of crystallization inferred from compressed included garnet: J. Geol., v. 87, p. 333-340. First author at Dept. Earth Sci., Univ. Calif., Riverside, California 92521.

Data on the compressed state of garnet included in diamond are used to place restrictions on the pressure(P)-temperature(T) conditions of inclusion. To do this we first locate a P-T point or region within which the relative compression between host and inclusion is eliminated. Then we use comparison dilatometry of the two minerals to 7 kbar to determine a set of P-T curves of constant difference in natural strain. From that set we then select a subset encompassing the P-T condition(s) found in the first step. Extrapolation of such curves to plausible geotherms shows that the probable source of many diamonds associated with garnets of the type found in eclogites lies within the stability field of diamond somewhere between 145 km and 300 km beneath the surface, consistent with independent inferences from chemical petrology. (Authors' abstract)

COLE, D.R. and OHMOTO, H., 1979, Mechanisms of oxygen isotope exchange between aqueous solutions and granitic rocks (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 403.

COLLINS, P.L.F., 1979, Gas hydrates in CO_2-bearing fluid inclusions and the use of freezing data for estimation of salinity: Econ. Geol., v. 74, p. 1435-1444.

During cooling of CO_2-bearing fluid inclusions the clathrate compound carbon dioxide hydrate ($CO_2 \cdot 5.75H_2O$) freezes out prior to the freezing of the remaining aqueous solution to ice. When crystallized in aqueous solution, gas hydrates form pure compounds of the encaged species and H_2O molecules and reject from the hydrate lattice any salts or ions in solution. Thus the residual aqueous solution, after clathration, is more saline than the original solution, and measurement of the salinity using depression of the fusion temperature of ice by salt will give an inaccurate estimate of the salinity of that solution. Although the formation of CO_2 hydrate in CO_2-bearing fluid inclusions, or any gas hydrates in fluid inclusions, invalidates use of the depression of the fusion temperature of ice for estimating the salinity of the aqueous solution, the depression of the temperature of decomposition of the CO_2 hydrate in the presence of CO_2 liquid and CO_2 gas can be a useful measure of salinity, provided CH_4 and other gases are not present in the inclusion. (Author's abstract)

CORLISS, J.B., and 10 others, 1979, Submarine thermal springs on the Galapagos Rift: Science, v. 203, p. 1073-1083. First author at School of Oceanography, Oregon State University, Corvallis 97331.

The submarine hydrothermal activity on and near the Galapagos Rift has been explored with the aid of the deep submersible Alvin. Analyses of water samples from hydrothermal vents reveal that hydrothermal activity provides significant or dominant sources and sinks for several components of seawater; studies of conductive and convective heat transfer suggest that two-thirds of the heat lost from new oceanic lithosphere at the Galapagos Rift in the first million years may be vented from thermal springs, predominantly along the axial ridge within the rift valley. The vent areas are populated by animal communities. They appear to utilize chemosynthesis by sulfur-oxidizing bacteria to drive their entire energy supply from reactions between the seawater and the rocks at high temperatures, rather than photosynthesis. (Authors' abstract)

CORREIA, M.M. and SILVA, L.C., 1979, On the genesis of quartz and fluorite crystals associated with carbonate rock xenoliths occurring in basaltic flows from Boa Vista Island (Cape Verde Republic): Communic. Serv. Geol. Portugal, v. 64, p. 269-284 (in Portugese).

On the basis of field work, petrographic studies and microthermometric results from fluid inclusions, a possible explanation is presented for the genesis of euhedral quartz crystals and small fluorite masses found in intimate association with carbonated rock xenoliths enclosed in sub-aerial basaltic flows.

Microthermometric studies have shown the existence of aqueous fluids (liquid and gas H_2O phases), of low salinity (about 3% of NaCl), poor in CO_2 or even free from this component, within the environment of crystallization of the mentioned minerals.

As deduced from Th, quartz crystallized ~360°C and fluorite not lower than 200°C. (Authors' abstract)

CRAWFORD, M.L., FILER, Jon and WOOD, Cynthia, 1979, Saline fluids associated with retrograde metamorphism: Bull. Minéral, v. 102, p. 562-568. First author at Dept. Geol., Bryn Mawr College, Bryn Mawr, Pennsylvania 19010, U.S.A.

Fluid inclusions contained in quartz veins and pods from two suites of retrograded regionally metamorphosed rocks have compositions that suggest they equilibrated with the retrograde mineral assemblages. $CaCl_2$-NaCl brines occur in the calcium-rich amphibolite-graywacke assemblage whereas NaCl brines are associated with the calcium-poor pelitic assemblages. Additional substances such as KCl may be dissolved in the brines but cannot be confirmed. The following postulated retrograde reactions suggest a mechanism for concentrating Na^+, K^+, and Ca^{-2} in fluids, for producing quartz veins and pods, and for creating oxidizing conditions during the retrograde process:

3 microcline + H_2O = muscovite + 6 quartz + $2K^+ + O^{-2}$;

3 albite + $H_2O + K^+$ = muscovite + 6 quartz + $3Na^+ + O^{-2}$;

3 anorthite + 1-1/2$H_2O + K^+$ = epidote + muscovite + $Ca^{+2} + 1/2O^{-2}$;

2 biotite + $4H_2O$ = chlorite + 3 quartz + $2K^+ + (Mg, Fe)^{+2} + O^{-2}$.

(Authors' abstract)

CRAWFORD, M.L., KRAUS, D.W. and HOLLISTER, L.S., 1979, Petrologic and fluid inclusion study of calc-silicate rocks, Prince Rupert, British Columbia: Amer. J. Sci., v. 9, p. 1135-1159. First author at Dept. Geol., Bryn Mawr College, Bryn Mawr, PA 19010.

A coordinated petrologic and fluid inclusion study on calc-silicate samples, selected from an area of known metamorphic T and P, shows that the H_2O/CO_2 compositions of the fluid inclusions generally agree with those predicted from the observed mineral asemblages. In the calc-silicates fluid inclusions in matrix quartz grains are aqueous brines with high salinities and a high proportion of $CaCl_2$. Nearby carbonaceous semipelites contain dense CO_2 and CO_2-CH_4 inclusions in matrix quartz. The variations in fluid compositions in inclusions between samples supports the hypothesis that the fluid compositions are internally controlled. Density determinations, however, suggest the inclusions now observed were not formed at peak metamorphic T and P. The discrepancy between predicted and observed densities may permit deductions as to uplift history for the samples. (Authors' abstract)

CUNNINGHAM, C.G., STEVENS, T.A., RASMUSSEN, J.D. and ROMBERGER, S.B., 1979, The genesis of the Marysvale, Utah, hydrothermal uranium deposits (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 408.

Uranium deposits of the central mining area near Marysvale, Utah, are hydrothermal veins that cut granitic and volcanic rocks in the eastern source area of the Mount Belknap Volcanics, adjacent to the Red Hills caldera. Shallow cupolas were progressively emplaced over a larger magma chamber between 21 and 16 m.y. ago. Most veins are in an elongate area 500 by 1,300 m across, at the center of a fracture pattern that reflects local distention imposed on regional late Cenozoic east-west faults; they formed as open-space fillings. The principal ore minerals in the veins are uraninite, coffinite, jordisite, and umohoite, all of which occur in a matrix of purple fluorite, quartz, and minor pyrite. Near the surface, in the zone of oxidation, secondary uranium and molybdenum minerals are common.

A tentative model for the origin of the veins indicates deposition in near-surface fractures above an unexposed pluton that energized the hydrothermal system. Fluid-inclusion data indicate that the primary uranium minerals were deposited from dilute hydrothermal fluids at approximately 150°C. Mineral association and paragenesis suggest that the fluids were reducing, acid, and fluorine-rich. Uranium was probably complexed as $UF_2^{=}$ and related tetravalent species, sulfur was probably present as dissolved H_2S, and Ca was ubiquitous. Calculated fO_2-pH stability fields indicate that log fO_2 was near -40 and pH near 4. As the fluids rose along fractures, they cooled, depressurized, and reacted with wall rocks. Uranous fluoride complexes became unstable as the pH increased. With breakdown of the complexes, F^- combined with Ca to form fluorite, and U^{+4} combined with oxygen and silica to form uraninite and coffinite. (Author's abstract)

DECHOMETS, Roland, 1979, The fluorite deposit of Trébas (Tarn, France): Bull. du BRGM (ser. 2) Sec. II, no. 4, p. 301-321 (in French). Author at Dépt. Mines, Ecole nat. supér. des Mines de Saint-Etienne.

The vein fluorite deposit of Trébas is situated inside a large E-W oriented fracture which cuts the schists of the Paleozoic and epimetamorphic Tarn valley series; most of fluorite is found at the intersection of the fracture with a layer of characteristic satin-like schists.

Fluorite is associated with quartz, chalcopyrite and pyrite. Baryte is not related to fluorite. The fluid inclusions in fluorite and in quartz show that these minerals have crystallized at Th 82-168°C from highly saturated salt-bearing solutions (Tm -10 to -25°C). The geobarometric study indicates a depth of at least 1100 m, which is in good accordance with the Hercynian age of the ore-deposit. The crystal growth possibly occurred from supersaturated hydrothermal brines. The origin of the fluorite is unknown, but there is a strong ressemblance between the Tarn valley series and that of the Southern Albigeois which contains a low percentage fluorite bearing layers. (From the author's abstract, modified by E.R.)

DEGENS, E.T. and PALUSKA, Antonin, 1979, Hypersaline solutions interact with organic detritus to produce oil: Nature, v . 281, p. 666-668.

Salt is a major factor in the origin of petroleum. It leads to the extraction of hydrocarbons from sediments and the formation of oil droplets. Also, salt domes and their cap rocks may trap oil. Although the diagenesis of salt and brines is well understood, little is known what salty brines may do to infalling organic detritus. Using results from the Caspian Sea and the North Sea we show here that hypersaline solutions close to the sediment-water interface will cure organic matter and that this "pickling effect" is essential for obtaining black and oil shales. (Authors' abstract)

DELANEY, J.R. and KARSTEN, J.L., 1979, Ion microprobe determination of water in silicate glasses (abst.): Eos, v. 60, p. 966.

The ion microprobe at Johnson Space Center has been used to determine in situ water concentrations on a 10-20 micron scale in basaltic rhyolitic and albitic glasses. A calibration curve using glasses with known water contents gives similar results for wt. % H_2O vs. either $^{1}H/^{16}O$ or $^{1}H/^{30}Si$ in the range .2 to 2 wt. % water for basalts, 0 to 6.8 wt. % H_2O for albite glass, and .2 to 3.7 wt. % H_2O for rhyolite glass. The basalt calibration curve differs substantially from the albite and rhyolite curves indicating a need to carefully match compositions and/or structure between H_2O standards and the unknowns.

The system at Houston has been used for two types of studies: 1) to examine the diffusivity of water as a function concentration and time by measurng water diffusion profiles induced in rhyolite glass at elevated temperatures and pressures; and 2) to measure the water concentration of glass-vapor inclusions trapped in phenocrysts from the glassy rinds of submarine pillow basalts.

Results of the diffusion study indicate diffusivities in the range 10^{-7} to 10^{-3} cm^2/sec for 0.4 to 3.3 wt. % H_2O. Preliminary results indicate a pronounced compositional dependence of D and imply that this dependence is nonlinear. A study of the glass-vapor inclusions in a porphyritic basalt dredged near Bouvet Island indicates that the water content of a number of inclusions of basaltic composition is equal to or less than that of the matrix glass enclosing the phenocrysts. The matrix glass contains 0.50 wt. % H_2O. (Authors' abstract)

DEMIDOVICH, L.A. and MATVEEVA, L.I., 1979, Interstitial solutions and aqueous vacuoles of sedimentary rocks of petroleum- and gas-containing areas of the Pripyat trough: Geol. Izuch. Territorii Belorussii, Minsk, 1979, p. 140-144 (in Russian).

DeNEGRI, G. and TOURET, J., 1979, Fluid inclusions in metapelites from Vale Strona, province of Novara: Proceedings of the 2nd symposium Ivrea-

Verbano, Mem. Ist. Geol. Miner. Univ. Padova, v. 33, p. 87-94 (in English).

DHAMELINCOURT, Paul, BENY, Jean-Michel, DUBESSY, Jean and POTY, Bernard, 1979, Analysis of fluid inclusions with the MOLE Raman microprobe: Bull. Minéral., v. 102, p. 600-610. First author at Lab. Spectrochimie infrarouge et Raman du C.N.R.S., Univ. des Sci. et Tech., Lille, 59650 Villeneuve-d'Ascq, France.

Nine fluid inclusions have been analyzed both by microthermometry and by Raman spectroscopy with the MOLE microprobe. Quantitative analyses are given for CH_4, C_2H_6, C_3H_8, CO_2, N_2 and H_2S of the gaseous phase of four inclusions, rich in hydrocarbons (Remuzat, Drome; Lastourville, Gabon; Wermutfluh, Berne and Val d'Illiez, Valais) and of two CO_2 rich inclusions (Bournac, Massif central and Camperio, Tessin). Isotopic analysis (^{13}C) for the Camperio CO_2 has been attempted. Daughter minerals of three fluid inclusions have been determined: calcite in quartz from Bitsch (Valais), nahcolite in quartz from Bancroft (Ontario) and hematite in dolomite from Rabbit Lake (Saskatchewan). The sensitivity of the Raman microprobe and the limits of its use in mineralogy are discussed. (Authors' abstract)

DICKSON, F.W., RYE, R.O. and RADTKE, A.S., 1979, The Carlin gold deposit as a product of rock-water interactions, in Papers on mineral deposits of western North America, IAGOD Fifth Quadrennial Symposium Proc., v. 2, J.D. Ridge, ed.; Nevada Bur. Mines and Geology Report 33, p. 101-108.

The Carlin gold deposit formed at shallow depths from hydrothermal fluids heated by late Tertiary volcanic energy. The fluids ascended from depth along steep faults into permeable thin-bedded carbonate rocks, where they dissolved carbonate minerals, principally calcite, and deposited quartz and pyrite and fine-grained gold. The fluids also introduced Al, K, and Ba, organic materials, plus Hg, As, Sb, and Tl, all closely associated with Au, and the base metals Zn, Pb, and Cu. Late fluids deposited barite and calcite, and minor quartz, in fractures, together with sparse sulfides of Hg, Sb, As, Tl, Pb, Zn, and Cu. During vein formation the fluids boiled, releasing H_2O vapor, CO_2, and H_2S to the oxygenated ground waters or to the aerated zone above the water table. Atmospherically derived oxygen oxidized H_2S to H_2SO_4. Rocks in the upper part of the ore deposit were strongly leached and oxidized during boiling.

Stable isotope data on fluid inclusions and on vein and rock-forming minerals indicate that the hydrothermal fluid was of meteoric origin, that the introduced sulfur is of sedimentary origin, and that Pb in galena in barite veins is similar to Pb in the host rocks of the Roberts Mountains formation. Temperatures based on $\delta^{34}S$ fractionation between barite and sulfide minerals ranged from 270-305°C, in contrast to lower temperatures obtained from fluid inclusions in vein barite, calcite, and quartz of 175°C. Sedimentary rocks adjacent to and below the Carlin deposit contain organic carbon compounds, diagenetic pyrite, quartz, illite, calcite and dolomite. They also contain anomalously high levels of Au, Hg, As, Sb, and Tl.

We suggest that the introduced components were leached from Paleozoic sedimentary rocks below the deposit at temperatures above 300°C by mildly saline solutions, migrating as part of a circulating water system set into movement by a buried thermal anomaly. The fluids rose rapidly up steep faults, dropped in temperature and pressure, and became supersaturated with regard to quartz, pyrite, and gold, and undersaturated with regard to calcite. The solutions migrated into host rocks where they formed tabular-shaped orebodies with attitudes similar to those of the sedimentary host rocks. The mainstage mineralization could have been accomplished in 50,000 years, assuming continuous flow. A minimum of about 10^9 tons of aqueous fluid passed through the rocks during main-stage mineralization. The beginning of vein formation coincided with the onset of boiling. The vein-forming stage perhaps lasted about the same time as main-stage mineralization, but more than 10^{10} tons of fluid were involved. Boiling coincided with more rapid fluid flow from hotter regions at depth. The vein formation ceased when the excess pressures of the system were relieved, and cold ground waters were able to reoccupy the fractures. The Carlin deposit is the integrated result of igneous heat, injected into sedimentary rock-fluid systems, dispersed by convective movements of fluids, which dissolved components at high temperatures and deposited them at low temperatures. (Authors' abstract)

DIXON, Susan and RUTHERFORD, M.J., 1979, Plagiogranites as late-stage immiscible liquids in ophiolite and mid-ocean ridge suites: an experimental study: Earth and Planet. Sci. Lett., v. 45, p. 45-60.

DMITRIEV, E.A., 1979, Nepheline from alkaline gabbroic rocks of the eastern Pamirs: Mineral. Tadzhikistana, Dushanbe 1979, (3) 119-121 (in Russian).

Fluid inclusions studies indicate formation of nepheline from $Cl\text{-}Na^+$ aq. solns. at 320-530° and 1100-1500 atm.

DOBROVOL'SKAYA, M.G., PASHKOV, Yu.N., LETEYSKA, I., and IGNAT'YEVA, I.B., 1979, Mineral parageneses and temperatures of ore formation in the Shumachevskiy Dol deposit (Madan ore region, Bulgaria): Geol. Rudnikh. Mestor. v. 21, no. 3, p. 76-82 (in Russian).

Madan ore region of Zn-Pb deposits occurs in the Rodopes Mts. Ore bodies are veins in fault zones. Shumachevskiy Dol deposit is typical of the quartz-polymetal formation. The samples were taken from the mine Stratiev Kamyk. Main ore minerals are galena and sphalerite, along with quartz, arsenopyrite, chalcopyrite, tetrahedrite and pyrrhotite. The deposit formed during four stages: 1) quartz-pyrite (Th of two-phase inclusions 300-360°C in L, Th of three-phase inclusions G + L + dm halite ~15% vol. 270-310°C, when halite dissolved after G bubble, P was estimated to be ~500 atm); 2) quartz-sphalerite-galena (Th in quartz 180-230°C in L, S incs. in sphalerite 90-120°C); 3) quartz-galena-sphalerite (Th in quartz and sphalerite 100-130°C); 4) quartz-calcite (Th in both minerals 90-110°C). Also Td of minerals was investigated (quartz 300°C, sphalerite 200°C). Gases in inclusions, by chromatography from samples of 0.1-0.5 g (g/1): quartz I - CO_2 69, H_2 nil, N_2 312, H_2S nil, galena I - CO_2 118, H_2 5.35, N_2 nil, H_2S 57.6, sphalerite II - CO_2 096, H_2 1.8, N_2 nil, H_2S nil. (Abst. by A.K.)

DOLGOV, Ya and SHUGUROVA, N.A., 1978, Genetic mineralogy of inclusions in minerals: Institut Geologii i Geofiziki (Novosibirsk), 174 pp. (in Russian).

DOLOMANOVA, E.I.: BOGOYAVLENSKAYA, I.V.: BOYARSKAYA, R.V., and LOSEVA, T.I., 1979, Physicochemical conditions for the formation of cassiterite-quartz deposits determined from data on gas-liquid inclusions in minerals: Nov. Dannye Miner. SSSR, v. 28, p. 58-78 (in Russian).

Th and Td of Transbaikalian cassiterite and quartz ranged from 440-220°C; gases present include CO_2, CO, and CH_4.

DOLOMANOVA, Ye.I., BOGOYAVLENSKAYA, I.V., GROSHENKO, A.R. and ROZHDESTVENSKAYA, I.V., 1978, Comparison of formation temperatures of tin ore deposits from Transbaikalia on the basis of decrepitation and homogenization of gas-liquid inclusions in minerals and isotope-oxygen geothermometer (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 65-66 (in Russian). Authors at IGEM, Moscow, USSR.

The authors compare Td, Th and T derived from oxygen isotope ratio of samples from the deposits: Onon, Imalka, Etyka, Shumil, Ushmun, Aldakacha and Khapeheranga, claiming them to be very similar but criteria of this correlation are not specified. (A.K.)

DOLOMANOVA, Ye.I, BOYARSKAYA, R.V., BORISOVSKIY, S.Ye. and LUPANOV, L.M., 1978, Application of X-ray spectral microanalysis and electron microscopy for the study of precipitates in vacuoles of minerals, in Theory and Practice of Thermobarogeochemistry, N.P. Ermakov, ed., Izd. Nauka, p. 222-228.

DOLOMANOVA, Ye.I. and NOSIK, L.P., 1977, Possibility of determining the chemical composition of inclusions of hydrothermal solutions in mineral vacuoles by mass spectrometry: Dokl. Akad. Nauk SSSR, v. 234, p. 1186-1188 (in Russian; translated in Doklady Akad. Sci. USSR, v. 234, p. 161-163, 1979). Abstracted in "Fluid Inclusion Research--Proceedings of COFFI v. 10, p. 63, 1977.

DOLOMANOVA, Ye.I., NOSIK, L.P. and ROZHDESTVENSKAYA, I.V., 1978, Contribution to physico-chemical conditions of formation of tin ore deposits on the basis of mass spectrometry of gas-liquid inclusions (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 64-65 (in Russian). Authors at IGEM, Moscow, USSR.

Amount of CO_2, SO_2, H_2O was determined in G/L inclusions in syngenetic cassiterite and quartz from 15 tin ore deposits. The determinations were performed by decrepitation of inclusions at T intervals 20-300, 300-450, 450-600°C and average for a given mineral. ^{13}C and ^{18}O in inclusion CO_2 were studied. CO_2 was always $\gg SO_2$, contents of both gases vary irregularly in various T intervals, although SO_2 is more abundant in low T inclusions; H_2O in quartz > H_2O in cassiterite and it usually releases at 300-450°C. Amount of meteoric water determined in structure of quartz, muscovite and chlorite by ^{18}O content varies from 6.5 to 16% and only in subsurface deposits it achieves 25-87%. Variations of $\delta\ ^{13}C$ and $\delta\ ^{18}O$ in CO_2 prove unstable conditions of crystallization. Two types of deposits were distinguished: 1) $\delta\ ^{13}C$ from +0.07 to +0.66%* and 2) $\delta\ ^{13}C$ from -0.11 to -2.86%. Also two groups were distinguished on the basis of $\delta\ ^{18}O$ values: 1) from +0.22 to +1.29% and 2) from -0.33 to -3.0%. The signs "plus" or "minus" in the same deposit frequently differ for $\delta\ ^{13}C$ and $\delta\ ^{18}O$. Maybe this suggests different sources of C and O_2 in hydrothermal solutions. Variations of ^{18}O in solutions are greater than in quartz and cassiterite lattices. (From the authors' abstract, transl. by A.K.)*(sic.; should be ‰?)

DONALDSON, C.H., 1979, An experimental investigation of the delay of nucleation of olivine in mafic magmas: Contrib. Min. and Petrol., v. 69, no. 1, p. 21-32.

DONETS, A.I., KONKIN, V.D., and KRUTIY, V.M., 1978, Metasomatic dolomites: the principal country rocks of the Sardan ore district, Yakutia: Geol. Rud. Mestorozhd., v. 20, no. 6, p. 90-93 (in Russian).

Indexed under "Fluid inclusions".

DOROGOVIN, B.A. and SHATAGIN, N.N., 1977, Behavior of inclusions of mineral-forming media at temperatures and pressures of contact and regional metamorphism, as shown by experimental data: Akad. Nauk SSSR, Doklady, v. 236, no. 5, p. 1192-1195 (in Russian; translated in Dokl. Acad. Sci. USSR Earth Sci. Sect., v. 236, p. 145-147, 1979).

Abstract in <u>Fluid Inclusion Research--Proceedings of COFFI</u>, v. 10, p. 64-65, 1977. (E.R.)

DOROSHENKO, Yu.P. and PAVLUN', N.N., 1978, Thermobarogeochemistry of the deposit Akchatau (Central Kazakhstan) (abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 90-91 (in Russian). Authors at L'vov State Univ., Ukrainian SSR.

The deposit is of quartz-vein and greisen type and it is spatially and genetically connected with Upper Permian Akchatau granites. Ore mineralization occurs in topaz-quartz, quartz and muscovite greisens and in quartz veins. The mineral associations in origin sequence are as follows: for greisens - molybdenite-quartz (440-320°C, 1400-1000 atm), complex rare metal and pyrite-wolframite-quartz (480-260°C, 1500-600 atm); for veins - galena-sphalerite-quartz (310-170°C, 500-200 atm), fluorite-quartz (180-90°C) and zeolite-calcite (160-60°C). From pneumatolytic-hydrothermal solutions crystallized greisen associations, from hydrothermal-vein associations. During early stages of crystallization the solutions periodically boiled. Solutions in greisenization process bore from 28 to 40 Wt.% of NaCl+KCl (first association) and 27 to 65 wt.% of NaCl+KCl (second and third associations) and they had Cl-Na and F-Cl-K-Na compositions. The first vein association origin is accompanied by heterogenization of solutions (probably splitting into LH_2O and LCO_2 phases, A.K.). During origin of the two earliest greisen associations an abrupt T increase and P decrease were found, probably connected with injection of granite-aplites. (From the authors' abstract, transl. by A.K.)

DOUKHAN, J.-C. and TREPIED, Louis, 1979, Plasticity of quartz: Crystallographic models and T.E.M. observations: Bull. Minéral., v. 102, p. 138-147.

DOWLER, M.J. and INGMANSON, D.E., 1979, Thiocyanate in Red Sea brine and its implications: Nature, v. 279, p. 51-52.

A thiocyanate concentration of approximately 2.8×10^{-5} M was detected. (E.R.)

DRUMMOND, S.E. and OHMOTO, H., 1979, Effects of boiling on mineral solubilities in hydrothermal solutions (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 416.

Transition of homogeneous fluids to the liquid-vapor boundary, termed boiling or condensation depending on the P-T path, has been recognized from fluid inclusion evidence in a large number of hydrothermal ore deposits. Other investigators have suggested this phenomenon as an important ore localization mechanism. Lack of reliable data on the solubility of important gases in concentrated electrolyte solutions at high temperatures has previously prevented a quantitative evaluation of the chemical processes accompanying boiling or condensation of hydrothermal fluids. Consequently, the solubilities of CO_2, H_2S, and SO_2 in NaCl solutions up to 6 molal and 400°C were experimentally determined.

During boiling fO_2 increases as a result of increasing CO_2/CH_4, SO_2/H_2S, and SO_4/H_2S ratios in the solution. Sulfur fugacity decreases with H_2S and SO_2 loss from the system. pH increases due to CO_2,H_2S and SO_2 loss to the vapor phase. For example, a solution at 250°C and initial $CO_2(aq)$ molality = 0.10 and initial NaCl molality = 1.0, pH increases by one unit after 50% water loss to the vapor phase in a system closed to mass, but after only 3% boiling in a system open to mass. Shifts in fO_2, fS_2, and pH along with increasing chloride and metal concentrations produce varied changes for mineral solubilities in the residual boiling solution. Minerals that are most likely to precipitate upon boiling include quartz, gold and silver metals, and sulfates. Carbonates are unlikely to precipitate during boiling. Sulfide mineralization is more complex and depends primarily on the initial CO_2/H_2S ratio in the solution. If $CO_2 \ll H_2S$ in the solution, sulfide deposition is unlikely, however, if $CO_2 \gg H_2S$ sulfides can precipitate initially and possibly redissolve with continued boiling. (Authors' abstract)

DRUMMOND, S.E., Jr., OHMOTO, H. and BARNES, H.L., 1979, Solubility of CO_2 in aqueous NaCl solutions (abst.): Eos, v. 60, p. 422.

The solubility of CO_2 in 0-6m NaCl was determined up to 400°C using a rocking autoclave to measure the P-V-T properties of the CO_2-H_2O-NaCl system along the L-V boundary. Regression of over 500 experimental points within this range yields for Henry's law constants, $K = fCO_2\ (g)/mCO_2(aq)$: $\ln K = 13.188 - 0.00758T + 0.122X - 2028.0/T + 4.52/X - 0.583\ln X + 0.000089XT + 30.4X/T - 0.00712T/X - 970.0/XT$ where T = Kelvin, X = NaCl molality + 1.0, f = atm, and the S.D. = 0.0758 ln K.

The change in Henry's law constants with NaCl concentration is a function of H_2O activity and the hydration number for the solvation of CO_2 in aqueous solutions. For CO_2 the apparent hydration number (N) = $\ln(K°/K)\cdot\ln^{-1}aH_2O$, where K° and K are the Henry's constants for CO_2 in pure water and salt solutions respectively. Generally, N increases continuously with decreasing NaCl concentration, e.g., at 200°C and 1m NaCl, N = 9 and at 6m NaCl, N = 5. The temperature-dependence of N shows a broad minimum around 100°C but increases rapidly with temperature especially above 200°C, e.g., in 3m NaCl, N = 4,5, and 10 at 25°C, 100°C and 300°C, respectively. The CO_2 solubility goes through a minimum near 200°C and rises parallel with N at higher temperatures. The complex dependence of N on temperature and salt content implies variability in the CO_2-H_2O interaction, thereby causing large uncertainty in extrapolating CO_2 solubilities to untested temperatures and salt concentrations.

These data have important implications for: CO_2 evolution from boiling hydrothermal solutions, interpreting CO_2-bearing fluid inclusions, understanding decarbonation and dehydration reactions and controlling the pH in CO_2-H_2O-NaCl experimental systems, for examples. (Authors' abstract)

DUBROVSKIY, V.N., MALINOVSKIY, Ye.P. and RODIONOV, S.M., 1979, Structure and zoning of tin-ore deposits of the Komsomol'skiy region: Moscow, "Nauka" Publishing House, 136 pp. (in Russian). Authors at the Inst. of Geol. of Ore Deposits, Petrogr., Mineral. and Geochemistry of Acad. Sci. of the USSR, Moscow.

Komsomol'skiy ore region (Soviet Far East) is in the NE part of a large geosynclinal structure folded during the Mesozoic, with tectonic-magmatic activity of Cretaceous age. Ore mineralization occurs in quartz-tourmaline (more rarely quartz-sericite) metasomatic zones of some tens of km in length and from a few to several tens of meters wide. Ore zones bear tin, tungsten, copper, polymetallic and mercury mineralization. In such zones occur the main tin deposits: Solnechnoe, Ozernoe, Pereval'noe, Festival'noe, Pridorozhnoe and Oktyabr'skoe. Ore associations are quartz-arsenopyrite-cassiterite veins, sometimes with scheelite and wolframite, cutting tourmaline or quartz-tourmaline veinlike metasomatites. Th was measured for P and PS inclusions in cassiterite from the Pridorozhnoe deposit; for two-phase P inclusions 300-320°C, 290-310 C for PS polyphase inclusions and 180-200°C for PS inclusions with L CO_2. Homogenization was in L phase. Evaluated P was 400-500 atm. hence P corrections to Th were 27-30°C. Also Td was measured. Gradient of Td is about 30°/100m, changing from 320-420°C. (Abstract by A.K.)

DUFFY, C.J., and GREENWOOD, H.J., 1979, Phase equilibria in the system MgO-MgF_2-SiO_2-H_2O; Amer. Mineral., v. 64, p. 1156-1174.

ĎURIŠOVÁ, Jana, CHAROY, Bernard and WEISBROD, Alain, 1979, Fluid inclusions studies in minerals from tin and tungsten deposits in the Krušné Hory Mountains (Czechoslovakia): Bull. Minéral., v. 102, p. 665-675. First author at Geol. Survey Prague, Malostranske, nam. 19, Praha 1, ČSSR.

The Krupka and Cinovec tin and tungsten deposits are closely associated with small, shallow, highly differenciated granitoid intrusions. Late to post-magmatic hydrothermal alterations are of major importance. Fluid inclusions have been studied in quartz, topaz and cassiterite from greisens and quartz veins in these deposits:

- The earlier fluids are low density, low salinity (~2 to 3 wt. % eq. NaCl) CO_2-bearing aqueous solutions, with small but significant CO_2 content, circulating at high temperatures (above 390°C) and rather low pressures (less than 800 bar). These fluids have a low K/Na ratio (~0.1) and are thought to be responsible for the transportation of tin, the growth of K-feldspar, and for part of the greisenization.

- Moderate unmixing occurs in the 300-500°C temperature range. It probably mostly concerns the CO_2-aqueous solution system and may account, around 400°C, for cassiterite precipitation and a part of the greisenization.

- Marked unmixing with generation of brines (35 wt. % NaCl) and formation (or, at least, recrystallization) of topaz locally occurs between 300 and 500°C in response to sudden drop of fluid pressure.

- The evolution ends with cooler fluids circulating at very shallow depth between 300 to 100°C. These fluids can be related to the sulfides-sulfates stage. (Authors' abstract)

DZHUN', V.S. and MOSKALIK, J.O., 1978, New apparatus for recording of decrepitation of inclusions in minerals (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 1, Thermobarogeochemistry in geology: Vladivostok, Acad. Sci. USSR, p. 212-213 (in Russian). Authors at the Inst. of Mineral Deposits, Simferopol', Ukrainian, SSR.

A device for recording of decrepitation with the possibility of visual observation was designed so that only strong decrepitation impulses are recorded. Acoustic isolation is not needed. The heating chamber may be put on the stage of binocular for visual observation of the contemporaneously recorded decrepitation. Heating electric element and surface where sample is placed, is a plate of stainless steel. The sample is covered by glass or mica membrane collecting decrepitation effects and joined with piezoelement. Piezoelectric signals are recorded. (From the authors' abstract, trans. by A.K.)

EBY, G.N., 1979, Mount Johnson, Quebec-An example of silicate-liquid immiscibility?, Geology, v. 7, no. 10, p. 491-494.

EDMOND, J.M., CRAIG, H., GORDON, L.I. and HOLLAND, H.D., 1979, Chemistry of hydrothermal waters at 21°N on the east Pacific Rise (abst.): Eos, v. 60, p. 864.

EDWARDS, P.W., 1979, Alteration and mineralization of greywackes and associated rocks near Coromandel, NZ. M.Sc. thesis, Univ. Auckland, NZ.

Previously unrecognized hydrothermal alteration of greywackes (Manaia Hill Group) and the overlying volcanics (Beesons Island Volcanics) near Coromandel is mapped and described. Propylitic, argillic (sericitic), quartz-sericitic and silicic alteration zones are distinguished, covering an area of at least 11km^2. Both the greywackes and the volcanics have been intruded by numerous dikes and stocks.

The alteration zones and the mineralization are considered due to the development of a porphyry type system. The first phase involved the intrusion of quartz-diorite or diorite plutons. The second intrusive phase, emplaced at depths of 2½-3km during the mid- to upper Miocene, was responsible for the prevasive alteration of the country rock.

The numerous base metal bearing veins in the area postdate this alteration and may be due to renewed hydrothermal activity at greater depths than the first.

Bulk chemical changes accompanying alteration involves increases in SiO_2, K_2O and Fe_2O_3 with increasing alteration grade, and corresponding decreases in MgO, CaO, FeO, and Na_2O with Al_2O_3 and TiO_2 remaining fairly constant. The observed mineralogical changes and the derived alteration reactions are in accordance with the chemical trends, hydrogen and potassium metasomatism together with base-leaching being the dominant processes.

A mechanism of hydrothermal alteration involving fluids of changing chemical composition (brought about by the alteration reactions) is presented to explain the development of the alteration zones, while temperature is considered only a minor factor. The original fluids are assumed to be heated magmatic-meteoric waters enriched in potassium and hydrogen. (Author's abstract)

Fluid inclusions from vein quartz crystals homogenized at 260-265°± 10°C. A load pressure of 0.5kb was used to correct these temps to 300-

305°. Stable isotopes on 3 sulfide pairs gave formation temperatures of between 290-320°C. (A.B. Christie, pers. comm).

EGGERS, A.J., ROBINSON, B.W., and DUCKWORTH, E.G., 1979, Sulfur isotope and fluid inclusion investigations of molybdenum mineralization in NW Nelson (abst.): Program and Abstracts, Nelson Conference, Nov., 1979 (Geol. Soc. New Zealand) p. 27. First author at Ministry of Works and Development, Alexandra, New Zealand.

Molybdenum mineralization occurs in quartz veins and stockworks within the Palaeozoic metasediments and Cretaceous granites of North West Nelson. Sulfur isotopic values ($\delta^{34}S_{CDT}$) of mineral sulfides around +1±1‰ are typical of magmatic sulfur; more positive or negative values indicate the addition of sea-water or biogenic sulfur to the system. Temperatures of mineralization derived from sulfur isotopic compositions of mineral pairs average about 500°C.

Quartz from the Cobra Face prospect (Roaring Lion River) contains many secondary fluid inclusions along annealed fractures. Primary and pseudo-secondary inclusions occur in the clearer quartz associated with sulfides. They contain varying proportions of liquid and gaseous H_2O and CO_2 (up to 25 vol %) in two and three phases, with no daughter minerals. Upon heating, some high CO_2 inclusions decrepitated around 370°C, before homogenization, suggesting high pressures (~1 Kbar) and still higher Tf. Other inclusions had Th up to 300°C. Pressure corrected Th are up to 100°C higher. (Authors' abstract)

EGGLER, D.H., 1979, Experimental igneous petrology: U.S. National Report, 17th General Assembly, IUGG, Canberra, Australia, Dec. 1979, Papers in volcanology, geochemistry, and petrology: Reviews of Geophysics and Space Physics, v. 17, no. 4, p. 744-760.

EGGLER, D.H., MYSEN, B.O., HOERING, T.C., and HOLLOWAY, J.R., 1979, Solubility of carbon monoxide in silicate melts at high pressures and its effect on silicate phase relations: Earth Plan. Sci. Lett, v. 43, p. 321-330.

EGGLER, D.H., WENDLANDT, R.F., and OLAFSSON, M., 1979, Volatiles and the generation of kimberlitic liquids: experimantal studies: Program, Kimberlite Symposium II. Cambridge, England. July, 1979 (unpaginated).

Studies of the solubilities of volatiles in silicate melts, the melting of peridotite, and the system $KAlSiO_4$-MgO-SiO_2-CO_2-H_2O at various pO_2 (E.R.)

EGIN, D., 1979, Polymetallic, sulfide ore deposits and associated volcanic rocks from the Harsit River area, N.W. Turkey: Ph.D. Thesis, Univ. of Durham, U.K.

Indexed under "Fluid Inclusions".

ELDERS, W.A., HOAGLAND, J.R., MCDOWELL, S.D. and COBO, J.M., 1979, Hydrothermal mineral zones in the geothermal reservoir of Cerro Prieto: Geothermics, v. 8, p. 201-209. First author at Inst. Geophys. Plan. Phys., Univ. Cal., Riverside, CA 92521.

Detailed petrologic studies completed to date on ditch cuttings and core from 23 wells in the Cerro Prieto field have led to recognition of regularly distributed prograde metamorphic mineral zones. The progressive changes in mineralogy exhibit a systematic relationship with reservoir temperature.

The Cerro Prieto reservoir consists of a series of sandstones, siltstones, and shales composing part of the Colorado River delta. The western part of the field contains relatively coarser sediments apparently also derived form the delta and not from the basin margins as formerly thought. The most abundant detrital minerals in the sediments include quartz, feldspar, kaolinite, montmorillonite, illite, chlorite, mixed-layer clays, calcite, dolomite and iron hydroxides. Some of these minerals were also formed diagenetically.

The following progressive stages of post-depositional alteration in response to increasing temperature have been observed: (1) *diagenetic zone* (low temperature, (2) *illite-chlorite zone* (above ~ 150°C), (3) *calc-aluminum* silicate zone (above ~ 230°C) and the *biotite zone* (above ~ 325°C). These zones are transitional to some degree and can be further subdivided based on the appearance or disappearance of various minerals.

One immediate application of these studies is the ability, from a study of cuttings obtained during drilling of a well, to predict the temperatures which will be observed when the well is completed. (Authors' abstract)

ELIAS, Karol, 1979a, Thermometric data for studying the formation conditions of magnesite deposits: Zapadne Karpaty, Ser.: Mineral., Petrog., Geochem., Metalogeneza, v. 6, p. 7-31 (in Slovak).

Indexed under fluid inclusions. (E.R.)

ELIAS, K., 1979b, Thermometric investigation of the Jurassic Pb-Zn deposit in the Low Tatras: Zapadn. Karpaty, Ser. Mineral., Petrogr., Geochem., Loziska 6, p. 33-60 (in Slovak).

Indexed under fluid inclusions. (E.R.)

ELLIS, A.J., 1979, Chemical geothermometry in geothermal systems: Chem. Geol., v. 25, p. 219-226.

The application of chemical and isotopic geothermometry to geothermal systems is reviewed, pointing out the uses and limitations of specific reactions in estimating deep temperatures from well, hot-spring and fumarole discharges.

At present the most reliable indicators are: the silica-water equilibria; the Na/K ratio; the isotopic distributions $\Delta^2H(H_2-H_2O)$, $\Delta^2H(H_2-CH_4)$, $\Delta^{18}O(H_2O-HSO_4)$; and the gas reactions $CO_2 + 4H_2 = CH_4 + 2H_2O$, and $2NH_3 = N_2 + 3H_2$. Many other qualitative chemical indicators exist. (Author's abstract)

ELLIS, D.E., and WYLLIE, P.J., 1979, A model of phase relations in the system $MgO-SiO_2-H_2O-CO_2$ and prediction of the compositions of liquids coexisting with forsterite and enstatite, *in* Kimberlites, diatremes, and diamonds: their geology, petrology, and geochemistry, Proceedings of the Second International Kimberlite Conference, edited by Boyd, F.R., and Meyer,H.O.A.: Washington, Amer. Geophys. Union, v. 1. p. 313-318. Authors at Dept. Geophys. Sci., Univ. Chic., Chicago, Il 60637.

A comprehensive model has been developed for the system MgO-SiO_2-H_2O-CO_2 on the basis of experimental studies, Schreinemaker's rules, and thermodynamic data. The assemblage forsterite plus enstatite is predicted to melt in the presence of vapor of any H_2O/CO_2 ratio at low pressures, in the presence of vapor whose H_2O/CO_2 ratio is buffered by the presence of magnesite at intermediate pressures, and at a vapor-absent eutectic with brucite and magnesite at high pressures. The composition of the liquid at the solidus for a bulk composition of forsterite plus enstatite plus a small amount of volatiles with a 3/1 H_2O/CO_2 ratio changes from enstatite-quartz normative at 20 kbar, to periclase-forsterite normative at 50 kb, to forsterite-enstatite normative at 90 kbar and greater pressures. Forsterite cannot coexist with H_2O-CO_2 vapor at pressures greater than 90 kbar. Thus all melting in the earth's mantle at higher pressures must be vapor-absent. (Authors' abstract)

EL SHATOURY, H.M., TAKENOUCHI, S. and IMAI, H., 1978, Geologic structure and fluid inclusion study at the Toyoha Mine, Hokkaido, in Geological studies of the mineral deposits in Japan and East Asia, H. Imai, ed., Univ. of Tokyo Press, p. 75-85 (in English).

ENJOJI, Mamoru, 1979a, Fluid inclusions in barite from Fukazawa mine, Akita Prefecture: Rep. Sci. Res. Fund, Japan. Ministry Educ., 1979, p. 13-19. (in Japanese).

ENJOJI, Mamoru, 1979b, Synthetic quartz and liquid inclusions: Koen Yoshishu - Jinko Kobutsu Toronkai, 24th p. 63-64 (in Japanese).

ERAME, S., 1979, Mineralization near the northeast margin of the Nelson Batholith, southeast British Columbia; MS thesis, Univ. of Alberta, Edmonton, Alb., Canada.

Indexed under "Fluid Inclusions".

ERMAKOV, N.P., and DOLGOV, Yu.A., 1979, Thermobarogeochemistry: Moscow, "Nedra" Press, 271 pp. (in Russian).

ERMAKOV, V.A., CHERNYKH, E.N., and MILIUTIN, S.A., 1979, Liquation in ultrabasites with the formation of ultrabasic and pyroxenite melts: Dokl. Akad. Nauk SSSR, v. 249, p. 175-178 (in Russian).

ERWOOD, R.J., KESLER, S.E., And CLOKE, P.L., 1979, Compositionally distinct, saline hydrothermal solutions, Naica mine, Chihuahua, Mexico: Econ. Geol., v. 74, p. 95-108. First author at Dept. Geol., Univ. Toronto.

Naica is a chimney-manto, limestone-replacement, skarn-sulfide deposit typical of those that have yielded much of the silver, lead, and zinc production of the western hemisphere. Fluid inclusions in fluorite deposited throughout late skarn and most sulfide mineralization at Naica provide the first direct observations of main-stage fluids in these deposits. The inclusions can be divided into three compositionally distinct groups: (A) liquid + vapor (119° - 379°C homogenization temperatures), (B) liquid + vapor + halite (237° -

369°C; salinities of 31-43 equiv. wt.% NaCl containing less than 12% KCl); (C) liquid + vapor + halite + sylvite (277° - 490°C; 52-63 equiv. wt.% NaCl containing 22-31% KCl) with some high temperature inclusions (565° - 684°C; ~40 equiv. wt.% NaCl with ~25% KCl). Types A, low-salinity B, and high-temperature C inclusions homogenize by vapor disappearance. High-salinity type B and most type C inclusions homogenize by halite disappearance. Evidence for boiling is seen in type A and low-salinity type B inclusions.

Types A, B, and C inclusion solutions occupy relatively small, compositionally distinct fields in the NaCl-KCl-H_2O system. High-salinity type B and most type C solutions were apparently saturated with halite. The composition of high-temperature, unsaturated type C solutions could have been controlled by equilibration with granitic rock and that of saturated, low-temperature solutions could have been controlled by halite substraction. Wide and completely overlapping spatial distribution of all three inclusion types, combined with the fact that all three solutions are fully miscible, requires that the three compositionally distinct solutions were present in the deposit at different times. The most likely order of appearance of the solutions was C, then B, and finally A with pressures considerably above lithostatic during C solution activity, lower but still exceeding lithostatic during early B activity, and hydrostatic during late-B and throughout A time. (Authors' abstract)

ESPINOZA REYES, S., 1979, Genesis and evolution of fluid inclusions in hydrothermally formed crystals; use as geologic thermometers: Congr. Geol. Chil., Actas 2, v. III, p. E193-E212 (in Spanish).

EVANS, A.M., HASLAM, H.W., and SHAW, R.P., 1979, Porphyry style copper-molybdenum mineralization in the Ballachulish igneous complex, Argyllshire with special reference to the fluid inclusions (abst.): Program of Fourth Meeting of the Geological Societies of the British Isles, Univ. Sheffield, Sept., 1979 (unpaginated).

Copper-molybdenum mineralization occurs over an area of at least 1800 x 700 m in the Gleann a Chaolais area of the Ballachulish igneous complex. The mineralization is best developed in and around the eastern part of an outcrop of microadamellite which has not been previously described. Marked wall rock alteration, principally of a phyllic nature, accompanies the mineralization and there is some evidence for the possible pre-existence of propylitic alteration. Fluid inclusions in both primary and secondary quartz have been studied. The principal inclusions are aqueous ones of moderate salinity (mainly 0-13 equiv. wt. % NaCl) homogenizing at 100-300°C. The presence of co-existing gas-rich inclusions with similar homogenization and salinity values suggests the trapping of a boiling fluid, in which case no pressure correction is necessary and the depth at which trapping occurred can be estimated to be less than 2 km. Higher temperature and salinity values tend to be developed in and close to the microadamellite suggesting that it may have been an important channelway for rising solutions. The nature of the mineralization, the wall rock alteration and the density and type of fluid inclusions show that the mineralization is of porphyry type and it is suggested that the present level of exposure may be near the top of a more extensive mineralized zone. (Authors' abstract)

EVANS, S.H., Jr., and NASH, W.P., 1979, Diffusion gradients in natural silicic liquids, (abst.): Eos, v. 89, p. 402.

Electron microprobe analyses of natural rhyolite glass reveal chemical gradients 10-15 μm wide adjacent to microphenocrysts of plagioclase, alkali feldspar, and magnetite. The presence of such gradients has previously been interpreted as indicative of disequilibrium between liquid and solid. If crystals and liquid are not in equilibrium, temperatures determined from the compositions of coexisting mineral phases might be erroneous. Chemical gradients may be attributed, however, to diffusion controlled equilibrium crystallization. Because the concentration of minor constituents in the crystal is not equal to that in the liquid at some distance from the diffusion zone, the steady state model of Tiller, Jackson, Rutter, and Chalmers is not appropriate for rhyolites. The microprobe data are consistent with the model of Burton, Prim, and Slichter in which the liquid is stirred by convection and the crystals are surrounded by a diffusive boundary layer. Computed apparent and equilibrium distribution coefficients for natural rhyolites, combined with published diffusion coefficients for K, yield linear growth rates for feldspars on the order of $2x10^{-7}$ cm sec^{-1}, similar to experimentally determined equilibrium growth rates. The analytical data are consistent with equilibrium crystallization in natural silicic liquids, and the utilization of coexisting phases for thermometry remains reasonable in the presence of narrow chemical gradients. (Authors' abstract)

FAHLEY, M.P., 1979, Fluid inclusion study of the Tonopah district, Nevada: M.S. thesis, Colo. School of Mines.

The Tonopah mining district, Nye County, Nevada, has produced over 170 million ounces of silver and 1.8 million ounces of gold from quartz veins in rhyolitic to andesitic late Oligocene to early Miocene volcanic rocks. Mineralization occurs along the shallow, northwest-dipping normal Tonopah fault and along steeply-dipping hanging wall fractures containing high grade ore shoots. Rhyolite sills and dikes, which were intruded along the deeper segments of the Tonopah fault, are closely related in time to the main episode of mineralization.

Wall rock alteration zones adjacent to veins consist of an inner potassic (adularia) zone which grades outward into argillic and propylitic alteration. With increasing depth, phyllic (quartz-sericite-pyrite) alteration predominates over potassic and argillic alteration.

Vein filling consists of three stages: early barren stage (quartz + sericite + adularia + pyrite), silver stage (quartz + base metal sulfides + gold + adularia + sericite + pyrite + argentite + pyrargyrite + polybasite), and late barren stage (quartz + calcite + barite). Fluid inclusion filling temperatures indicate that early barren stage fluids were between 290°C and 240°C, silver stage fluids between 280°C and 220°C, and late barren stage fluids between 260°C and 140°C. Variable liquid to vapor ratios in primary fluid inclusions suggest boiling of the hydrothermal fluids occurred at higher elevations above the Tonopah fault. Tm determinations indicate the salinity of the hydrothermal solutions averaged between 1 and 3 wt. % NaCl equivalent, suggesting a meteoric origin for the fluids. This conclusion is in close agreement with stable isotope data.

Preliminary theoretical considertions at 250°C suggest that mineralizing fluids were in equilibrium with sericite + adularia + quartz (pH=6.2) and were dilute, meteoric waters with log fO_2 values in the range -32 to -34.

A model in which meteoric waters circulated to substantial depths below the surface and became heated by shallow-seated igneous intrusions is proposed. As these solutions became heated, metals were leached from the Paleozoic-Mesozoic basement and Tertiary wall rocks. Dilute, metal-bearing solutions then travelled along the Tonopah fault and were deflected into hanging wall fractures where periodic boiling and mineral precipitation occurred at depths between 2,000 and 1,000 feet below the surface. A drop in temperature, an increase in pH and fO_2, and a decrease in fS_2 accompanying boiling are believed to be the primary mechanisms for metal precipitation. (Author's abstract)

FAIZIEV , A.R. and ISKANDAROV, F.Sh., 1979, Thermodynamic conditions of solutions which formed fluorite at some ore deposits and occurrences of the Pamirs: Izv. Vyssh. Uchebn. Zaved., Geol. Razved., v. 22(12), p. 75-83 (in Russian). Authors at Tadzh. Gos. Univ., Dushanbe, USSR.

The formation conditions of fluorite in various ore deposits was estd. from Th, Td, cryometry, etc. of the inclusions in fluorite crystals. The compn. of the solns. in the inclusions was detd. from Te; the concn. was estd. from the "freezing point" and soly. of the solid phase. The fluorite in rare-metal and many Sn deposits crystd. at 170-340° and 270-600 atm. from solns. with a high concn. of dissolved chlorides and carbonates (25-40 wt.%). The fluorite of com. fluorspar deposits formed at comparatively low temps. (80-180°) and pressures (100-250 atm) from solns. with low concns. (8-30 wt.%) of salts. The fluorite-forming solns. were mainly the F-HCO_3-Cl-type, with high content of alkali metals. (C.A. 92:79690f)

FASS, F.W.R. and HAGNI, R.D., 1979, Mineral asymmetry and directions of flow of the ore-forming fluids in the Viburnum trend, southeast Missouri (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 424.

FATYANOV, I.I., PISKUNOV, Yu.G., FILIN, S.I., MAKIYEVSKIY, V.P. and IGONIN, I.P., 1978, Changes and temperature conditions in the formation of gold ore deposits of vulcano-tectonic structures: Termobarogeokhimiya Zemnoy Kory I Rudoobrazovaniye, N.P. Ermakov, ed.: Moscow, Izd. Nauka, p. 192-196 (in Russian).

Indexed under fluid inclusions, geothermometry, geobarometry. (E.R.)

FAYZIYEV, A.R., KISELEV, V.I., ISKANDAROV, F.Sh. and ALIDODOV, B.A., 1978, Temperature conditions during mineral formation in the magnesium-silica-gangue occurences of Kukhilal, Southwestern Pamirs: Termobarogeokhimiya Zemnoy Kory I Rudoobrazovaniye, N.P. Ermakov, ed.: Moscow, Izd. Nauka, p. 177-179 (in Russian).

Indexed under fluid inclusions, geothermometry, geobarometry. (E.R.)

FEDOROV, Yu.A., 1979, Results of a study of deuterium in solutions of gas-liquid inclusions in halogen minerals of the northeastern Caucasus: Deposited Doc. 1979, VINITI 4282, p. 53-60 (in Russian). Author at Rostov. Gos. Univ., Rostov, USSR.

The δ D value was detd. in solns. of gas-liq. inclusions in halite and anhydrite. The aq. solns. have a total mineralization 278-302 g/kg; the chem. type of these waters changes in relation to mineralization and is mostly of the Mg-Ca chloride type. The δ D value in halite is from

-51.1 to $-77.8‰$ and in anhydrite $\sim -46.1‰$. The data suggest evapn. concn. of the Jurassic salt deposits of northern Caucasus. (C.A. 92:87300k)

FEDOROV, Yu.A., GAL'CHIKOV, V.V. and DONTSOVA, T.K., 1979, Study of the aqueous phase of evaporite minerals in the Northern Caucasus: Deposited Doc., 1979, VINITI 3132, p. 237-246 (in Russian).

Indexed under fluid inclusions. (E.R.)

FEISS, 1979 (See p. 210)

FERRAND, A., GRAPPIN, C., IGLESIAS, J.G. and TOURAY, J.C., 1978, New data on the fluorite deposit of Villabona (Asturias, Spain) and its conditions of formation: Bull. Bur. Rech. Geol. Min., Sect. 2: Geol, Gites Miner. p. 357-369 (in French).

FERRY, J.M., 1979, A map of chemical potential differences within an outcrop: Am. Min., v. 64, p. 966-985. Author at Dept. Geol., Arizona State Univ., Tempe, Arizona 85281.

Mineral assemblages in different samples of metamorphosed argillaceous carbonate rock, collected from a single, large outcrop in south-central Maine, record differences in the chemical potentials of CO_2 and H_2O between samples during metamorphism. Because all samples contain graphite and pyrrhotite of constant composition, differences in the chemical potentials of O_2, H_2, CH_4, and H_2S existed as well. Thermodynamic analysis of the mineral assemblages indicate that maximum chemical potential differences were on the order of 100 calories. Maximum differences in the chemical potentials of FeO, MgO, K_2O, Al_2O_3, and CaO between samples are of approximately the same magnitude. The differences in chemical potentials of CO_2 and H_2O between beds, however, correspond to a difference of only a few hundredths XCO_2 in the composition of a CO_2-H_2O fluid in equilibrium with the samples. Maximum gradients in the chemical potentials of CO_2 and H_2O during metamorphism at the outcrop were 5-6 cal/m in magnitude.

Differences in chemical potentials of CO_2 and H_2O can be mapped in three dimensions in the outcrop, and they exhibit an extremely regular pattern. With the exception of one sample, there are no detectable differences in chemical potentials parallel to bedding and schistosity (which have identical orientations in the outcrop). All other differences occur between different beds. The mapped differences in chemical potentials can be used to quantitatively estimate upper bounds on mass transfer of CO_2 and H_2O during metamorphism at the outcrop. The estimated upper bounds on mass transfer are consistent with (but do not require) a model of channelized fluid transfer during metamorphism in which fluid transfer primarily occurs in directions parallel to bedding and schistosity. (Author's abstract)

FIELD, J.E., ed., 1979, The properties of diamond: England, Academic Press, 674 pp.

Includes chapters on various aspects of the internal growth features of diamonds that are of value to interpretation of the solid inclusions found in diamond and the gases obtained on crushing or heating diamond. (E.R.)

FILIPISHIN, F.L. and GROMOV, A.V., 1979, Inclusions of mineral-forming media in main minerals of magnesia skarns at the Katalakhskoe and Tsvetkovskoe phlogopite deposits: Izv. Vyssh. Uchebn. Zaved., Geol.

Razved., v. 22(3), p. 62-66 (in Russian).

Scapolite, diopside, and apatite in the skarns of the title deposits (central Aldan region, USSR) have inclusions large enough to study by the homogenization method. Solid-phase as well as fluid inclusions are widespread in the minerals. Most of the solid inclusions are oriented along the long axis of crystals. The principal minerals of the phlogopite-bearing bodies crystd. from high-temp. solns. with a CO_2 compn. The min. temps. of formation were 330-630° (scapolite), 300-520° (diopside), and 280-430° (apatite). At these temps., the total fluid pressure was 1.7-3.9 kbars. (C.A. 91:178241w)

FLEROV, B.L., STEPANOV, Ye.R. and YAKOVLEV, Ya.V., 1978, Temperature conditions during the formation of the stratiform polymetallic deposits of Sardana in eastern Yakutia, Termobarogeokhimiya Zemnoy Kory I Rudoobrazovaniye, N.P. Ermakov, ed.: Moscow Izd. Nauka, p. 150-155 (in Russian).

Indexed under fluid inclusions, geothermometry, geobarometry. (E.R.)

FOO, B.N., 1978, Mineral paragenesis, fluid inclusion studies and geochemistry of the Sungei-Lembing tin lodes, West Malaysia (abst.): J. Geol. Soc. (London), v. 135, no. 2, p. 255-256.

FORESTIER, F.-H. and TOURET, J., 1979, Granulites, eclogites, and peridotites in France. Sciences de la Terre, Nancy, v. 23, no. 3,43 p. (in French). First author at Univ. Nantes, Dép. Sc. Terre, 2, rue de la Houssinière, 44072 Nantes Cedex.

This paper was prepared as a guide book for a cancelled excursion of the 26th Int. Geol. Congress, Paris 1980. With the contribution of many local specialists, it describes most occurrences of granulites, eclogites and peridotites in South Brittany, Massif Central and Pyrenees. A summary of the estimated P-T conditions of formation and frequency histograms for CO_2 are given, based on work by Bilal, 1978. (J. Touret)

FORGOTSON, J.M., Sr., 1979, Super overpressured gas: AAPG Bull., v. 63, p. 1534-1537.

A blowout after acidization of perforations at 10,800 ft (3,291 m) in limestone of the Cotton Valley Group (Upper Jurassic) in a field-extension well in Upshur County, in east Texas, gauged pressure in excess of 12,000 psi before equipment failure. The pressure dissipated rapidly and a 200-ft (60 m) offset well was normal for the field.

Cause of the unique high-pressure zone is unknown. Possibly the high pressure is relict from a time of deeper burial when such pressures were field-wide before uplift and migration. A local chamber or vault, sealed off, for example, by calcium carbonate, may have retained earlier pressures until its walls were dissolved by the acid treatment. (Author's abstract)

FRANCHETEAU, J. and 14 others, 1979, Massive deep-sea sulphide ore deposits discovered on the East Pacific Rise: Nature, v. 277, p. 523-528.

Massive ore-grade zinc, copper and iron sulphide deposits have been found at the axis of the East Pacific Rise. Although their presence on the deep ocean-floor had been predicted there was not supporting observational evidence. The East Pacific Rise deposits represent a modern analogue of Cyprus-type sulphide ores associated with ophiolitic rocks on land.

They contain at least 29% zinc metal and 6% metallic copper. Their discovery will provide a new focus for deep-sea exploration, leading to new assessments of the concentration of metals in the upper layers of the oceanic crust. (Authors' abstract)

FRANKS, Felix, (Ed.), 1973, Water, a comprehensive treatise, Vol. 2,: New York, Plenum Press 683 pp.

Includes a long chapter on clathrates (by D.W. Davidson), and on thermodynamic properties, phase behavior at high pressures, and solution models. (E.R.)

FRANTZ, J.D., and POPP, R.K., 1979, Alteration of calcium-magnesium silicates by chloride-bearing hydrothermal fluids: Carnegie Inst. Wash. Yearbook 78 (1978-1979) p. 596-602.

FRECKMAN, J.T., 1978, Fluid inclusion and oxygen isotope geothermometry of rock samples from Sinclair 4 and Elmore 1 boreholes, Salton Sea geothermal field, Imperial Valley, CA, U.S.A.: Master's thesis, Univ. of California, Riverside, CA

FREESTONE, I.C., and HAMILTON, D.L., 1979, The role of liquid immiscibility in carbonatite genesis (abst.): Mineralog. Soc. (London) Bull., no. 45, p. 4. Author at Dept. of Geology, University of Manchester.

The two-liquid field between alkaline-carbonate liquids and phonolite or nephelinite magmas from the Oldoinyo Lengai volcano has been determined between 0.7 and 7.6 kb and 900°-1250°C. The miscibility gap expands with increase in P_{CO_2} and decreases in temperature. Concomitantly there is a rotation of tie-lines so that the carbonate liquids become richer in CaO. The element distribution between the melts indicates that a carbonatite liquid equivalent in composition to Oldoinyo Lengai natrocarbonatite lava would have separated from a phonolitic rather than a nephelinitic magma. CO_2-saturated nephelinites coexist with carbonate liquids much richer in CaO than the Lengai carbonatites, but even so these liquids have high alkali concentrations. (Authors' abstract)

FRIDMAN, A.I., REMIZOVA, L.I., VOYTOV, G.I. and CHEREVICHNAYA, L.F., 1977, Natural gas of the Beloreschenskoye barite deposit, northern Caucasus: Akad. Nauk SSSR Doklady, v. 233, no. 3, p.470-472 (in Russian; translated in Doklady Acad. Sci. USSR, Earth Sci. Sects., v. 233, p. 194-197, pub. 1978).

See <u>Fluid Inclusion Research--Proceedings of COFFI</u>, v. 10, p. 83 (1977) for abstract. (E.R.)

FROST, B.R., 1979, Mineral equilibria involving mixed-volatiles in a C-O-H fluid phase: The stabilities of graphite and siderite: Amer. Jour. Sci., v. 279, p. 1033-1059. Author at Dept. Geol., Univ. Wyo., Laramie, Wyoming 82071.

The stability of graphite in the presence of C-O-H fluid-phase has been calculated for pressures below 10 kb and temperatures above 400°C. The modified Redlich-Kwong technique was used to model the behavior of the fluid phase. A compositional variable, X_C, has been defined ($X_C = XCO_2 + X_{CO} + 1/3\ XCH_4$) which allows one to depict the graphite-fluid equilibria as an isobaric, isothermal univariant curve on a log fO_2-X_C diagram. On such a plot the curve has a positive slope ($\partial \log fO_2/\partial X_C$) at high values of fO_2, where the dominant equilibrium is $C + O_2 = CO_2$ and a negative slope at lower oxygen fugacities where the major equilibrium is $C + 2H_2O = CH_4 + O_2$. The change in the fluid composition from a nearly pure mixture of CO_2 and H_2O at high fO_2 to a mixture of CH_4 and H_2O with minor H_2 at lower oxygen fugacities can be shown in the divariant field by using isobars for CO_2 and CH_4. In general the field of stability for graphite + fluid shrinks with increases in temperature at constant pressure and with decreases in pressure at constant temperature. Increases in temperature at constant pressure also tend to enrich the fluid in the reduced species (CO, CH_4, and H_2).

The log fO_2-X_C diagrams produced by these calculations are applied to show how graphite veins can form by oxidation of a methane-rich fluid phase and how it is possible for carbon to be transported in the fluid phase from a graphite-bearing gneiss to a graphite vein. The diagrams are also useful to understanding the stability of siderite in the system Fe-C-O-H. They show that methane plays an important part in siderite breakdown only over a narrow range of oxygen fugacity; under most conditions the fluid coexisting with siderite will be essentially a binary CO_2-H_2O mixture. Furthermore, at temperatures of very low-grade metamorphism siderite can coexist with a fluid which is very rich in H_2O. (Author's astract)

FRYER, B.J., KERRICH, R., HUTCHINSON, R.W., PEIRCE, M.G. and ROGERS, D.S., 1979, Archaean precious-metal hydrothermal systems, Dome Mine, Abitibi Greenstone Belt. I. Patterns of alteration and metal distribution: Can. J. Earth Sci., v. 16, p. 421-439. First author at Dept. Geol., Memorial Univ. of Newfoundland, St. John's, Nfld., Canada, A1B3X5.

The Porcupine District, Abitibi Greenstone Belt is one of the most extensive areas of Archaean auriferous mineralization. At least two stages of lode gold emplacement may be recognized. The first involves gold-bearing ferroan dolomite layers with subordinate chert, sulphides, and graphite deposited as laterally extensive chemical sediments at interflow horizons within the mafic volcanic sequence. The second stage is represented by major gold-bearing hydrothermal quartz-albite-dravite veins which transect diverse host rocks including the carbonate chemical sediments. Differences between gold-bearing chemical sediment and auriferous hydrothermal veins, in terms of texture, mineralogy, and nature of inclusions, together with considerations of chemistry are not compatible with local derivation of veins from enveloping chemical sediments or adjacent host rocks. The chemical sediments display slump structures and predate all tectonic deformation. In general, auriferous hydrothermal quartz veins transect bedding and/or schistosity, and are at a low state of internal strain. They appear to have been emplaced late during the second regional fold episode.

Au, Ag, and Pd average 10, 2, and 0.1 ppm respectively in ore types at the Dome mine; representing concentration factors of 10,000, 40, and 10 times background values in unmineralized metabasalt, and primary igneous rocks worldwide. Au and Ag are inhomogeneously distributed.

Mineralized metabasic rocks adjacent to vein stockworks have Ti/Zr and Ti/Al_2O_3 ratios comparable to tholeiitic basalts, but display variable enrichment of depletion of silica, systematic depletion of Na_2O, and where intensely altered significant extraction of calcium. The low Ni and Cr contents of the carbonate layers, together with low Ti/Zr ratios (43-78) of the carbonates and their enveloping mafic schists, are not consistent with the hypothesis that these auriferous rocks are carbonated ultramafics. Massive banded quartz-fuchsite-dravite veins have Cr and Ni abundances averaging 350 ppm, implying hydrothermal transport of these elements. Ti/Zr ratios of 120, together with high Mg, Cr, and Ni abundances in magnesite-dolomite-quartz-chlorite schists which host the banded veins are compatible with a primary komatiitic composition. Mineralized metabasic rocks are reduced ($Fe^{2+}/\Sigma Fe = 0.9$) relative to rocks with primary background abundances of precious metals ($Fe^{2+}/\Sigma Fe = 0.7$). This change of oxidation state implies that large volumes of reducing hydrothermal solutions were involved in vein mineralization. (Authors' abstract)

FUNICIELLO, R., MARIOTTI, G., PAROTTO, M., PREITE-MARTINEZ, M., TECCE, F., TONEATTI, R. and TURI, B., 1979, Geology, mineralogy and stable isotope geochemistry of the Cesano geothermal field (Sabatini Mts. volcanic system, northern Latium, Italy): Geothermics, v. 8, p. 55-73. First author at Inst. di Geol. e Paleon., Univ. di Roma, 00100 Roma, Italy.

Some deep wells (1400-3000 m) have been drilled into the volcanic system of the Sabatini Mts., north of Rome, in search of high enthalpy geothermal fluids.

The isotopic analyses all show values comparable to those of the sedimentary carbonate host rocks, suggesting limited circulation of the hydrothermal fluids. $^{18}O/^{16}O$ analyses on specimens in the most restrictive locations next to interfaces show a relatively larger extent of isotopic exchange with aqueous fluids.

Fluid circulation, which is mainly extinct, seems to belong to a closed system. Two types of circulation have been recognized: the first of these is connected to the stratigraphic discontinuities (especially at the contact between the allochthonous flysch complex and the basal carbonate sequence) and is characterized by mainly K-feldspar and sulphide-sulphate mineralizations; the second circulation is tied to the fracture systems and is particularly widespread in the pyroclastic cover where it appears in the form of sulphate-and carbonate-rich dykes. This system seems to have undergone a mixing with surface waters. (From the authors' abstract)

GAFFNEY, E.S. and CHEUNG, H., 1975, Migration of fluid inclusions in salt adjacent to a radioactive waste canister (abst.): Eos (Am. Geophys. Union, Trans.), v. 59, n. 12, p. 1065.

GAMOV, M.I. and VYALOV, V.I., 1978, Temperature and geochemical zonalty of the Slepaya* ore body of the Tyrnyauz deposit (abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 86-76 (in Russian). Authors at the Rostov State Univ., USSR.

The ore body consists of pyroxene hornfelses and skarns with W-Mo mineralization, formed at the contact of marbles and biotite hornfelses. Five generations of pyroxenes and garnets, the main minerals of skarns, were distinguished. Gas and essentially gas inclusions prevail in those minerals; liquid inclusions are rare, of tubular habit 2-7 μm long, and their amount increases only in veinlets of pyroxene and garnets. Among L inclusions also polyphase ones occur with 1-2 grains of dm with

cubic habit. First two generations of pyroxenes and associated garnets yield Td 520-610°C, for other pyroxene generations including the veinlet one, Td was 570-660°C. The third generation of garnet has Td 500-660°C. All quartz generations except the first one (which is a relic generation that does not decrepitate) have Td 230-450°C, with maximum of gas release moving from 380°C for the earliest one to 330°C for the last one. Td decrease was noted both toward upper and lower boundary of the ore body. (Authors' abstract, transl. by A.K.)
*I.e., hidden ore body? (A.K.)

GANEYEV, I.G., 1978, The mode of transport of mineral materials in hydrothermal solutions; Termobarogeokhimiya Zemnoy Kory I Rudoobrazovaniye, N.P. Ermakov, ed.: Moscow Izd. Nauka, p. 11-27 (in Russian).

Indexed under fluid inclusions. (E.R.)

GANT, J.L. and BOWSER, C.J., 1979, Brine-related metalliferous sediments in the Suakin Deep, Red Sea (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 429-430.

An investigation of brine deeps of the Red Sea which are not spatially associated with the hydrothermal hot brine system of the Atlantis II Deep area. (E.R.)

GEGUZIN and DZYUBA, 1977 (See p. 211)

GEGUZIN, Ya.E., DZYUBA, A.S. and KRUZHANOV, V.S., 1978, Motions of gas-liquid inclusions in a crystal in a temperature gradient field: Kristallografiya, v. 23(4), p. 880-881 (in Russian).

GEGUZIN, Ya.E, KALININ, V.V. and KAGANOVSKII, Yu.S., 1979, Effects of foreign particles on a macroscopically smooth surface on the movement of steps due to evaporation and condensation: Growth of Crystals, v. 11, p. 183-190.

A theoretical and experimental study of the effects of solid particles on a growing crystal face. (E.R.)

GEGUZIN, Ya.E. and KRUZHANOV, V.S., 1979, Movement of liquid inclusions in a single crystal in a stress gradient field: Kristallografiya, v. 24, no. 4, p. 866-867 (in Russian).

GERLACH, T.M., 1979a, Volcanic gases from Erta Ale volcano and Surtsey volcano and magma outgassing in crustal spreading zones (abst.): Hawaii Symposium on Intraplate Volcanism and Submarine Volcanism, Hilo, Hawaii, July 16-22, 1979, Internat. Assoc. Volc. and Chem. of Earth's Interior, p. 62.

The analyses of gas samples from Erta Ale lava lake and from Surtsey volcano were corrected for modifications imposed during and after collection. Eruptions between 1964 and 1967 (Sigvaldason and Elisson, 1968) gave similar results after removal of small modifications imposed during collection. The restored compositions also have O_2 fugacities near QMF and show a long-term decrease in CO_2.

Simple thermodynamic models suggest that the CO_2-rich vesicle gases of seafloor basalts and the relatively H_2O-rich volcanic gases of Erta Ale and Surtsey are components of a spectrum of gas compositions evolved during the outgassing of tholeiitic basalt at shallow depths. The H_2O-rich volcanic gases are consistent with the observed outgassing patterns of submarine basalts from progressively shallower depths along the Reykjanes Ridge. If allowance is made for the effect of pressure on gas-melt solubility relationships, the Erta Ale and Surtsey gases can be shown to lie on an outgasing trend calculated for tholeiitic basalts from mid-ocean ridge spreading zones. (From the author's abstract)

GERLACH, T.M., 1979~~b~~, Evaluation and restoration of the 1970 volcanic gas analyses from Mount Eta, Sicily: J. Volcanol. Geotherm. Res., v. 6, p. 165-178.

GHENT, E.D., ROBBINS, D.B. and STOUT, M.Z., 1979, Geothermometry, geobarometry, and fluid compositions of metamorphosed calc-silicates and pelites, Mica Creek, British Columbia: American Mineralogist, V. 64, p. 874-885.

Fluid compositions estimated from paragonite-quartz-albite-kyanite equilibria from the metapelites are dominated by H_2O, and fluid compositions estimated for calc-silicates have $XCO_2 > XH_2O$. Calc-silicates formed at carbonate-pelite contacts appear to have equilibrated at temperatures near 610°C and XCO_2 near 0.25. (From the authors' abstract)

GIBSHER, N.A., 1978, Paleotemperature gradients in the pyrite-polymetallic deposits of Rudny Altai; Termobarogeokhimiya Zemnoy Kory I Rudoobrazovaniye, N.P. Ermakov, ed.: Moscow Izd. Nauka, p. 130-135 (in Russian).

Indexed under fluid inclusions, geothermometry, geochemistry. (E.R.)

GIBSHER, N.A., 1979, Physico-chemical conditions for the formation of certain pyrite-polymetallic ore deposits of the Rudny Altai; according to gas-fluid inclusions, in Major parameters of natural processes of endogenetic ore formation, V.A. Kuznetsov, ed.: Novosibirsk, Izdat. Nauka, v. 2, p. 101-108 (in Russian). [Dokl. Vses. Soveshch., 1977]

A review of Rudnyi Altai pyrite-polymetallic ore deposits based on studies of fluid inclusions. Most ores formed at <350°C. (E.R.)

GIORDANO, T.H. and BARNES, H.L., 1979, Ore solution chemistry VI. PbS solubility in bisulfide solutions to 300°C: Econ. Geol., v. 74, p. 1637-1646.

GONCHAROV, V.I. and SIDOROV, A.A., 1979, Thermobarogeochemistry of volcanogenic ore formation: Moscow Izd. Nauka, pp. 207 (in Russian).

GORDON, L.I. and CORLISS, J.B., 1979, On the formation of metal-rich deposits at ridge crests: Earth and Planet. Sci. Lett., v. 46, p. 19-30. First author at Dept. Earth and Planet. Sci., Mass. Inst. Tech., Cambridge, MA 02139 U.S.A.

Data from the hot springs at the Galapagos spreading center (T = 3-13°C) show depletions of the existing waters in Cu, Ni, Cd, Se, Cr and U relative to ambient seawater. Manganese is strongly enriched. Iron shows highly variable behavior between vent fields but is in general low. The data confirm the occurrence of extensive subsurface mixing between the primary high-temperature, acid, reducing hydrothermal fluids and "groundwater." The composition of the latter is indistinguishable from that of the free water column adjacent to the ridge axis. The final solutions are on the boundary between those forming MnO_2 crusts and those producing iron-manganese rich sediments. The suite of metal rich deposits observed at ridge crests - Mn-O, Fe-Mn-O, Fe-S - can be explained as the manifestation of the degree of subsurface mixing, decreasing from >100:1 to <1 across the series (assuming an end-member temperature of 350°C). (Authors' abstract)

GRABER, Ronald, SAWKINS, F.J. and KOWALIK, Joseph, 1979, Gas analysis studies at Casapalca, Peru - Implications for ore genesis (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 80.

Analyses of fluid inclusion gases in 34 samples, representing various stages of formation of the Casapalca Ag-Pb-Zn-Cu ven deposits, provide a clear differentiation between isotopically distinct sulfide and post-sulfide vein filling events. The gas suite obtained from post-sulfide vein minerals (H_2-CH_4-N_2-CO-CO_2-O_2-NO) implies the presence of meteoric fluids. The gas suite associated with sulfide stage deposition (CH_4-N_2-CO-CO_2-C_hH_n-S-SO_2) suggets a magmatic source, buffered by the assemblage py-po-mag.

Episodes of boiling of sulfide stage fluids, as evidenced by fluid inclusion assemblages, are characterized by a sharp increase in SO_2 levels. Thermochemical calculations based on the gas data indicate log f_{O_2} values of -30 to -31 during non-boiling episodes and -25 during boiling episodes. Log f_{S_2} values based on similar calculations indicate a range from -7.4 to -8.9, in excellent agreement with X_{FeS} contents of Casapalca sphalerites.

The available data suggest that episodic boiling and a general decrease in temperature were the main mechanisms of sulfide precipitation at Casapalca. During boiling episodes strong isotopic disequilibrium of sulfur species is indicated. (Authors' abstract)

GRAHAM, D.G., 1978, A mass spectrometric investigation of the volatile content of deep submarine basalts: Doctoral dissertation, Univ. of Hawaii, Honolulu, Hawaii, USA, 187 pp.

GRAPPIN, C., SALIOT, P., SABOURAUD, C. and TOURAY, J.C., 1979, Variations of the Cl/Br, Na/Br and K/Br ratios in fluid inclusions of quartz in the Bramans-Termignon evaporites, Vanoise, French Alps: Chem. Geol., v. 25: p. 41-52 (in French). First author at Lab. Pierre Sue, Groupe des Sci. de la Terre, C.E.N.-Saclay, Gif sur Yvette Cedex 91190 France.

The ratios Cl/Br, Na/Br, K/Br of fluid hypersaline inclusions of quartz situated in the Bramans-Termignon evaporites have been measured by means of neutronic activation. The results obtained: Cl/Br (90-1000), Na/Br (100-500) and K/Br (8-50) indicate that those fluids are natural samplings of very ancient marine evaporitic brines whose geochemical evolution is derived from regional "tectonometamorphic" processes. These results are discussed by comparison of a simple mixture model between Br-rich brines with an evaporitic origin and Br-poor ones coming from the re-dissolution of halide formerly present in the sediments. The evolution of the chemical composition of the solutions corresponds both on the NaCl dissolution and on the neoformation of some minerals, such as albite. (Authors' abstract)

GRAZIANI, G. and DI GIULIO, V., 1979a Growth of an aquamarine crystal from Brazil: N. Jb. Miner. Mh., 1979, p. 101-108.

The manners of growth of an aquamarine crystal from Brazil were studied in relation to the mineralogical study of the host mineral and its inclusions.

Two stages in the growth of the aquamarine were identified: the first characterized by the presence of well-grown crystals of magnetite, fluor-apatite, and corundum; the second by clusters constituted of quartz, fluor-apatite, corundum, epidote, and ilmenite.

The unusual inclusion, characteristic of the first stage of growth of the host mineral, formed of magnetite and corundum crystals together in the aquamarine matrix, is emphasized. (Authors' abstract)

This and the next paper describe optical, X-ray, SEM and microprobe studies on aquamarine and beryl crystals from Brazil. An attempt at estimating the T-P conditions of formation is made on the basis of solid inclusions in the crystals. No fluid inclusion is described or reported (P. Latanzi)

GRAZIANI, G. and DI GIULIO, V., 1979,b Some genetic considerations on a Brazilian aquamarine crystal: N. Jb. Miner. Abh., v. 137, p. 198-207 (in English).

Electron microprobe analysis of solid inclusions of apatite, epidote, and fuchsite, from aquamarine are given. Inclusions of quartz ilmenite, lepidocrocite, and corundum are also reported. (E.R.)

GRAZIANI, G. and GUIDI, G., 1979 Mineralogical study of a star-beryl and its inclusions: N. Jb. Miner. Mh., 1979, p. 86-92.

A rare star-beryl and its inclusions were studied by optical observations, X-ray, SEM investigations and electron microprobe analyses. The inclusions are: quartz, corundum, pyrrhotite and, subordinately, epidote, apatite and pyrite. The T-P range of this beryl is determined. The unusual inclusion of quartz and corundum crystals together in the beryl matrix is emphasized. (Authors' abstract)

GREEN, H.W., II, 1979, Trace elements in the fluid phase of the Earth's mantle: Nature, v. 277, p. 465-467.

An ion probe study revealed the presence of significant quantities of cations other than carbon in the CO_2 fluid inclusions in olivine from a dunite specimen from Hawaii. The inclusions were released into the instrument by the oxygen ion beam sputtering. Only certain elements could be detected without ambiguity (e.g., ^{40}Ar and ^{40}MgO). Positive identification: 39(K) and 47(Ti); suggestive for 140 (Ce);and inconclusive for 1(H), 85(Rb), 86(Sr), 87(Sr), 138(Ba), 142(Ce), and 208(Pb). These materials are believed to be in a surface film lining the CO_2 inclusions, which was formerly in solution in the CO_2. (E.R.)

GRISHINA, S.N., 1979, The microprobe analysis of gas phase of inclusions in minerals (sic): Zapiski Vses. Mineral. Obsh., 1979, pt. 5, p. 617-621 (in Russian).

GROMOV, A.V. and FILIPISHIN, F.L., 1979, Temperature regime for the crystallization of post-phlogopite mineral associations in magnesium skarns of the central Aldan: Vyssh. Uchebn. Zaved., Izv., Geol. Razved., 1979, no. 7, p. 52-58 (in Russian).

Indexed under fluid inclusions. (E.R.)

GROSHENKO, 1978 (See p. 211)

GROSHENKO, A.R. and PARSADANYAN, S.T., 1978, The new automatic decrepitation-acoustic instrument DFU-1, in Theory and Practice of Thermobarogeochemistry, N.P. Ermakov, ed., Izd. Nauka, p. 253-256; (in Russian).

GÜBELIN, E., 1979a, Tell-tale inclusions in a phenakite from Brazil: The Journal of Gemmology, v. XVI, p. 357-362.

H_2O-CO_2 fluid inclusions in phenakite from Brazil are described, attached to solid inclusions of acicular aikinite. Salinity 3.5-4.2% NaCl equiv.; CO_2 hydrate dissociation +8° to +9°C (i.e., <6 Wt.% CO_2); Tm unidentified solids 20-50°C; Tm unidentified birefringent solid 60°C. (ER).

GUEBELIN, E., 1979b, Inclusions in tourmaline: Lapis, v. 4, no. 1, p. 38-40 (in German).

GUHA, Jayanta, LEROY, Jacques and GUHA, Denise, 1979, Significance of fluid phases associated with shear zone Cu-Au mineralization in the Doré lake complex, Chibougamau, Québec: Bull. Minéral., v. 102, p. 569-576. First author at Sci. Terre, Univ. Que. à Chicoutimi, Chicoutimi, Québec, Canada.

Microthermometry of 400 secondary inclusions from the B zone and D zone of the Henderson ore bodies shows the presence of two coexisting fluids, one an aqueous chloride solution, highly charged with salts (both NaCl and $CaCl_2$) and other rich in methane. Analyses of dissolved ions of 16 samples indicate that Na^+ and Ca^{+2} represent nearly the total quantity of dissolved cations in the fluids. The temperature of formation established from the relation of NaCl saturation is in the order of 240° ± 10°C. Utilizing the isochore of methane to trace the isochore of brine, the pressure is deduced to be around 800 bar. Possible genetic implications in relation to the fluids are discussed. (Authors' abstract)

GUHA, Jayanta and MAILLET, James, 1979, Hydrothermal systems related to the copper-gold mineralization in the Chibougamau region (abst.): Geol. Assoc. Canada-Min. Assoc. Canada Program with Abstracts, v. 4, p. 55.

The formation of the copper-gold vein deposits within shear zones in the Dore Lake Complex is the major mineralizing event in the region. A systematic study of the dykes in and around the northern flank of the Dore Lake Complex reveals several kinds of dyke including two quartz feldspar porphyry types. No direct spatial relationship may be demonstrated between the mineralization and a particular type of dyke. At least one of the quartz feldspar types, however, appears to be related to a period of fluid activity contemporaneous with mineralization. This relationship coupled with fluid inclusion and isotopic data permits a better definition of the hydrothermal mineralizing event. (Authors' abstract)

GUTMANN, J.T., 1977, Textures and genesis of phenocrysts and megacrysts in basaltic lavas from the Pinacate volcanic field: Amer. J. Sci., v. 277, p. 833-861. Author at Dept. Earth and Envir. Sci., Wesleyan U., Middletown, CT 06457.

The Pinacate volcanic field, Sonora, Mexico, contains alkali basalts and hawaiites of Pleistocene age. These rocks are characterized by the presence of phenocrysts and megacrysts of labradorite, olivine, and, in much lesser abundance, calcic augite and magnetite. In contrast to many other suites of megacrysts described from mafic, alkaline lavas elsewhere, subhedral to euhedral crystals of plagioclase dominate both phenocryst and megacryst assemblages volumetrically, and the plagioclase megacrysts are among the most calcic feldspars, or nearly so, in their host units. The labradorite megacrysts, which are as much as 10 cm long in some units, grade continuously downward in size into phenocrysts and microphenocrysts. Many of these smaller crystals are as calcic as the associated megacrysts, although others exhibit resorbed cores ranging downward in anorthite content to calcic andesine.

The compositions of the lavas cannot be derived from one another by addition and subtraction of olivine and plagioclase. The groundmasses of rocks rich in coarse labradorite crystals are correspondingly depleted in plagioclase. The gem-quality labradorite megacrysts, which are in fact megaphenocrysts, contain primary tubular fluid inclusions of large size and probably grew within the upper crust concomitant with evolution of fluid from adjacent silicate melt. Many of the phenocrysts and megacrysts exhibit skeletal crystal forms typical of rapid growth from melts moderately to strongly supersaturated with crystalline phases.

A petrogenetic model for near-surface crystallization in rising magmas is proposed. This model involves evolution of water from the melts, perhaps initially by partitioning into a separate, CO_2-rich, fluid phase. Supersaturation promoted by this exsolution of water may be nil or only slight at first but evidently induced formation of numerous skeletal crystals, some more than 1 cm long, at depths within or not far below the Pinacate volcanic pile. Caution is indicated in interpreting the textures and paragenesis of coarse crystals in volcanic rocks. (Author's abstract)

GUTSALO, L.K., VETSTEIN, V.E. and ARTEMCHUK, V.G., 1979, The use of isotopic composition of brines for drawing conclusions concerning the source of salts and the mechanism of their concentration in salt-generating basins: Dokl. Akad. Nauk SSSR, v. 247, no. 3, p. 692-695 (in Russian)

GÜVEN, Necip and CARNEY, L.L., 1979, The hydrothermal transformation of sepiolite to stevensite and the effect of added chlorides and hydroxides: Clays and Clay Minerals, v. 27, no. 4, p. 253-260. First author at Dept. Geosci., Texas Tech Univ., Lubbock, TX 77027.

Hydrothermal reactions in the system sepiolite/H_2O have been examined between 149° and 316°C. Approximately 10-20% of the starting sepiolite was converted to a smectite (stevensite) at 204°C within 24 hr. Similar results were obtained when $CaCl_2$, NaOH, $Ca(OH)_2$, or $Mg(OH)_2$ was added to the system. In the presence of NaCl, about 60% of the sepiolite was converted to stevensite, whereas, only 5% stevensite formed in the presence of $MgCl_2$. Greater amounts of stevensite formed at 260°C in these systems. Above 316°C, 60-80% of the sepiolite was converted to stevensite in 24 hr, regardless of the presence or absence of salts. Within the experimental conditions used, temperature is the most important factor in the sepiolite-to-stevensite conversion.

At or below 216°C, sepiolite appears to transform into stevensite by dislocations involving c/2 glides that are triggered by the stresses of the hydrothermal conditions. Above this temperature, stevensite seems to form by direct precipitation after dissolution of sepiolite. (Authors' abstract)

GVOZDLYEV, V.I., 1978, Stages of mineralization and temperatures of their formation at the Lermontovskoe tungsten deposit (abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 81-82 (in Russian). Author at the Far-East Geol. Inst. of Far-East Sci. Center of Acad. Sci. USSR, Vladivostok.

The deposit occurs in sedimentary, volcanic-sedimentary, volcanic and plutonic rocks of Paleozoic, Mesozoic and Quaternary age. The following stages of mineralization were distinguished (Td in °C): skarn 500-320 (pyroxenes 500-360, garnets 400-320°C), greisen 460-360, quartz-scheelite 440-280, sulfide 400-160. (From the author's abstract, transl. by A.K.)

HAAPALA, I., and KINNUNEN, K. 1979a, Fluid inclusion evidence on the genesis of tin deposits (abst.): Geological Society Newsletter (G.B.), v. 8, no. 6, p. 17.

Based on published data on fluid inclusions in cassiterite and associated minerals, a synthesis will be presented on the temperature and other characteristics of the mineralizing fluids in different genetic types of tin deposits. (Authors' abstract)

HAAPALA, Ilmari and KINNUNEN, Kari, 1979b, Fluid inclusions in cassiterite and beryl in greisen veins in the Eurajoki stock, southwestern Finland: Econ. Geol., v. 74, p. 1231-1238. First author at Dept. Geol., Univ. Helsinki.

Fluid inclusions in cassiterite and beryl were studied in greisen veins in a Proterozoic rapakivi granite stock in Eurajoki parish, southwestern Finland. In the greisen proper, formed by metasomatic alteration of granite, the cassiterite has primary fluid inclusions with filling temperatures and salinities generally increasing from the inner zones toward the margins of the crystals (filling temperatures from 260° to 390°C, salinities from 3 to 17 equiv. wt. percent NaCl). In the central quartz-beryl veinlets, formed by open space filling, the beryl shows primary fluid inclusions with filling temperatures of 360° to 480°C and salinities of 11 to 17 equiv. wt. percent NaCl. The secondary inclusions in beryl show filling temperatures of 360° to 410°C and salinities of 2 to 10 equiv. wt. percent NaCl. (Authors' abstract)

HAGGERTY, S.E., and McMAHON, B.M., 1979, Evidence for carbonatite liquids in kimberlites (abst.): Mineralog. Soc. (London) Bull., no. 45, p. 3. Authors at Dept. of Geology, University of Massachusetts, Amherst, Mass., U.S.A.

Although a genetic or coeval link between kimberlites and carbonatites has been challenged, the presence of liquids having carbonatitic affinities in kimberlites is unequivocal. The hallmark that such liquids are an integral component of kimberlite petrogenesis is the widespread distribution of magmatic calcite. That calcite displays skeletal quench textures, and that immiscible droplets are diapirically structured within kimberlite hosts, are irrefutable lines of evidence for liquidus $CaCO_3$. Supporting evidence for high calcium activity during kimberlite crystallization is provided by the presence of REE-perovkite, monticellite and diopside, Ca-rich olivine, and high-temperature reactions involving the presence of $CaCO_3$. (Authors' abstract)

HALLS, C., ALLEN, P.M., EASTERBROOK, G.D., PHILLIPS, W.J., MORRISSEY, C.J. and DUNHAM, K., 1979, Mineralized breccia pipe and other intrusion breccias in the Harlech Dome, North Wales discussion and reply: Inst. Min. Metall., Trans., Sect. B: Appl. Earth Sci., v. 88, p. 132-133.

A discussion of a paper of this title by Allen and Easterbrook Trans./Section B, Vol. 87, November, 1978, p. B157-161. Indexed under fluid inclusions.

HAMILTON, D.L., FREESTONE, I.C., DAWSON, J.B., and DONALDSON, C.H., 1979, Origin of carbonatites by liquid immiscibility: Nature, v. 279, no. 570B, p. 52.

HANOR, J.S., 1979, A mechanism for precipitating lead and zinc from sedimentary brines: Partitioning of CO_2 into a methane gas phase (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 438.

Current evidence indicates that sedimentary brines are a major component of ore-forming fluids in Mississippi-Valley-Type ore deposits. Among the many problems relating to the genesis of these deposits are the factors which cause precipitation of lead and zinc sulfides. Mixing of diverse waters, reduction of sulfate, and a decrease in temperature are all possible mechanisms. An additional mechanism is loss of dissolved CO_2 into a coexisting gas phase. Such a loss would increase solution pH, thus favoring precipitation of galena and sphalerite from a chloride-rich brine containing lead, zinc, and sulfide in solution.

A sedimentary gas phase could most likely be evolved by: (1) production of methane through decarboxylation of organic matter at depth and/or (2) a pressure drop induced by the upward migration of a CH_4-saturated brine. In the latter circumstance, precipitation of metals should be favored on regional structural highs. Variations in rate of regional fluid flow and degassing could give rise to a district-wide ore stratigraphy, perhaps similar to the zoning in sphalerite that can be correlated across the Upper Mississippi Valley District.

Because H_2S is more soluble than CO_2, it will preferentially remain in the aqueous phase. As a result of physical separation of gas and brine, remnants of the methane gas phase need not be preserved in fluid inclusions. (Author's abstract)

HARMON, R.S., ATKINSON, T.C., and SMART, P.L. 1979, Late Pleistocene palaeoclimate temperatures from fluid inclusion isotope studies in stalagmites (abst.): Program of Fourth Meeting of the Geological Societies of the British Isles, Univ. Sheffield, Sept., 1979 (unpaginated). First author at Isotope Geology Unit, SURRC, East Kilbride, Scotland.

Speleothems, the secondary $CaCO_3$ deposits which occur in caves, commonly contain a few tenths weight percent water trapped in the host carbonate as fluid inclusions. The inclusions are thought to contain parent seepage water from which the speleothems were originally deposited. Previous studies have shown that the temperatures in the deep interiors of most caves approximates the mean annual regional surface temperature and that the isotopic composition of ground-water seepage in a cave is representative of the average of meteoric precipitation falling on the ground above the cave. This being the case, and provided that speleothem deposition occurred under conditions of isotopic equilibrium, the isotopic composition of both the fluid inclusion water and the host carbonate can provide information about the prevailing regional climate at the time a speleothem was formed. In general, it has been found that stalagmites consisting of massively crystalline palisade calcite showing no signs of post-depositional, diagenetic alteration or leaching are suitable for palaeoclimate studies.

The isotopic compositions of fluid inclusions extracted from actively-forming speleothems in the Ozark Mountains, Missouri (USA) and the Mendip Hills (England) are identical to that of present meteoric precipitation and ground-water recharge in these areas. D/H ratios of fluid inclusion waters extracted from ^{230}Th/^{234}U dated fossil speleothems from Iowa, Missouri, W.Virginia, Kentucky and Texas (USA) all show that glacial-age waters were depleted in deuterium relative to interglacial waters at these sites. The average shift in hydrogen isotopic composition of meteoric precipitation over the ice-free areas of central North America during glacial episodes within the past 250,000 years is about -12 parts per thousand. Of particular interest is a Late post-glacial and Holocene stalagmite from the Mendip Hills, England, which shows short-term D/H variations of up to - 20 parts per thousand, encompassing the Windemere Interstadial and Younger Dryas Cold Stage.

Depositional temperatures can be estimated from the temperature dependence of the calcite-water oxygen isotope fractionation. At all sites so far investigated in N.America and Britain, glacial-age isotopic temperatures are between 3°C and 14°C less than at present. Interglacial temperatures are equivalent to, or slightly less than, those of the present.

Future of these studies should permit reconstruction of palaeotemperature and palaeoclimatic patterns for continental N.America and Britain during the past 350,000 years. (Authors' abstract)

HARMON, R.S., SCHWARCZ, H.P. and FORD, D.C., 1978, Stable isotope geochemistry of speleothems and cave waters from the Flint Ridge-Mammoth Cave system, Kentucky; implications for terrestrial climate change during the period 230,000 and 100,000 years, B.P.: J. Geol., v. 86, no. 3, p. 373-384.

Indexed under fluid inclusions. (E.R.)

HARMON, R.S., SCHWARCZ, H.P. and O'NEIL, J.R., 1979, D/H ratios in speleothem fluid inclusions: A guide to variations in the isotopic composition of meteoric precipitation?: Earth Planet. Sci. Lett., v. 42, p. 254-266. First author at South Methodist U., Dallas, TX 75275.

D/H ratios of fluid inclusion waters extracted from ^{230}Th/^{234}U-dated speleothems that were originally deposited under conditions of isotopic equilibrium should provide a direct estimate of the hydrogen isotopic composition of ancient meteoric waters. We present here D/H ratios for 47 fluid inclusion samples from thirteen speleothems deposited over the past 250,000 years at cave sites in Iowa, West Virginia, Kentucky, and Missouri. At each site glacial-age waters are depleted in deuterium relative to those of interglacial age. The average interglacial/glacial shift in the hydrogen isotopic composition of meteoric precipitation over ice-free areas of east-central North Amnerica is estimated to be -12‰. This shift is consistent with the present climatic models and can be explained in terms of the prevailing pattern of atmospheric circulation and an increased ocean-continent temperature gradient during glacial times which more than compensated for the increase in deuterium content of the world ocean. (Authors' abstract)

HARRIS, D.M., 1979a, Geobarometry and geothermometry of individual crystals using H_2O, CO_2, S, and major element concentrations in silicate melt inclusions: 2. The 1959 eruption of Kilauea volcano, Hawaii (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 439.

A microscope vacuum heating stage and gas analyzer has been designed for measuring H_2O, CO_2, and SO_2 evolved from glass at temperatures to 1280°C. Vapor pressure measurements from 77 to 273 K yield the partial pressures of CO_2, SO_2 and H_2O in the gauge volume and the solid-vapor P-T equilibrium for each component. The absolute masses are determined using the ideal gas law, molecular weights of the constituents, and the gauge constant. The advantages of this technique are observation of the sample during degassing, simultaneous determination of H_2O, CO_2, and SO_2, avoidance of chemical standards for calibration, and very low detection limits (10 ng for CO_2, SO_2, H_2O).

Four olivine crystals (Fo 86.5 to 87.7) with nine melt inclusions have been analyzed by electron microprobe for major elements and S. The temperatures of entrapment (1205 to 1248°C) have been inferred from the distribution of MgO between olivine and melt (Roedder, 1974) and agree with liquidus temperatures for the Kilauea olivine tholeiite series (Tilley <u>et al</u>., 1967). MgO, FeO, and S decrease with decreasing temperature, whereas SiO_2, Al_2O_3, Na_2O, K_2O, and TiO_2 increase. Sulfur decreases from 0.13 wt. % at 1240°C to 0.06 wt. % at 1205°C. Two olivine crystals with microprobe-analyzed inclusions have been heated individually for determination of CO_2 and H_2O. The absolute concentrations of H_2O and CO_2 in the melt are 0.21 ± 0.04 and 0.05 ± 0.02 wt. %, respectively. The molar ratio of H_2O:CO_2:S in the parent melt at 1240°C is 69:7:24. The entrapment pressure, if CO_2 saturated, is 1.0 ± 0.4 kb using new data on CO_2 solubility inferred from submarine basalts. The matrix glass was erupted and quenched at 1 bar and 1200°C and contains H_2O, CO_2, and S at concentrations of 0.063, 0.004, and 0.004 wt. %, respectively. Contrary to results of Muenow and others (1979), H_2O is the dominant volatile component for Kilauean magmas and is present in the melt at the onset of olivine crystallization. (Author's abstract)

HARRIS, D.M., 1979b, Pre-eruption variations of H_2O, S, and Cl in a subduction zone basalt (abst.): Eos, v. 60, p. 968.

A vacuum fusion method has been developed for measuring H_2O, CO_2, and SO_2 evolved from glass at temperatures of 1280°C. The technique has been applied to high-Al basaltic melt inclusions in olivine crystals (Fo77 to Fo71) from the October 1974 eruption of Fuego. Melt inclusions have been analyzed by microprobe for major elements, S and Cl. Temperatures of entrapment (1125 to 1055°C) have been inferred from the distribution of FeO between olivine and liquid. Compositions vary with temperature and reflect the crystallization of the liquid. Six crystals with probe-analyzed melt inclusions have been individually heated in vacuum for determination of H_2O and CO_2 in the melt. The concentration of H_2O increases from about 1.6 wt % in the least differentiated liquid (Fo77 host) to 3.2 wt % in a more differentiated liquid (Fo71 host). The average CO_2 concentration is 1300 ± 400 ppm. Sulfur decreases from 2800 to 1100 ppm during differentiation. The presence of 1.6% H_2O lowers the crystallization temperatures by about 60°C. The entrapment pressure is 2.9 ± 0.7 kb, using new data on CO_2 solubility inferred from submarine basalts and published H_2O solubility data. Molar ratios of H_2O:CO_2:S:Cl in the least differentiated liquid are 86:3:9:2. H_2O is the dominant volatile component and is present in the melt at the onset of olivine crystallization. The twofold increase of H_2O, Cl, and K_2O are consistent with vapor-absent crystallization (50%) of the initial liquid. There is no evidence for entry of H_2O, S, or Cl to the magma from sources other than the least differentiated liquid. The increase of PH_2O by 700 bars during pre-eruption crystallization may be related to the fracture strength of the rock surrounding the magma body, and is consistent with the explosive eruption of Fuego in October 1974. (Author's abstract)

HARRIS, J.W. and GURNEY, J.J., 1979, Inclusions in diamond, *in* The properties of diamond, Field, J.E. (Editor): England, Academic Press, p. 555-591.

A detailed review of the extensive studies that have been made of visible and invisible inclusions in diamond, including presumed submicroscopic "melt" inclusions, gases, etc. (E.R.)

HATTORI, Keiko and SAKAI, Hitoshi, 1979, D/H ratios, origins, and evolution of the ore-forming fluids for the Neogene veins and Kuroko deposits of Japan: Econ. Geol., v. 74, p. 535-555. First author at Dept. Geol. and Geopy., Univ. Calgary, Calgary, Alb. T2N IN4 Canada.

The δD values of inclusion fluids from quartz and calcite of the Au-Ag vein deposits range from -48 to -72 per mil, showing a strong correlation with values of the local meteoric waters. The $^{18}O/^{16}O$ ratios of the ore fluids of quartz, the filling temperatures of the fluid inclusions, and the isotopic fractionation factor between quartz and water show only slight shifts from these values in meteoric water.

The δD values of ore fluids for the Cu-Pb-Zn vein deposits vary from -42 to -74, showing a wider scatter within a single orebody than for the Au-Ag vein deposits. A weak but definite correlation exists between the D/H ratios of local meteoric waters and ore fluids for late-stage ore minerals. The ore fluid for the Cu-Pb-Zn veins have a 2 to 9 per mil positive oxygen isotopic shift from the meteoric values. These results and calculations based on a new model of rock-water interaction indicate that ore fluids for the Au-Ag vein deposits and for the later stage mineralization of the Cu-Pb-Zn deposits evolved from local meteoric waters under low rock/water ratios. Conversely, the major stage of mineralization of the Cu-Pb-Zn vein deposits precipitated from meteoric hydrothermal solutions that could have evolved under high rock/water ratios; this stage has a much higher salinity than fluids of the later stage. The contribution of magmatic fluids could have ranged from 0 to 20 volume percent in the major stage.

The δD and $\delta\ ^{18}O$ values for the Kuroko ore solutions were -10 to -30 and -1.0 to +1.0, respectively, for deposits in the Hokuroku basins, northeast Honshu, and -30 to -50 and about -2, respectively, for the Iwami mine, southwest Honshu. These isotopic results, the salinity data, and the calculations on the effect of rock-water interactions indicate that the Kuroko ore solutions of the Hokuroku basins could have evolved from mixtures of sea water and meteoric water. A small amount of magmatic water may have been present. The close association of sulfates and Mg-chlorites in the Kuroko deposits is the direct result of the incorporation of sea water into submarine hydrothermal systems.

This study shows that, contrary to the prevailing thought, the vein mineralization occurred under terrestrial environments and, thus is younger (upper Miocene to Pliocene) than the Kuroko deposits. All the constituents of the vein ores were leached from the Tertiary country rocks by the meteoric hydrothermal circulation. Sulfur isotopic studies indicate that the sulfur came from Miocene sea-water sulfate trapped in the Tertiary sediments as dissolved sulfates in pore water or as anhydrite and gypsum. The lead isotope abundances, mineralogy, and chemistry of both the veins and the Kuroko deposits also are in accord with the present results. The close association of sulfates and Mg-chlorites in the Kuroko deposits is the direct result of the incorporation of sea water into submarine hydrothermal systems. (Authors' abstract.)

HATTORI, K., URABE, T. and MUEHLENBACHS, K., 1979, $\delta^{18}O$ and δD study of Kuroko ores (abst.): Eos, v. 60, p. 425-426.

$\delta^{18}O$ and δD analyses of 60 samples from the Uwamuki orebody, Kosaka, Japan, support the following model: (I) Sea water mixed with ascending ore fluid within the upper part of the "white rhyolite lava dome," causing mineralization. The lower part of the dome was altered by the ore fluid which was a mixture of magmatic and heated sea water. (II) Alteration of the "rhyolite dome" occurred at about 300°C. (III) The Tesusekiei (qtz-Fe oxide bed) which directly lies on the sulfide ores was formed later in time than the sulfide mineralization, and at much lower temperatures. (IV) The Anhydrite/Gypsum orebody was formed by sea water-rock reaction of high temperatures (140-270°C).

The model is based on the following data: (i) Variation in δD; δD varies from -35 to -47‰ in sericite from the sulfide ores but from -41 to 57% in altered "white rhyolite dome." Fairly fresh samples and the underlying Torigoe rhyolite formation was -60 to -63‰. (ii) O-18 partitioning between sericite and quartz (3.9‰) in silicified zones in the "rhyolite dome" indicate a temperature of 290°C and $\delta^{18}O$ fluid of +2‰. (iii) The surrounding rock is highly altered but uniform in $\delta^{18}O$, 8.0 ± 1.2‰. (iv) $\delta^{18}O$ of quartz from the sulfide ores range from +7.7 to 9.4‰. On the other hand, the Tetsusekiei zone which lies on the B.O. is composed of quartz enriched in O-18, 16‰-19‰ (Matsubaya). This difference in $\delta^{18}O$ indicates a time gap between sulfide mineralization oxide formation. (v) Mg-chlorite and sericite in Anhydrite/Gypsum are bodies from various localities have $\delta^{18}O$ of +0.6 to +4.5‰ and δD of -42 to -44‰ indicating that they formed from sea water of hydrothermal temperatures. (Authors' abstract)

HAYNES, F.M. and TITLEY S.R., 1979, The evolution of fracture-related permeability within the Ruby Star Granodiorite, Sierrita porphyry copper deposit, Pima County, Arizona (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 441.

Quantitative data from the margins of the Sierrita porphyry copper deposit were derived by direct measurement of fractures in the field and fluid temperatures in the laboratory. These data constrain interpretations of the nature and extent of fracture permeability at different stages of cooling of porphyry plutons which invade the Granodiorite host.

Breaking coeval with formation of the orebody extends into the Granodiorite some 4.5 km away from the porphyry center of the hydrothermal system. Integrated fracture densities decrease from values of 0.2 to 0.3 cm^{-1} near the system's center to a background value of 0.03 cm^{-1} or less outside the system. Four mineralogically distinct vein types with a persistent paragenetic relationship are present. Distribution of vein types in the Granodiorite indicates that the areal extent of fracturing associated with each type diminishes with time.

Vein-filling temperatures determined from fluid inclusions at two localities reveal a decrease in the temperature of vein quartz of each vein type as the system evolved. Sulfide-bearing quartz veins collected at sites 1.8 and 2.9 km from the system's center showed similar temperatures of formation; however, secondary inclusions representing later events at the 1.8 km site, were absent at the 2.9 km site suggesting that the late lower temperature event was less widespread. (Authors' abstract)

HAYNES, S.J., 1979, Carbonate-hosted lead-zinc occurrences in northeastern British Columbia with emphasis on the Robb Lake deposit: Discussion: Can. J. Earth Sci., v. 16, p. 1641-1642.

Discussion of Macqueen and Thompson, 1978 (see abstract this volume). (E.R.)

HAYNES, S.J. and MOSTAGHEL, M.A., 1979, Formation temperature of fluorite in the Lockport Dolomite in upper New York State as indicated by fluid inclusion studies-with a discussion of heat sources-a discussion: Econ. Geol., v. 74, p. 154-159.

This is a discussion of Kinsland (1977; see Fluid Inclusion Research--Proceedings of COFFI, v. 10, p. 126, 1977). The authors believe Kinsland's Th values are too high due to natural leakage and necking down, disagree with his criteria for PS inclusions, and suggest trapping occurred during blasting in the stone quarry from which the samples were taken. They also disagree with his estimate of depth of burial and geothermal gradient. (See Kinsland, 1979, this volume, for reply.) (ER)

HELOVUORI, O., 1979, Geology of the Pyhäsalmi ore deposit, Finland: Econ. Geol., v. 74, p. 1084-1101.

Fluid inclusions have Th 292-315°C. Tm of an isotropic (also stated as anisotropic, p. 1100) ~ 290°C, pyrrhotite dm did not dissolve even at 400°C. Tm ice -2.0 to -5.1°C, with "carbon compounds" suggested. (E.R.)

HELZ, R.T., 1979, Kilauea Iki Lava Lake: Results of coring the upper crust, 1967-1976,(abst): Hawaii Symposium on Intraplate Volcanism and Submarine Volcanism, Hilo, Hawaii, July 16-22, 1979, Internat. Assoc. Volc. and Chem. of Earth's Interior, p. 145.

The petrography and petrology of the core samples are discussed in terms of the probable mechanisms active in the lake crust. (ER)

HENLEY, R.W. and THORNLEY, P., 1979, Some geothermal aspects of polymetallic massive sulfide formation: Econ. Geol., v. 74, p. 1600-1612.

HIBBARD, M.J., 1979, Myrmekite as a marker between preaqueous and postaqueous phase saturation in granitic systems: Geol. Soc. Amer. Bull., Pt. 1, v. 90, p. 1047-1062. Author at Dept. Geol. Sci., Mackay School of Mines, Univ. of Nevada, Reno, Nevada 89557.

A nonreplacive, nonexsolution model of myrmekite growth is based on textural relationships in the Sand Springs porphyritic granodiorite, west-central Nevada. A sequence of crystallization is divided into (1) a preaqueous-phase saturation stage, characterized by major growth of plagioclase (zoned), quartz, and K-feldspar (phenocrysts), and (2) a postaqueous-phase saturation stage characterized by myrmekite, final euhedral growth of plagioclase and quartz, and final growth of K-feldspar phenocrysts and most K-feldspar of the matrix, including some crystals with adularia-habit characteristics. Myrmekite results from micropressure quenching during the separation of an aqueous phase as crystallization progresses. The occurrence of myrmekite as lobate units on plagioclase, extending into K-feldspar, results from precipitation of oligoclase (the basic ingredient of myrmekite) as local continuations of plagioclase growth from a melt that simultaneously expels an aqueous-rich fluid enriched in K-feldspar component. Late K-feldspar crystallizes from the aqueous-rich fluid, filling in around the myrmekite. Quartz in myrmekite represents the inability of silica to diffuse from the quenched melt and occurs as vermicules chiefly in accord with the principles of binary eutectic crystallization.

The Sand Springs myrmekite model is tested by evaluating its occurrences in aplite-pegmatite systems, in granitic gneisses, and in the hydrothermal secondary K-feldspar environment. Myrmekite commonly occurs in all but the hydrothermal environment, which is postmyrmekite, and a fundamentally magmatic origin can be reasoned for the other rock types if the tectonic environment during crystallization is also considered. (Author's abstract)

HIGGINS, N.C., 1979, Theory, methods, and application of fluid inclusion research: Geological Assoc. Canada, Newfoundland Section, Short Course Notes, November 17, 1979 (mimeographed, about 80 pp.). Author at Geol. Dept., Memorial Univ., St. Johns, Newfoundland A1B 3X5, Canada.

Consists of 42 pages of notes and about 40 pages of tables and figures to introduce students to various aspects of fluid inclusions. (ER)

HIKITA, H., ASAI, S., ISHIKAWA, H., SEKO, M. and KITAJIMA, H., 1979, Diffusivities of carbon dioxide in aqueous mixed electrolyte solutions: The Chem. Engrg. J., v. 17, p. 77-80.

HILBERT, Richard, 1979, PVT data on water and water solutions of sodium chloride to 873K, 4000 bar and 25 wt. % NaCl: Doctoral dissertation, Univ. Karlsruhe, 212 pp. (in German).

HING, T.T., 1979, The genesis of the King Island scheelite (Dolphin) deposit as determined from fluid inclusion and mineral chemical zoning studies: PhD dissertation, La Trobe Univ., 367 pp.

The scheelite-bearing deposits of King Island Dolphin Mine were formed through replacement of marble horizons by skarns. The replacement extends from the Grassy granodiorite contact 500 meters into the country rock. Fluids emanating from the granodiorite were $CaCl_2$- NaCl-KCl brines, having a maximum salinity of about 64 weight per cent. The early fluids boiled as a result of fracturing in the forming skarn horizon. With cessation of boiling, the salinities decreased progressively with time as well as with distance from the igneous contact, to a minimum of about 4 weight per cent NaCl equivalent.

The high $CaCl_2$ contents in the primary fluid inclusions, the greater dilution trends and the change in chemical compositions of skarn minerals in the 400 to 500 meter interval of the skarn horizon indicate that magmatic-derived fluids mixed with fault-derived fluids. The latter fluids were introduced into the skarn by way of the active Northern Boundary Fault. Over the entire skarn body, both the magmatic-derived and the mixed fluids evolved to more dilute NaCl brines during the later stages of skarn formation.

During the initial stages of skarn development, the depositional temperatures first increased to a maximum of about 780°C, then decreased systematically with time as well as with distance from the igneous contact to a minimum of about 170°C.

The boiling event initiated scheelite mineralization. Subsequent dilution and lowering of temperature resulted in a second generation of scheelite precipitation. The second mineralization event produced the major portion of the tungsten deposit. (Author's abstract).

Some vapor bubbles have no gases, others have CO_2. Daughter minerals reported include halite, sylvite, a $CaCl_2$ salt (hydrophyllite?) hematite, $CaSO_4$ (anhydrite or gypsum?), $FeSO_4$, $FeCl_2$, dawsonite, calcite, quartz, opaques, unknowns, wollastonite, magnetite, pyrite, and fluorides (?). Liquid H_2S (light brown) and liquid CO_2 reported. Clathrates melted at 13.7 to 14.0°C. Tm KCl 70-110°C, Tm NaCl 100-430°C. Some immiscible globules (p. 195) interpreted as CO_2. (ER)

HING, T.T. and KWAK, T.A.P., 1979, The measurement of the thermal history around the Grassy Granodiorite, King Island, Tasmania by use of fluid inclusion data: J. Geol., v. 87, p. 43-54. Authors at Dept. Geol., La Trobe Univ., Bundoora, Victoria 3083, Australia.

Measurements of Th of fluid inclusions relative to their location in colored and chemically zoned garnet crystals collected along a 500 m traverse from a granodiorite contact, King Island, Tasmania, Australia give a thermal history of the cooling pluton. Th vs. distance curves are essentially linear. The gradients are approximately 385°C at the contact to 305°C at 500 m from the inner core; 420°C to 305°C, outer core; 740°C to 425°C, inner midsection; 800°C to 470°C, central midsection; 680°C to 420°C, outer midsection; 540°C to 305°C, inner edge and 470°C to 305°C, outer edge. The thermal model suggested is that relatively small amounts of hotter saline aqueous solutions permeated large quantities of cooler contact rocks (at approximately 350°), already having a thermal gradient, caused the crystallization of andradite-core garnets. The solutions initially were not in thermal equilibrium with the contact rocks but ultimately the resultant temperature recorded in the inclusions did reach thermal equilibrium. As convective heat-loss from the pluton continued the isotherms moved out from the granodiorite during crystallization. Due to decarbonization reactions, overpressures exceeding the breaking strength of the overlying rocks were produced resulting in faulting with the aqueous fluid entering a 2 phase area (boiling) and garnet cores generally being fractured. With the waining of pluton-produced heat, lower temperature inclusions were trapped in the now unfractured grossular-rich garnet rims. These represent the return of the isotherms back to the pluton's contact. (Authors' abstract)

HOANG Shao, 1978, Thermobaric conditions of formation of rare-metal ore mineralization in the region Tam-Dao (NE Vietnam) (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 77 (in Russian). Author at Rostov State Univ., USSR.

Endogene mineralization in the Sn-W deposits Tam-Dao consists of four types: tin-bearing greisens, quartz-tourmaline with wolframite and cassiterite, quartz-wolframite-cassiterite and quartz-cassiterite-sulfide. The deposits are connected with early leucocratic apogranites of the complex Pia-Oak of Upper Cretaceous age and they occur in parent apogranites, older granites, volcanic and metamorphic rocks. Vein quartz of the rare-metal stage bear G/L, polyphase and $LH_2O + LCO_2$ inclusions. Th in quartz-tourmaline veins were 400-270°C, quartz-wolframite - 350-200°C (P 1100-600 atm), quartz-cassiterite-sulfide veins - 300-200°C ($P \leq 1000$ atm). (Author's abstract, transl. by A.K.)

HOEFS, Jochen and MORTEANI, Giulio, 1979, The carbon isotopic composition of fluid inclusions in Alpine fissure quartzes from the western Tauern Window (Tyrol, Austria): Neues Jahrb. Mineral. Mitt., 1979, no. 3, p. 123-134.

The carbon isotopic composition of fluid inclusions from 34 fissure quartz samples has been determined. The CO_2-contents, liberated through thermal decrepitation of the quartzes, are in many cases too low to be measured isotopically. In those cases where a mass-spectrometric determination was possible, the $\delta^{13}C$-values of the CO_2 varies between -1.5 and -7.0‰. The CO_2 may either be of a) juvenile origin, or may represent b) a mixture of decarbonatization-CO_2 and CO_2 from the decomposition of organic matter, or c) a mixture of a) and b).

The $\delta^{13}C$-values of total carbon vary between -10.7 and -30.1‰. The heavier values between -10 and -20, correlating with the highest CO_2-contents, have been found in the western and central part of the investigated area. The lower values between -20 and -30 correlate with low CO_2 and high water contents in the fluid inclusions. From mass-spectrometric spectra and isotopic data the presence of relatively large amounts of methane, especially in the latter group, have been deduced. It is concluded that the methane has been generated by the loss of volatiles from carbonaceous matter of the surrounding rocks with increasing metamorphic temperatures. The higher CO_2-contents correlate with higher metamorphic grades (amphibolite facies) whereas the region with lower CO_2-contents and higher hydrocarbon contents correlates with lower metamorphic grades (greenschist facies). (Authors' abstract)

HOLLAND, T.J.B., 1979, High water activities in the generation of high pressure kyanite eclogites of the Tauern Window, Austria: J. Geol., v. 97, p. 1-27. Author at Dept. Geol. Min., Parks Road, Oxford, England.

Quartz-kyanite eclogites in the Tauern Window of the Eastern Alps contain abundant hydrous phases and carbonates. Glaucophane-kyanite eclogites have been identified, and the relationships among the phases paragonite, glaucophane, zoisite, talc, magnesite and dolomite in association with garnet, omphacite, kyanite and quartz are discussed. Quartz-omphacite-kyanite veins, together with the observation of aqueous fluid inclusions ($XCO_2<0.1$, $X_{NaCl}\leq 0.02$) in omphacite and zoisite suggest crystallization under conditions of high water activity. Conditions of 620 ± 30°C, 19.5 ± 2.5 kb, $XCO_2=0.02 \pm 0.02$, are indicated by the coexistence of the assemblages paragonite + omphacite + kyanite and dolomite + omphacite + quartz. Two structural subareas within the Peripheral Schieferhulle of the Pennine domain have been identified in the Grossvenediger area; one subarea comprises metabasites which underwent eclogite facies conditions along with their enclosing metasediments. It was tectonically introduced into the rest of the Schieferhulle prior to the development of blueschist facies assemblages and the overthrusting of the Austroalpine nappes. The process of subduction is required to explain the depths (≈ 70 km) implied by the mineral assemblages developed. (Author's abstract)

HOLLISTER, L.S., 1979, Metamorphism and crustal displacements, Coast Ranges, British Columbia (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 445.

About 3 x $10^5 km^3$ of clastic sediment were eroded during the Eocene from the Central Gneiss Complex of the B.C. Coast Ranges between latitudes 52 and 55°N. Conditions of final mineral equilibration in granulite facies rocks from the Central Gneiss Complex have been established at 4.9 ± 0.5 kb, 775 ± 25°C, X_{H_2O} = 0.4-0.6. Whole rock and mineral dates by Armstrong and co-workers suggest cooling from about 775°C at 52 Ma to about 300°C by 47 Ma. An interpretation of preserved high pressure mineral relics is that the rocks were undergoing decompression when last equilibrated. Fluid inclusions in quartz have the characteristic shapes of autodecrepitation that occur when pressure inside the inclusion cavity significantly exceeds the confining pressure (over 850 bars at room temperature); densities of these inclusions show that they were entrapped at P-T conditions along a model thermal gradient of about 66°C/km. The combined data are consistent with an interpretation of about 20 km of uplift in the Eocene at an average rate of about 5 mm/yr, based on the thermal uplift model of Albarede.

Clastic sediments of appropriate age are virtually absent from either side of the Coast Ranges between the lines of latitude bounding the area of uplift. The only place in the Pacific Northwest where a large volume of early Tertiary sediment occurs is along the coast of Washington and Oregon. Whether or not these are the missing sediments, the identification of a source of sediment during a specific time interval provides important new data to be incorporated into tectonic reconstructions of the Pacific Northwest. (Author's abstract)

HOLLISTER, L.S., BURRUSS, R.C., HENRY, D.L. and HENDEL, E.M., 1979, Physical conditions during uplift of metamorphic terranes, as recorded by fluid inclusions: Bull. Minéral, v. 102, p. 555-561. Authors at Dept. Geol. Geophys. Sci., Princeton Univ., Princeton, New Jersey 08540, U.S.A.

The pressure and temperature conditions through which five metamorphic terranes may have passed during uplift have been estimated using the measured compositions and densities of fluids in fluid inclusions, the rupture strength of quartz, and the minimum temperature (~ 380°C) of CO_2-H_2O miscibility in natural solutions. The pressures and temperatures of final mineral equilibration are taken as starting points. For four localities, thermal gradients of approximately 27, 33, 54 and 660°C/km existed at some stage during uplift after the rocks had cooled below 380°C. The P-T path during uplift in four localities was convex towards the temperature axis. (Authors' abstract)

HONDA, Masahiko, OZIMA, M., NAKADA, Y. and ONAKA, T., 1979, Trapping of rare gases during the condensation of solids: Earth Planet. Sci. Lett., v. 43, p. 197-200. First author at Geophys. Inst., Univ. Tokyo, Bunkyoku, Tokyo 113, Japan.

Rare gas trapping during crystallization from vapor phases of (1) CdTe, (2) Zn, (3) Mg and (4) Fe_3O_4 has been studied. Samples were deposited as very find crystals (about several hundred angstroms) in ambient Ar atmospheres of various pressures. It was found that the amount of Ar trapped in the samples was proportional to the ambient Ar pressure. Stepheating degassing of the crystals showed that Ar was rather loosely trapped and released at relatively low temperatures. However, on a simple mechanical compaction of the crystal powder the retentivity of Ar was considerably enhanced. (Authors' abstract)

(Note - Of importance to cryoscopic separation techniques used in vacuum extraction of gases from inclusions. [E.R.])

HONMA, Hisahide, 1979, Chemical composition of Kuroko-type "ore-forming solution" inferred from partitioning between barite and water of hot springs: The Journal of the Japanese Association of Mineralogists, Petrologists and Economic Geologists, v. 74, p. 189-194 (in Japanese with English abstract).

HORIKOSHI, E. and SHIKAZONO, N., 1978, Sub-types and their characteristics of Kuroko-type deposits: Min. Geol. (Soc. Min. Geol. Jap.), v. 28, (4), no. 150, p. 267-276 (in English).

Indexed under fluid inclusions. (E.R.)

HORNER, C., 1979, Solubility and hydrolysis of $FeWO_4$ and $MnWO_4$ in the 25°-300°C range, and the zonation of wolframite: Chem. Geol., v. 27, p. 85-97.

HOWE, S.S., OHMOTO, Hiroshi and ROSE, A.W., 1979, Sulfur isotopes of lead-zinc occurrences in central Pennsylvania (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 16-17.

The parageneses and sulfur isotopes of lead-zinc mineralizations within a 5000 km^2 region in central Pennsylvania were examined in order to place constraints on the character and genesis of the mineralizing fluid. Sphalerite, galena, pyrite, and barite occur as fracture-, joint-, and breccia-fillings in lower Paleozoic carbonates shales, and sandstones. Pyrite is also disseminated in sandstones and sandy laminae of shales. Although the paragenesis is simple and grossly similar at each location, barite is more abundant to the northwest and tends to occur late in the sequence. The average sulfur isotopic compositions of the sulfides fall within a relatively narrow range of +21.7 ‰ to +25.5 ‰, with a trend of increasing $\delta^{34}S$ values from Woodbury and Birmingham in the northwest of Mapleton, 40 km to the southeast. Contours of isotopic values parallel the curvature of the fold axes of the Paleozoic strata.

One type of mineralizing fluid suggested by the data is that of a connate- or seawater-derived brine. The late Paleozoic Appalachian Orogeny likely mobilized this fluid with mineralization occurring either during or after deformation of the host rocks. The fluid may have flowed from northwest to southeast, possibly controlled by lineaments that lie perpendicular to the structural grain, such as the Tyrone-Mt. Union lineament. Changes in the chemistry and the sulfur isotopic composition of the fluid in time and space are responsible for the variation observed in the parageneses and isotopic compositions of the precipitated sulfides. (Authors' abstract)

HYMAN, D.M., 1979, Methodology for determining occluded gas contents in domal rock salt: United States Bur. Mines Report of Investigations 8700, 11 pp.

The Bureau of Mines has developed two experimental designs for determining the volumes and relative proportions of the various gas species, particularly methane (CH_4), occluded in rock salt. To date, the rock salt samples analyzed have been relatively small (400- to 1,000-gram) grab samples from Louisiana Gulf Coast domal salt mines. The results obtained are comparable to results in Polish domal salt mines, in terms of occluded gas volumes per mass of rock salt. The notable difference between the Louisiana and Polish occluded gas mixtures is in the relative proportions of the individual gas species.

The two methods used by the Bureau are ballmill crushing and dissolution. Of the two, the dissolution method appears to be more versatile because it can be performed in situ. The relevance and applicability of data on the occluded gas contents of rock salt are dependent on sample size, sample collection method, geologic context of the sample, and the correlation with gas emissions that occur as a result of mining-induced fractures and pressure differentials. (Author's abstract)

IIYAMA, J.T., 1979, Trace element distribution in rock-forming silicates. The alkali and alkaline earths, <u>in</u> Origin and distribution of the elements, Proc. of the Second Symposium, Paris, May 1977, L.H.Ahrens, ed.: Oxford, Pergamon Press, p. 161-174.

Trace element partition between silicates and hydrothermal solution is controlled by the thermodynamic properties of the silicate solid solution formed by the substitution of its major constituent M by a trace ion A. Experimental studies using feldspars, micas, leucite and nepheline are summarized in this paper.

The difference $\Delta r = r(M)-r(A)$ of the ionic radii of M and A compared to the dimension d of the sites for M in the silicate is the most determining factor for the variation of the function of distribution D(AR/MR) with the composition x of the solid solution.

(1) The substitution with a cation having small Δr realizes a random distribution of the A atom among the M sites in the silicate structure. The variation of D(AR/MR) with an increase in A in the mineral is caused by the enthalpy of mixing of the silicate solid solution.

(2) The presence of two non-equivalent sites for A in the silicate strongly modifies D(AR/MR) with an increase of A in the mineral.

(3) Substitution with 1 rl/d greater than 0.07 causes a local lattice deformation around the sites substitute d by A. This local deformation rapidly changes the D(AR/MR).

Variation of the partition relation in cases (2) and (3) is caused principally by the non-ideal entropy of mixing.

(4) In some cases, especially with micas, the initial pattern of trace element distribution with local lattice deformation is degenerated by further substitution of M by A.

(5) For a given mineral species, a smaller Δr gives a stronger tendency to concentrate A into the silicate.

(6) The difference in ionic charge of M and A (M^+ and A^{++}) amplifies the relation stated in (5).

(7) Slight variation in the constitution of the silicate radical can strongly modify the partition relation. This fact should be taken into consideration when the trace element partitioning of complex silicates such as biotite is discussed. (Author's abstract)

IKORSKIY, S.V., 1978, Qualitative determination of waters during thermo-vacuum decrepitometry of inclusions in minerals, in Theory and Practice in Thermobarogeochemistry, N.P. Ermakov, ed., Izd. Nauka, p. 249-252; (in Russian).

IMAI, H., 1978, Osarizawa Mine, Akita Prefecture; Geological studies of the mineral deposits in Japan and East Asia, H. Imai, ed., Univ. of Tokyo Press, p. 58-59 (in English).
Indexed under fluid inclusions. (E.R.)

IMAI, H., KIM, M.Y., FUJIKI, Y. and TAKENOUCHI, S., 1978, Geologic structure and fluid inclusion study at the Ohtani and Kaneuhi mines, Kyoto Prefecture; Geological studies of the mineral deposits in Japan and East Asia, H. Imai, ed., Univ. of Tokyo Press, p. 27-40 (in English).

IMAI, H., TAKENOUCHI, S. and KIHARA, T., 1978, Geologic structure and fluid inclusion studies at the Taishu Mine, Nagasaki Prefecture; Geological studies of the mineral deposits in Japan and East Asia, H. Imai, ed., Univ. of Tokyo Press, p. 43-53 (in English).

IMAI, H., TAKENOUCHI, S, SHOJI, T. and NAGANO, K., 1978, Porphyry copper deposits in the Southeast Asia, with special reference to fluid inclusion study, in Geological studies of the mineral deposits in Japan and East Asia, H. Imai, ed., Univ. of Tokyo Press, p. 265-280 (in English).

ISHAN-SHO, G.A., 1979, Location of quartz in mineral formation in mercury-antimony deposits in central Tadzhikistan (according to thermobarogeochemical data): Mineral. Tadzh., v. 4, p. 13-21 (in Russian).

Quartz is widespread in the Hg-Sb deposit and occurs in all stages of the hydrothermal process, in three forms: Q1, Q2, and Q3. The fluids from inclusions in Q1, Q2, and Q3, resp., 1) temps. of formation 310-60, 230-310, and 190-210°; 2) pressures of formation 650-800, 650-60, and 600-40 kilobars (sic); 3) residual solns. with Ca^{2+} as the predominant cation and HCO_3, CO_3^{2-}, Cl, and rarely F; and 4) small amts. of atm. O_2 and ^{40}Ar were included at the time of mineral formation. During ore genesis, hydrothermal solns. initially alk. and contg. oxysilicate complexes were periodically introduced into the country rocks. Reaction with free O_2 at the soln. front lead to neutralization of the alk. soln. and development acid solns. in which SiO_2 pptd. (C.A. 93:76015z)

IVANOV, O.P. EFREMENKO, L.Ya., BOYKOV, I.S. and EFREMENKO, E.A., 1979, Peculiarities of the spatial orientation of vectors of the intra-vein zonality of the Iul'tin deposit (problem of ore magmas): Akad. Nauk SSSR Doklady, v. 244, no. 2, p. 446-449 (in Russian; translated in Dokl. Acad. Sci. USSR, v. 244, p. 135-137, 1981). First author at the Central Sci.-Research Inst. of the Tin Industry (location not given).

Cassiterite-wolframite-quartz veins (0.5-2 m thick) of the Iul'tin deposit occur in hornfelsed sandy and clayey rocks above a hidden granite cupola. Near the contact with granite, the veins change into veinlet-disseminated ore. The veins might have formed either from dilute hydrothermal solutions or from viscous ore-forming fluid. Td of cassiterite equal 270-265°C in central parts of veins and 265-250°C in their marginal parts; weight loss of cassiterite on decrepitation ranges from 0.16 to 0.24 wt.%. T decrease to the top of veins and to their margins (from the center) is interpreted as the evidence of the vein origin from dense viscous ore-forming fluid that one time filled a fracture. (Abst. by A.K.)

IVANOV, D.N. and KHARLAMOV, B.P., 1979, On the characteristics of pre-crystallization liquation in some granites: Dokl. Akad. Nauk SSSR, v. 248, p. 1406-1409 (in Russian; translated in Dokl. Acad. Sci. USSR, v. 248, p. 112-114, 1981).

IVANOVA, A.A. and MOSKALYUK, A.A., 1979, Fluorite formation parameters: Osnovn. Parametry Prir. Protsessov Endog. Rudoobraz., (Dokl., Vses. Soveshch.), Kuznetsov, V.A. (Ed), v. 2, p. 236-241 (in Russian).
Indexed under fluid inclusions. (E.R.)

JACKSON, N.J., 1978, The Halvosso pegmatites: Ussher Soc., Proc. 4, Part 2, p. 190-191.
Indexed under fluid inclusions. (E.R.)

JAKOVLEV, B.G., MATJASH, I.V., LITOVCHENKO, A.S. and PROSHKO, V.J., 1978, On water inclusions in alkali feldspar solid solutions and peculiarities of their crystallization in charnokites and pegmatites of the Ukrainian Shield: Dopov. Akad. Nauk Ukr. RSR Ser. B (Kiev), v. 8, p. 705-709 (in Russian).

JANARDHAN, A.S., NEWTON, R.C. and SMITH, J.V., 1979, Ancient crustal metamorphism at low pH_2O: charnockite formation at Kabbaldurga, south India: Nature, v. 278, p. 511-514. First author at Dept. Geol., Mysore Univ., India.

Arrested charnockitic conversion of amphibolitic gneiss at Kabbaldurga, Karnataka State, south India, was studied mineralogically. Iron-rich pyroxenes were generated from amphibole in patches and stringers without melting. The dark color of charnockite arises from numerous tiny veins of chlorite and manganese-bearing calcite, particularly in feldspars. The metamorphism was effected by very local, mainly grain-boundary, migration of volatiles low in H_2O, and probably dominantly CO_2. This was followed by vein alteration at lower temperatures from volatiles richer in H_2O. The volatiles are ascribed to massive libration from the mantle in upwelling areas, and this may have been an important process in the evolution of the deep continental crust. (Authors' abstract)

JANECKY, D.R., 1979, Experimental seawater-peridotite interaction at 300°C, 500 bars: Implications for metallogenesis at oceanic fracture zones (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 450.

JANSSEN-VAN ROSMALEN, R., VAN der LINDEN, W.H., DOBBINGA, E. and VISSER, D., 1978, The influence of the hydrodynamic environment on the growth and the formation of liquid inclusions in large potassium dihydrogen phosphate (KDP) crystals: Krist. Tech., v. 13(1), p. 17-28.

JEFFERIS, Robert and VOIGHT, Barry, 1979, Fracture analysis near the mid-Atlantic plate boundary, southwest Iceland (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 451.

The geometry and thermal history of fractures at 62 stations have been studied from Reykjavik to Hvalfjordur in southwestern Iceland, on the flank of the Icelandic extension of the mid-Atlantic Ridge. Two major generalized fracture orientations are present. A northeast system trends 010-030°, except on Akranes where the orientation is 040-060°, and one or more sets are contained in a roughly defined east-west system with strikes between 070-130°. Thermal history, determined from secondary minerals in vugs and fractures and fluid inclusion filling temperatures, indicates that the northeast fractures opened when the area was buried within the hot axial rift zone. A geothermal gradient of 80 ± 15°C/km, linear to 3 km, is estimated for the Tertiary axial rift zone, based on regional secondary alteration. Temperatures of 150-300°C at 1 km occurred locally, near central volcanoes. Some east-west trending fractures also opened at this time but many formed later, after the area had begun to spread and cool beyond the active zone. The northeast fracture system, with trends essentially parallel to dikes and normal faults in southwest Iceland, are interpreted as extension fractures (about 0.4% maximum extension) forming generally from the same stress field associated with normal faulting and dike injection in the active zone. Fracturing in an east-west direction (estimated 0.1% maximum extension) indicates a reorientation of the causative stress field. The east-west fractures can account for a significant portion of the predicted thermoelastic contraction parallel to the axial rift zone, arising from cooling of the spreading lithospheric plate. (Authors' abstract).

JOHNSON, P.B. and MAZEY, D.J., 1978, Helium gas bubble lattices in face-centered-cubic metals: Nature, v. 276, p. 595-596.

KALINKO, M.K. and LEVSHUNOVA, S.P., 1978, Diagnostic potential of adsorbed hydrocarbon gases for identifying oil-gas sources: Int. Geol. Rev., v. 20, no. 2, p. 247-248 (in English).

Indexed under fluid inclusions. (E.R.)

KALYUZHNYI, V.A., 1978, Approximate VTX-diagram of the H_2O-NaCl system and its significance for investigation of fluid inclusions in minerals: Dokl. Akad. Nauk Ukr. SSR, Ser. B, no. 4, p. 302-306 (in Russian).

A new diagram of the system H_2O-NaCl is suggested, derived from the literature. A previously unknown maximum in the curve of specific volumes was determined. Typical properties of the diagram and its sections at constant specific volumes and concentrations determined the regularities of phase transitions in fluid inclusions during homogenization by heating. (Author's abstract)

KALYUZHNYI, V.A. and SVOREN', I.M., 1978, Rational method of release and analysis of gas components of inclusions during mechanical destruction of minerals, (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 1, Thermobarogeochemistry in geology: Vladivostok, Acad. Sci. USSR, p. 175-176, (in Russian). Authors at Inst. Geol. Geochem. of Mineral Fuels of Acad. Sci. of Ukrainian SSR, L'vov, USSR.

The main complications during the mechanical destruction of minerals are: a) gas release from the surface of the grinding vessel, b) opening of the micropores in minerals, c) influence of water vapor, d) chemical reactions under mechanical action, e) selective gas adsorption on the surface of ground mineral; the first three factors are most important. For mass-spectrometric determinations of G two methods were used: grinding of mineral in an electromagnetically operated stainless steel mortar, and opening of individual inclusions. To minimize the gas contamination from steel, the working surfaces were covered with a polished, very hard alloy. Water was absorbed by phosphorus pentoxide. Experiments showed that all metals release gas (essentially #2) during deformation under high vacuum conditions; the longer the time of grinding, the higher the H_2 content in analysis. By opening of individual inclusions H_2 was not found in many minerals. (From the authors' abst.)

KALYUZHNYY, V.A. and SVOREN', I.M., 1979, The fundamentals of efficient use of methods for analyzing the gaseous components in fluid inclusions; the problem of hydrogen determination: Mineral. Sb. (L'vov. Gos. Univ.), v. 33, no. 1, p. 35-41 (in Russian).

See previous item. (E.R.)

KAMILLI, R.J., OHMOTO, H., PETERSEN, U. and DIAZ, N., 1979, Geochemistry of the Finlandia Vein, and origin of bonanza-type silver and gold deposits: Annals of the Fourth Peruvian geological congress, Valdivia Ampuero, H. *et al.*, eds., Soc. Geol. Peru. Bol., v. 60, p. 73-100 (in Spanish).

Indexed under fluid inclusions. (E.R.)

KANEOKA, Ichiro and TAKAOKA, Nobuo, 1979, Rare gas studies in ultramafic nodules and phenocrysts in basaltic lava flows from Hawaiian Islands relevant to the characterization of their magma sources (abst.): Hawaii Symposium on Intraplate Volcanism and Submarine Volcanism, Hilo, Hawaii, July 16-22, 1979, Internat. Assoc. Volc. and Chem. of Earth's Interior, p. 166.

Rare gas isotopes were studied for ultramafic nodules and phenocrysts in basaltic lava flows from Hawaii, Maui and Oahu Islands in order to characterize the magma sources for these samples in the light of rare gas isotopes.

Hualalai dunites included in basalts erupted in 1801 in the Hawaii Island and ultramafic nodules from Salt Lake Crater in the Oahu Island show similar He-3/He-4 ratios to those found in pillow basalts erupted at the ridge (He-3/He-4=1.4x10^{-5}). Whereas, olivine phenocryst in the Kapoho lava in the Hawaii Island and augite phenocrysts in a lava flow in the Maui Island show higher He-3/He-4 ratios than those found in ultramafic nodules by a factor of about two. It is interesting to note that such a high He-3/He-4 ratio has also been observed in fumarolic gases from Kilauea (Craig and Lupton, 1976). Thus, the high He-3/He-4 ratio observed in phenocrysts of lava flows from Hawaii and Maui Islands may characterize the magma source of lava flows in the Hawaiian Islands. Such high He-3/He-4 ratios are observed in a particular region such as Iceland and Yellowstone where the existence of a hot spot has been suggested. Present results on He-3/He-4 ratio of phenocrysts in lava flows are not incompatible with this trend and indicate a different character of the magma source from the one that produced the lithosphere under the Hawaiian Islands.

Such a difference is also observed in the Ar-40/Ar-36 ratio between ultramafic nodules and phenocrysts in lava flows, though the difference is less clear than that observed in the He-3/He-4 ratio. Ar-40/Ar-36 ratios in ultramafic nodules are higher than 1000, whereas those in phenocrysts seem to be less than 1000.

In these samples, excess Xe-129 is also observed compared to the atmospheric Xe. However, no definite evidence has been observed for the occurrence of excess Xe-129 in ridge basalts, which may suggest the heterogeneity for the occurrence of excess Xe-129 in the interior of the earth.

Thus, we can characterize the magma source of lava flows in the Hawaiian Islands which seems to be different from that of the ridge region in the light of rare gas isotopes. (Authors' abstract)

KARAYEVA, Z.G., VORONINA, L.B., GAYDUKOVA, V.S. and KHARLAMOV, Ye.S., 1978, Near-surface greisen deposits of tin: Sov. Geol., v. 3, p. 81-92 (in Russian).

Indexed under fluid inclusions. (E.R.)

KARSKIY, B.Ye. and FORTUNATOV, S.P., 1978, The decrepitation method for the exploration of mica-bearing pegmatites; Thermobarogeokhimiya Zemnoy Kory I Rudoobrazovaniye, N.P. Ermakov, ed.: Moscow, Izd. Nauka, p. 228-233 (in Russian).

Indexed under fluid inclusions, geothermometry, geobarometry. (E.R.)

KARWOWSKI, Lukasz, KOZLOWSKI, Andrzej, and ROEDDER, Edwin, 1979, Gas-liquid inclusions in minerals of zinc and lead ores from the Silesia - Cracow region, in, Research on the Genesis of Zinc-Lead Deposits of Upper Silesia, Poland, v. 95, p. 87-96 (in English, with Polish summary).

This paper presents the result of studies of the temperature of homogenization of gas-liquid inclusions in sphalerite, and the chemical composition of the mineral-forming solutions, based on analyses of inclusions in sphalerite, galena, calcite, marcasite and barite from the Silesia - Cracow region. The most probable temperature interval of crystallization of the Zn-Pb ores was 95-140°C. No distinct temperature differences or trends were found, either between deposits and mineral associations or between adjacent lamellae in one mineral sequence. The major ions in the solutions in the inclusions are Cl^-, Na^+, K^+, and Ca^{2+}. (Authors' abstract)

KASHKAY, M.A., AZADALIYEV, D.A., SAMEDOV, M.M. and KURBANOV, N.A., 1978, Temperature of formation of metasomatic rocks of the Ordubadsk region, in Metasomatism in Ore Formation, D.S. Korzhinskiy, ed., Izd. Nauka, p. 96-97 (in Russian).

Indexed under fluid inclusions. (E.R.)

KELLY, W.C., NESBITT, B.E., METZGER, F.W. and ESSENE, E.J., 1978, Scanning electron microscopy of ancient geological fluids and their crystallization products: Proc., Annu. Conf. - Microbeam Anal. Soc., v. 13, Paper No. 94, 3 pp.

KELLY, W.C. and RYE, R.O., 1979, Geologic, fluid inclusion, and stable iosotope studies of the tin-tungsten deposits of Panasqueira, Portugal: Econ. Geol, v. 74, p. 1721-1822. First author at Dept. Geol. Sci., Univ. Mich., Ann Arbor, MI.

The tin-tungsten deposits of Panasqueira, Portugal, are the leading source of tungsten in western Europe and are geologically important as a major example of hydrothermal tin-tungsten mineralization of plutonic association and Hercynian age. Integrated field, mineralogic, fluid inclusion, stable isotope, and other studies were undertaken to illuminate the character and origin of the ores.

The deposits consist of a large number of near horizontal, ferberite-bearing quartz veins which cut sharply across the steep bedding and foliation of their Beira Schist host rocks. The vein openings were created by purely vertical dilation of the flattest sets of available, preore joints; development of the jointing postdated regional metamorphism, overlapped introduction of granite, and terminated prior to mineralization. The jointing is thought to have been caused by erosional unloading and concomitant release of residual, post-tectonic stress in the schists. It is proposed that the unusual flat vein openings were created, and subsequently supported, by hydraulic pressures of the early tin-tungsten vein fluids. Fluid inclusion data indicate that the vein fluid pressures were at times adequate to lift the existing rock load. Economic veinage occurs in a laterally extensive but vertically restricted zone, 100 to 300 m thick. The geometry of this zone is interpreted as being due to hydraulic dilation over a limited depth range in which fluid pressures exceeded lithostatic values.

The tin-tungsten veins are spatially associated with one or more greisenized granite cupolas that probably represent high points on an underlying batholith. Isotope studies suggest that the granite is of the S-type associated with tin-tungsten mineralization elsewhere. Although both are of late Hercynian age, the tin-tungsten veins are distinctly younger than the Panasqueira Granite. The veins were mineralized at temperatures of 360°C or less. Several features - such as the increasing tin content of the veins and the increasing abundance of CO_2-rich fluid inclusions in vien quartz as one approaches the known or suspected granite cupolas - suggest that these intrusives served as structural conduits for the introduction of vein fluids. An unusual, lensoid cap of quartz, resembling a stockscheider, occurs at the apex of the one known cupola, separating it from the overlying schists. All lines of evidence indicate that this silica cap is a hydrothermal filling of an open chamber formed by slight contraction or withdrawal of the granitic melt, accompanied by block caving of the overlying schist. Subsequent to granite crystallization, the cap opening was filled by vein matter of subeconomic grade.

The vein paragenesis is complicated by repeated deposition of some minerals like quartz, muscovite, and tourmaline, but four distinct depositional stages can be recognized at most points in the vein system: (1) oxide-silicate stage, (2) main sulfide stage, (3) pyrrhotite alteration stage, and (4) late carbonate stage. The precise manner in which these stages or facies spread in time and space through the large vein system is not firmly established.

Fluid inclusion data indicate that the tin-tungsten vein fluids were NaCl-dominated brines that were well below their critical temperatures throughout the mineralization. During the oxide-silicate, main sulfide, and pyrrhotite alteration stages, fluid temperatures were in the range of

230° to 360°C salinities in the range of 5 to 10 equivalent weight percent NaCl, and fluid densities in the range of 0.74 to 0.93 g/cc. During the closing late carbonate stage, temperatures decreased to 120°C or lower and salinities to values below 5 percent, while fluid densities increased to values around 1.00 g/cc. Carbon dioxide contents of the vein liquids declined through the depositional sequence; early fluids of the oxide-silicate stage were saturated and at time effervesced CO_2, but such "boiling" did not continue into the later stages. Values as high as 9 mole percent CO_2 were attained during early filling of the silica cap over the cupola and at rare times during vein quartz deposition, but throughout most of the vein filling the CO_2 contents in the liquids were below 2 mole percent. Fluid pressures followed a comparable path, reaching values close to 1 kb when CO_2 contents were high but remaining below about 100 bars during most of the vein mineralization. These low pressures indicate shallow depths of formation of the tin-tungsten veins-depths on the order of 600 to 1,300 m below the ground-water table existing during mineralization.

Various oxygen and sulfur isotope thermometers were tested on the vein assemblages, but they generally gave inconsistent or unreasonable results. The FeS contents of typical Panasqueira sphalerites require their deposition below 300°C. Such low temperatures, supported by the fluid inclusion data, raise questions as to the origin of pyrrhotite, chalcopyrite, and stannite apparently exsolved from these sphalerites.

The ^{18}O contents of fluids of the late carbonate stage require predominance of meteoric water in the veins at that time, but the record is ambiguous for the earlier stages. The $\delta^{18}O_{H_2O}$ values for the earlier fluids indicate extensive exchange with the schist and/or granite host rocks and are nonspecific as to the original water sources(s). The high degree of oxygen isotope equilibration, coupled with a lack of correlation between fluid inclusion salinities and temperatures, suggests that any fluid mixing at this time took place outside of the observed vein system - probably at depth.

The warm meteoric waters of the late carbonate stage derived both their carbon and sulfur from a shallow, heterogeneous source, probably the Beira Schist. The $\delta^{34}S$ values for sulfides of this stage range widely from -13.2 to 12.2 per mil. The $\delta^{13}C$ values range from -9.3 to -12.9 for dolomites and from -13.2 to -14.2 for calcites. These low values imply a graphitic or organic component for the hydrothermal carbon. The δD values of these late waters, known to be meteoric from the ^{18}O contents, fall in a range of -43 to -55 per mil which, combined with paleomagnetic evidence of an equatorial setting, suggests only moderate topographic elevations in the meteoric recharge area.

The isotopic data present a different picture for earlier fluids in the tin-tungsten veins. Throughout the oxide-silicate, main sulfide, and pyrrhotite alteration stages, the $\delta^{34}S$ values of all sulfides remained in a narrow range of -0.1 to -0.9 per mil, indicating an H_2S-dominated hydrothermal solution and suggesting a deep-seated, possibly magmatic source of the sulfur. Siderites formed during the pyrrhotite alteration stage yield negative $\delta^{13}C$ values in the range of -10.9 to -13. per mil, again suggesting carbon derivation from, or at least equilibration with, an organic or graphitic source, probably the Beira Schist complex. This carbon signature could have been acquired at depth and in association with anatexis of the pelitic schists. The $\delta^{18}O_{H_2O}$ values of the earlier vein waters were fairly uniform and in the range 6 ± 2 per mil which is compatible with either a predominantly magmatic water or a highly exchanged meteoric water or some mixture of the two. The hydrogen isotope chemistry has not resolved this question but instead introduces additional complications unique among ore deposits studied in this manner to date. Apparently, two waters were present in the oxide-silicate stage, one with δD values of from -67 to -124 per mil and the other of from -41 to -63 per mil. In later stage of the mineralization, the lighter water progressively diminished in amount. Each of the two early waters apparently deposited different minerals, but texturally the different minerals appear penecontemporaneous. Various explanations of the data are attempted, but none fully solve the enigma. (From the authors' abstract.)

KENAH, C., 1978, Generation of the Quottoon Pluton (British Columbia) by crustal anatexis (abst.): Geol. Soc. Am., Abstr. Programs, v. 10, n. 7, p. 433.

Indexed under fluid inclusions. (E.R.)

KERRICH, R., BECKINSALE, R.D. and SHACKLETON, N.J., 1978, The physical and hydrothermal regime of tectonic vein systems: evidence from stable isotope and fluid inclusion studies: N. Jb. Miner. Abh., v. 131, p. 225-239. First author at U. West. Ontario, London, Ont.

The origin of mineralization in tectonic vein systems and pressure shadows is investigated using oxygen isotope analysis to evaluate equilibrium between the rock matrix and secondary minerals. The $\delta^{18}O$ of vein quartz is controlled by that of detrital quartz in the country rock. It is concluded that vein systems in rocks deformed under conditions of low grade metamorphism form principally by local diffusional mass transport. The abundance of veining under these conditions coincides with the low-temperature deformation regime dominated by pressure solution processes, and it is not necessary to appeal to hydrothermal transport in solution. However, coexisting minerals in country rock and veins display isotopic disequilibrium. Pore fluids probably did not attain equilibrium exchange with detrital quartz.

Examination of primary fluid inclusions in vein quartz reveals that the fluids are high density, subcritical aqueous chloride solutions with a small component of CO_2. The $\delta^{18}O$ values of fluids calculated to be in equilibrium with vein quartz fall between 4 ‰ and 10 ‰, consistent with the accepted range of isotopic compositions of fluids implicated in diagenesis and metamorphism. From several lines of evidence it is suggested that the water/rock ratio during deformation and veining is low. (Authors' abstract)

KERRICH, R. and FRYER, B.J., 1979, Archaean precious-metal hydrothermal systems, Dome Mine, Abitibi Greenstone Belt. II. REE and oxygen isotope relations: Can. J. Earth Sci., v. 16, p. 440-458. First author at Dept. Geol., U. of Western Ontario, London, Ont., Canada, N6A5B7.

The Porcupine District, Abitibi Greenstone Belt, is one of the most extensive areas of Archaean auriferous mineralization. At least two stages of lode-gold emplacement are recognized: the first stage involves gold-bearing carbonate-chert chemical sediments within the lower mafic volcanic sequence; the second stage is represented by auriferous hydrothermal quartz veins which postdate deformation of the greenstone assemblage and transect diverse host rocks.

Rare-earth element (REE) concentrations in the stratiform carbonates are typical of the distinctive patterns recorded for Archaean chemical sediments. Chert in these rocks has a $\delta^{18}O$ value averaging 17.1‰, implying exchange from heavier 18/16 ratios during diagenesis and metamorphism. Metabasic volcanic rocks and quartz-feldspar porphyry stocks with background gold abundances have mean whole-rock $\delta^{18}O$ values of 9.1‰ and 10.7‰ respectively. Ths enrichment in ^{18}O relative to primary igneous rocks is attributed to oxygen isotope exchange with seawater at low temperatures during fluid transport through the oceanic crust.

Quartz in all of the five hydrothermal vein systems present has a $\delta^{18}O$ of 14‰ to 15‰, and quartz-muscovite fractionations are 3.4‰ to 3.8‰. Ambient temperatures of mineralization are estimated to have been 400°C to 450°C, from oxygen isotope thermometers, fluid inclusion filling temperatures, and metamorphic mineral assemblages. The calculated $\delta^{18}O$ of the mineralizing solutions is ~ 10‰, implying fluids of metamorphic origin. REE patterns in hydrothermal quartz veins suggest that they have been derived from high-temperature solutions in equilibrium with source rocks having relatively flat (chondrite normalized) REE distributions, such as tholeiitic and komatiitic volcanics. Adjacent to hydrothermal veins, quartz in igneous rocks approaches isotopic equilibrium with vein quartz, at 15‰, and whole-rock $\delta^{18}O$ values for metabasalts shift to ~ 11% , implying extensive water-rock interaction. Strong depletions in heavy REE of metabasic schists adjacent to veins provides further evidence for pervasive hydrothermal alteration. The Eu enrichment of all lode gold deposits analyzed at Dome Mine is consistent with the reduced state of the solutions involved in their deposition, as recorded by the predominance of Fe^{2+}. The gold-bearing veins are believed to have formed by focussed flow of fluids outgassed at the greenschist-amphibolite transition. Source volumes for Au in the Porcupine District exceed 600 km^3, the carrier fluid volume for mineralization was 60-90 km^3, the Au solute concentration in the low nanogram mL^{-1} range, and transport distances were of the order of 10 km. Such veins may be the precursors of precious-metal-bearing chemical sediments if fluids debouche into the hydrosphere. (Authors abstract)

KERRICK, D.M. and JACOBS, G.K., 1979, Analysis of Modified Redlich-Kwong equations for H_2O, CO_2, and H_2O-CO_2 mixtures at elevated pressures and temperatures, (abst): EOS, v. 89, p. 406.

KHARAK, Y.K., CALLENDER, E. and CHEMERYS, J.C., 1979, Heavy metals in migrating oil-field waters from the northern Gulf of Mexico basin (abst.): Program, 108th AIME Annual Meeting, New Orleans, Feb. 18-22, 1979, p. 18.

This study reports the concentrations of heavy metals in 54 formation-water samples having salinities of up to 75,000 mg/L dissolved solids. The samples, which were collected from ten oil and gas fields in the Houston-Galveston and Corpus Christi areas in Texas, are from geopressured and normally pressured zones in the Frio Clay of Oligocene (?) age. Hydraulic-fluid potentials and δD and $\delta^{18}O$ values indicate that the waters are of modified connate type squeezed from underlying shales and siltstones. Concentrations of Cu, Pb, Hg, Cd, Zn, Mn, and Fe range from 0 to 6, 8, 8, 150, 190, 3000, 140,000 µg/L, respectively. Computations show that solubilities of sulfide minerals are the main controls on these concentrations. (Authors' abstract)

KHARLAMOV, Ye.S., 1978, Diagnostic properties of carbon dioxide and hydrocarbons in inclusions of mineral-forming solutions (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978 v. 1, Thermobarogeochemistry in geology: Vladivostok, Acad. Sci. USSR, p. 179-181 (in Russian). Author at All-Union Inst. of Mineral Raw Materials, Moscow.

Liquid CO_2 freezes completely, forming the system CO_2 crystal hydrates-gas with other components in equilibrium only below CO_2 triple point -56.6°C. Crystal hydrates recrystallize into colorless weakly birefringent monocrystals of pseudo-octahedral habit. Below -56.6°C crystal hydrates are plastic, above -56.6°C. they rapidly sublimate with formation of L CO_2.

Liquid non-fluorescent hydrocarbons are colorless or of smoky-pink color. They do not freeze completely.

Mixtures of $CO_2 + CH_4$ are weakly transparent and dark-gray; they freeze into a viscous opaque mass which then becomes transparent without visible solid phases at -62° to -74°C. (From the author's abst.)

KHETCHIKOV, L.N., 1979, Composition of gases in inclusions in quartz crystals from vugs in hydrothermal quartz veins of various areas of the USSR: Tr. Tsentr. N.-i, Geol.-razved, In-t Tsvet, i Blagorod. Met., 1979, (142), p. 71-77 (in Russian). From Ref. Zh., Geol. 1980, Abstr. No. 5V181. (C.A. 93:117369p)

KHETCHIKOV, L.N., DOROGOVIN, B.A., SANDOMIRSKAYA, S.M. and POLYANSKIY, Ye.V, 1979, Inclusions of mineral-forming media in minerals synthetised from melts: Akad. Nauk SSSR Doklady, v. 245, no. 3, p. 706-708 (in Russian; translated in Dokl. Acad. Sci. USSR, v. 245, p. 185-187, 1981). First author at Central Sci.-Research Geol.-Prospecting Inst. of Color and Precious Metals, Moscow.

Crystals of $Bi_4(GeO_4)_3$, $Bi_{12}GeO_{20}$, garnet $(Y,Er)_3Al_5O_{12}$ and $K_3Nd(MoO_4)_4$, grown from stoichiometric melts, bear inclusions filled by G (10-15%) and brown or transparent silicate (sic.) melt; Th is almost the same as T of crystallization. $Bi_{12}GeO_{20}$ and garnet bear only inclusions of the same composition as host crystals, but $Bi_4(GeO_4)_3$ trapped inclusions of two types: with composition exactly similar to host crystal and rich in Bi but poor in Ge. Such different inclusions have the same Th. In $K_3Nd(MoO_4)_4$ xls inclusion composition always differs from crystal: inclusions (30-33%) are richer in K than xl (22-23%), but poorer in Nd (3-5% vs 16-17%). All Th are the same as T of xl origin.

Gahnite was grown from melt with MoO_3 added, at T 1450-1250°C; inclusions were filled by brown glass and G bubble (Th 1250-1300°C); glass was of two compositions: identical with crystal composition, and consisting essentially of Mo plus Zn and Al admixture. Next runs yielded gahnite crystals with inclusions: 1) G + brown glass, Th 1200-1300°C; 2) G + brown glass + cubic crystals up to 10% by vol., Th 1420°C; 3) G + cubic crystals $>$90 vol.% + brown glass, beginning of melting at T$>$1500°C. First type has similar composition as described above, the second type bears crystals of Al_2O_3 with Zn admixture and the third one consist of 98-99% of Al_2O_3.

Gd-Ga garnet was grown from stoichiometric components plus lead oxide, crystallization T = 1300-900°C; it bears only G + glass inclusions with Th 1150-1160°C and rare Th 800-850°C. The first type is filled by glass of the host crystal composition, but th second type consists essentially of Pb plus small Ga admixture. Y-Al-Ga garnet was grown during T drop from 1300 to 900°C in melt of stoichiometric composition plus 10% Y excess, and lead and boron compounds. Crystal composition was Y 33%, Ga 38-40%, Al 0.9-1.5%, Cr 0.06-0.1%. Inclusions in this garnet are two-phase, G + glass, and three types of them were distinguished: 1) same composition as host crystal, Th 1250-1260°C, 2) Y 52-55%, Pb 6-8%, Th 710-885°C, 3) essentially Pb (oxide? A.K.) compounds. Thus, only in simple systems without mineralizers do melt inclusions form, which are filled by melt of the same composition as host mineral and Th is the same as T of growth, In complex systems, inclusions of various composition may form, not necessarily having Th close to T of crystallization (Abst. by A.K.) (See also Fluid Inclusion Research--Proceedings of COFFI, v. 11, p. 102, 1978)

KHETCHIKOV, L.N., DOROGOVIN, B.A., VYAZOVOVA, R.V., BYDTAYEVA, N.I., KOMOV, I.L. and NOSOV, S.F., 1979, An experiment in the use of thermobarogeochemical data in the evaluation of crystal deposits: Sov. Geol., 1979, no. 5, p. 105-112 (in Russian).

Td revealed halos around crystal-bearing veins, useful for prospecting. (E.R.)

KHITAROV, D.N. and UCHAMEISHVILI, N.Ye., 1978, Study of inaccuracies connected with different preparation techniques of aqueous extracts, in Theory and Practice of Thermobarogeochemistry, N.P. Ermakov, ed., Izd. Nauka, p. 229-236 (in Russian).

KIMBERLEY, M.M., 1978, High-temperature uranium geochemistry, in Short course in uranium deposits; their mineralogy and origin, M.M. Kimberly, ed., Mineral. Assoc. Can., Short Course Handb., v. 3, p. 101-103.

Indexed under fluid inclusions. (E.R.)

KINSLAND, G.L., 1979, Formation temperature of fluorite in the Lockport Dolomite in upper New York State as indicated by fluid inclusion studies-with a discussion of heat sources-a reply: Econ. Geol, v. 74, p. 159-164.

This is a reply to a discussion by Haynes and Mostaghel (1979, see abstract in this volume), of an earlier article (Kinsland, 1977; Fluid Inclusion Research--Proceedings of COFFI, v. 10, p. 126, 1977). The author stoutly defends his data and indicates the possibility of his PS inclusions forming from quarry blasting is "absurd." He also defends his assumption of higher heat flow in the region than now, possibly from mantle convection. (ER)

KIRBY, S.H. and McCORMICK, J.W., 1979, Creep of hydrolytically weakened synthetic quartz crystals oriented to promote {2110} <0001> slip: a brief summary of work to date: Bull. Minéral., v. 102, p. 124-137. First author at Dept. Earth and Space Sci., Univ. Cal., Los Angeles, CA 90024, U.S.A.

Over 80 creep experiments have been carried out on hydrothermally grown single crystals of synthetic quartz with 50 to 4000 OH- per 10^6Si atoms and oriented with the compression direction at 45° to a and c. The creep tests were performed at temperatures between 400 and 800°C, at applied stresses between 434 and 1621 bars, and were compressed to strains of typically 4.5 ±1.0%. All of the creep curves were sigmoidal in shape, with an initial incubation stage of accelerating creep rates followed by a hardening stage in which creep rates decreased continuously with time. Cardinal rate parameters for each test are the maximum strain rate, the incubation time t_i (the zero strain intercept of the segment of the creep curve with the highest strain rate), and the strain rate at a specific creep strain, usually 2, 3, or 4%. The strain rates so chosen follow thermally activated power law rate equations. The stress exponent n is, within experimental uncertainty, independent of OH- concentration and unaffected by the alpha-beta phase transformation, and takes on values between 3.0 and 5.5. The activation energy for creep $E_c{}^*$ does not appear to vary systematically with OH- concentration but is strongly affected by the alpha-beta phase transformation, with $E_c{}^*$ ranging between 20 and 40 kcal/mole in the alpha quartz stability field and 8 to 18 kcal/mole in the beta quartz field.

Optical and transmission electron microscopy on the creep specimens have proven that {2110} <0001> is the dominant slip system. Dislocation density rapidly increases in the incubation stage. A dislocation multiplication model based on exponential growth quantitatively fits creep strain variations with time and the observed rate of increase of dislocation density with creep strain. At strains sufficiently low that dislocation interactions can be neglected, the inverse of the incubation time $1/t_i$ is proportional to the dislocation velocity. The effects of composition, temperature, and stress on dislocation velocity can then be inferred from the effects of these parameters on $1/t_i$. By this new technique, we show that the dislocation velocity follows a thermally activated power law with stress exponent and activation energy relatively insensitive to variations in OH- concentration. Preliminary experiments suggest that dislocation velocity increases with increasing OH- concentration.

In the hardening stage, the dislocation density is esentially constant, and the volume fraction of precipitated molecular water increases with time and strain. It is believed that the hardening stage is associated with the precipitation of molecular water into bubbles, but we have not been successful in quantitatively fitting the observed hardening rates to any precipitation hardening model. We have shown that the hardening effects associated with the obstruction of dislocation movement by bubbles are small relative to possible effects associated with the loss of structurally bound water during precipitation.

The evidence derived from the kinetics in the incubation stage suggests that the steady state flow law for synthetic quartz in the absence of precipitation hardening effect is of the form:

$$\dot{\varepsilon} = A\ \sigma^n \exp\ (-E_c{}^*/RT)$$

where $n = 3.5 \pm 0.5$, $E_c{}^* = 39 \pm 5$ kcal/mole and A increases with increasing OH- concentration. The parameters n and $E_c{}^*$ from the higher strain creep rate data deviate from these values, and we believe that the discrepancies stem from the effects of hardening by precipitation of molecular water and from the effects of strain-induced microfracturing in some of the tests. (Authors' abstract)

KIRKPATRICK, R.J., KUO, L.-C. and MELCHIOR, John, 1979, Crystal growth in programmed cooling experiments - diopside (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 458.

Programmed cooling experiments using a synthetic diopside glass and constant cooling rates of from 10°C/hr to 300°C/hr first crystallize forsterite and then with decreasing temperature clinopyroxene + wollastonite. The forsterite grows as hopper shaped crystals which then develop dendrites from external corners. The morphological development cannot be explained by constitutional supercooling theory, but requires a more complex model involving diffusion in the melt and interface attachment kinetics. Microprobe traverses across forsterite-glass interfaces show that the magnitude of the MgO depletion in the melt near flat interface segments varies from 1.72% to 4.28% and increases with increasing run-time for a given cooling rate and with increasing value of the product of the cooling rate times the run time for all cooling rates. The results are in good agreement with the theory of Muller-Krumbhaar (J. Chem. Phys., 63, 5131). Near a particular crystal MgO depletion is least at corners and greatest in reentrants. The clinopyroxene is more magnesian than diopside (solid solution towards forsterite) and grows as dendrites. The wollastonite occurs as rounded grains between the clinopyroxene dendrite arms. The clinopyroxene first appears at nominal undercoolings (1391-T_{quench}) of from 182°C to 240°C depending on the cooling rate. Unlike other sets of programmed cooling experiments which show a continual increase in nominal undercooling with increasing cooling rate, these experiments show a maximum in clinopyroxene undercooling at 50°C/hr. The undercooling is actually least for the 300°C/hr runs. This may be due to retention of the high temperature melt structure at high cooling rates. (Author's abstract)

KISH, L., 1979, The Johan-Beetz District; Travaux sur le terrain, 1979: Quebec, Direction Generale de la Recherche Geologique et Minerale, Quebec City, PQ, CAN, DPV-712, 26 p (in French).

Indexed under fluid inclusions. (E.R.)

KLATT, E., 1979, The fluid inclusions in the granulites of North Lapland and their host rocks: Fortschr. der Mineral., v. 57, pt. 1, p. 62-63 (in German).

CO_2 inclusions indicating temperatures of 700-750° and pressures of 5-7 kb are reported. (E.R.)

KOBILEV, G.A. and TRUFANOV, V.N., 1977, Principal stages of formation of lead-zinc deposits in the northern Caucasus: Akad. Nauk SSSR, Doklady, v. 234, p. 1156-1159 (in Russian; translated in Dokl. Acad. Sci. USSR, Earth Sci. Sects., v. 234, p. 111-113).

Abstract in Fluid Inclusion Research--Proceedings of COFFI, v. 10, p. 129 (1977). (E.R.)

KOGARKO, L. N., 1979, Microcomponents as indicators of the differentiation of alkaline magmatic series, in Origin and distribution of the elements, Proc. of the Second Symposium, Paris, May 1977, L. H. Ahrens, ed.: Oxford, Pergamon Press, p. 217-222. Author at Vernadsky Inst. Geochem. and Anal. Chem. U.S.S.R.

The distinction between two types of differentiation of alkaline magmatic series (1 related to the evolution of alkaline basaltic magma and 2 strongly undersaturated with silica, ultrabasic alkaline) is confirmed by the distribution of trace elements. Final products of both series are characterized by residual melts oversaturated in alkalies (agpaitic). (Author's abstract)

KOGARKO, L.N. and RYABCHIKOV, I.D., 1978, Volatile components in magmatic processes: Geokhimiya 1978, no. 9, p. 1293-1321 (in Russian; translated in Geochem. Internat., v. 15, no. 5, p. 9-32, 1978).

Abstract in Fluid Inclusion Research--Proceedings of COFFI, v. 11, p. 106 (1978). (E.R.)

KOL'KOVKI, B.G., MEL'NIKOV, F.P. and PETROV, P.P., 1978, Temperature of mineral formation of polymetallic deposits of the Madan ore field, Bulgaria, in Theory and Practice of Thermobarogeochemistry, N.P. Ermakov, ed., Izd. Nauka, p. 116-118 (in Russian).

See Kol'kovki and Petrov, Fluid Inclusion Research--Proceedings of COFFI, v. 11, p. 107-108, 1977. (E.R.)

KOLTUN, L.I. and PIZNYUR, A.V., 1979, Thermobarogeochemistry and ore formation: Mineral. Sb. (L'vov. Gos. Univ.), v. 33, Pt. 2, p. 109-112 (in Russian).

A review of the Vladivostok meetings. (E.R.)

KONNERUP-MADSEN, Jens, 1979a, Fluid inclusions associated with a metamorphosed molybdenite mineralization in Vest-Agder, south Norway: Econ. Geol., v. 74, p. 1221-1230. Author at Inst. Petrology, Univ. Copenhagen, 1350 Copenhagen, Denmark.

A number of generally small and economically unimportant Mo mineralizations are found in amphibolitic horizons in high-grade metamorphic rocks in the southernmost part of the Precambrian of Norway. All of these mineralizations are associated with a series of gray, amphibolitic gneisses.

The ores in the Flottorp area occur stratabound in a series of folded, high-grade amphibolitic and granitic gneisses. The mineralization is always found in connection with a folded zone of amphibolitic, banded gneisses. Molybdenite, pyrite, chalocopyrite, and pyrrhotite are the main ore minerals. Textural observations suggest that minimum temperatures of 450° to 500°C have been reached during metamorphism of ore and host rock.

Fluid inclusions in matrix quartz from the mineralized host rock were found to vary in composition from nearly pure CO_2 through H_2O+CO2 mixtures to entirely aqueous, saline fluids. High-density, isolated CO_2-rich fluid inclusions are considered to approximate most nearly the fluids present during peak conditions of metamorphism of ore and host rock and indicate pressures of 3.5 to 4.5 kb and temperatures around 650°C.

The majority of aqueous inclusions have salinities around 10 equiv. wt. percent NaCl. Microthermometry and chemical analysis of leachates indicate the presence of minor amounts of cation such as K^+, Ca^{+2}, and/or Mg^{+2} in the inclusion fluids. The aqueous inclusions primarily represent fluids present during repetitive episodes of microfracturing and progressive introduction of meteoric water during uplift and cooling. (Author's abstract)

KONNERUP-MADSEN, J., 1979b, Fluid inclusions in quartz from deep-seated granitic intrusions, south Norway: Lithos, v. 12, p. 13-23.

H_2O, CO_2, and H_2O-CO_2 inclusions were observed in quartz from deep-seated granitic intrusions belonging to the Precambrian Farsund plutonic complex, south Norway. These inclusions represent solidus and/or subsolidus fluids that were present in these rocks at some period between the initial melt and the present. Early CO_2 and H_2O-CO_2 inclusions with about 20 mole % CO_2 contain up to 10 mole % CH_4 in the CO_2 phase and have densities from 0.96 to 0.85 g/cc. These inclusions are considered to most nearly approximate solidus vapour phases and suggest conditions of final solidification of the magma at 5 to 6 Kb and 700°C to 800°C. The H_2O inclusions have salinities between 2 and 60 wt. %; the majority contain 5 to 20 equivalent wt. % NaCl and have densities from 1.05 to 0.85 g/cc. Microthermometry indicates that other cations such as K^+, Ca^{2+} and/or Mg^{2+} are present in these aqueous fluids. The H_2O inclusions primarily represent fluids present at a post-magmatic stage of fracturing and healing of these rocks during uplift. (Author's abstract)

KONNERUP-MADSEN, Jens, LARSEN, Elfinn and ROSE-HANSEN, John, 1979, Hydrocarbon-rich fluid inclusions in minerals from the alkaline Ilímaussaq intrusion, South Greenland: Bull. Minéral., v. 102, p. 642-653. First author at Inst. Petrol., Øster Voldgade 10, 1350 København K, Denmark.

Fluid inclusions in minerals from agpaitic nepheline syenites and hydrothermal veins from the alkaline Ilímaussaq intrusion in South Greenland are very rich in reduced gases such as hydrocarbons (predominantly methane) whereas the contents of CO_2 and CO are insignificant. The hydrocarbon-rich gases are thought to be of inorganic origin and to reflect very low oxygen fugacities during crystallization. It is proposed that they have been trapped as immiscible droplets of hydrocarbon-rich fluids in highly saline (33 to 46 equivalent weight % NaCl) aqueous solutions. Selected hydrocarbon-rich inclusions suggest conditions of entrapment at temperatures from 800 to 500°C and pressures from 1.4 to 0.8 kbar. (Authors' abstract)

KONONOV, V.I., 1979, Reykjanes thermal brines in the rift zone of Iceland: Proc. USSR Acad. Sci., Geological Series, 1979, no. 6, p. 138-151 (in Russian).

Includes 10 analyses for Na, K, Ca, Mg, Li, Cl, SO_4, S^{2-}, HCO_3, F, Br, H_2SiO_3, H_3BO_3. (E.R.)

KONOVALOV, I.V. and USHCHAPOVSKAYA, Z.F., 1979, Quartz in metamorphic hydrothermal gold-ore occurrences in black schist formations: Dokl. Akad. Nauk SSSR, v. 247, p. 933-935 (in Russian; translated in Dokl. Acad. Sci. USSR, v. 247, p. 118-120, 1981).

Th (max.) for quartz from various types of veins ranged from 370 to 450°C. Th is compared with precision determination of the lattice constants of the quartz. (E.R.)

KONSTANTINOV, M.M., ANDRUSENKO, N.I. and MOSKALYUK, A.A., 1979, Characteristics of the composition of mineral-forming solutions for different types of gold-silver ore mineralization, in Major parameters of natural processes of endogenetic ore formation, V.A. Kuznetsov, ed.: Novosibirsk, Izdat. Nauka, v. 2, p. 154-160 (in Russian). [Dokl. Vses. Soveshch., 1977]

The compn. of the ore-forming solns. of the near-surface Au-Ag mineralization in volcanic regions is considered, on the basis of fluid-inclusion studies. The Au-Te type ores formed from $HCO_3-K^+-Na^+$ solns.;

the Au type ores formed from $Cl-HCO_3$ solns. sometimes high in alk. earth components; and the Au-Ag type originated from $SO_4{}^{2-}-K^+$ solns. The solns. had pH ~7. The anion contents of the solns. were detd. by regional geotectonic factors, whereas the cation contents correlate with the compn. of the country rocks. The trace element content of the solns. can indirectly indicate a paragenetic relation of Au-Ag mineralization to intrusive magmatism. (C.A. 92:79636t)

KOPLUS, A.V., KHITAROV, D.N. and BOLOKHONTSEVA, S.V., 1978, The formation temperature conditions of fluorite deposits of different genetic types in Kazakhstan; Termobarogeokhimiya Zemnoy Kory I Rudoobrazovaniye, N.P. Ermakov, ed.: Moscow, Izd. Nauka, p. 109-122 (in Russian).

Indexed under fluid inclusions. (E.R.)

KORMUSHIN, V.A. and DARBADAEV, 1978, Apparatus for collecting gas from gas-liquid inclusions by the thermal method (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 1, Thermobarogeochemistry in geology: Vladivostok, Acad. Sci. USSR, p. 209 (in Russian). Authors at Inst. Geol. Sc. of Acad. Sci. of Kazakh USSR, Alma-Ata.

The apparatus (fig. 1) is used for gas release from thermoresistant minerals under vacuum conditions and compression to atmospheric pressure. The apparatus consists of glass ampoule 1 with mineral sample joined through the four-way valve 2 with rubber capsule 5 in metal cylinder 3 with valve 4 leading to vacuum pump. First through valve 2 branch "b" air is removed from ampoule with sample and rubber capsule, next through valve 4 air is pumped out from cylinder 3. Next sample is heated and the released gases flow to rubber capsule, which volume exceeds significantly the volume of ampoule, tubes and valves. Then branch "a" of valve 2 is closed and air comes into cylinder through valve 4. (Authors' abstract, transl. by A.K.)

KORNILOV, V.F., 1978, Temperature conditions for the formation of mercuric-antimonic mineralization; southern Kirghizia, in Thermobarogeochemistry of the Earth's Crust and Ore Formation, N.P. Ermakov, ed., Izd. Nauka, p. 155-161 (in Russian).

KOROBEYNIKOV, A.F., 1979, Composition and features of mineral-forming solutions in the gold ore deposits of the Sayano-Altaĭy folded area, as indicated by inclusions in minerals, in Major parameters of natural processes of endogenetic ore formation, V.A. Kuznetsov, ed.: Novosibirsk, Izdat. Nauka, v. 2 , p. 161-174 (in Russian). [Dokl. Vses. Soveshch., 1977]

Probably same as in Korobeynikov, 1977, Fluid Inclusion Research--Proceedings of COFFI, v. 10, p. 131-137, 1977. (E.R.)

KOSCHINSKI, G., 1979, Microstructural and microthermometrical investigations on quartz mineralizations from the eastern Rhenisch Slate Mountains. Diss. Gottingen, 146 pp., (in German).

Fluid inclusion measurements in quartz and sphalerite. (E. Horn)

KOSELUK, R.A., ELLIOTT, W.C. and ULMER, G.C., 1979, Gas inclusions and fO_2-T data for olivines from San Carlos, Arizona (abst.): Eos, v. 60, p. 419.

Abundant olivine (Fo_{91}) occurs in San Carlos basalt both as megaxenocrysts and as grains in xenolithic peridotite nodules. Gem quality olivines of both types were selected (hereinafter SCGO) with stereoscopic viewing at 40x. At 420x in doubly polished thick-sections, SCGO are seen to still be free of any second solid phases, but to contain many micro-vesicles often as large as 30μ. Roedder (1965) reported similar observations in olivines from over 70 sites.

SCGO was crushed and sieved into +2mm, +1mm, +500μ, +250μ, +100μ, +70μ, and -70μ fractions. The fO_2-T data for all olivine fractions prove they are more reduced than the host basalt, i.e., a true xenolithic relationship. However, variable amounts of auto-oxidation occur for the olivine even in duplicate runs of the same size fraction due to the random bursting and release of the CO_2-rich gas from the vesicles. During heating, small grains release CO_2 even below 800° and large grains release CO_2 as high as 1120°C. In cooling of Hawaiian olivines, Killingley and Muenow (1975) saw similar gas releases.

Offsets in the slopes of the fO_2-T plots for SCGO indicate that the released gas in every case oxidizes the host olivine. The lowest measured log fO_2 of -11.50 at 1200°C for SCGO precludes that the vesicular CO_2-rich gas has resulted from the oxidation of graphite; under these conditions, graphite oxidizes to CO_2 only at pressures less than 0.3 kb = <1 km depth (French and Eugster, 1965; Woermann et al., 1978). Group I peridotite nodule trace elements and REE (Frey and Prinz, 1978), and the textural evidence that these vesicles formed at the olivine liquidus also preclude that the CO_2 is of such a shallow origin. Hence upper mantle decarbonation equilibria must have provided the CO_2. (Authors' abstract)

KOSKI, R.A., 1978, Geology and porphyry copper-type alteration-mineralization of igneous rocks at the Christmas Mine, Gila County, Arizona: Doctoral thesis, Stanford Univ., Stanford, CA, USA, p. 268.

Indexed under fluid inclusions. (E.R.)

KOSOVETS, T.N., KRYLOVA, V.V., SHCHITOVA, V.I. and BARKHUDARYAN, N.B., 1978, Use of ancient temperature data for explanation of genetic characteristics of gold mineralization and the development of an ore inlet structure, in Thermobarogeochemistry of the Earth's Crust and Ore Formation, N.P. Ermakov, ed., Izd. Nauka, p. 183-191 (in Russian).

Indexed under fluid inclusions, geothermometry, geobarometry. (E.R.)

KOSUKHIN, O.N., 1978, Research on inclusions of fluid magma quartz from chambered pegmatites, in Thermobarogeochemistry of the Earth's Crust and Ore Formation, N.P. Ermakov, ed., Izd. Nauka, p. 99-101 (in Russian).

See Fluid Inclusion Research--Proceedings of COFFI, v. 11, p. 111-112. (E.R.)

KOTOV, Ye.I, 1978, Feasibility of using gas-liquid inclusions for exploration of telescoped hydrothermal mineralization, in Thermobarogeochemistry of the Earth's Crust and Ore Formation, N.P. Ermakov, ed., Izd. Nauka, p. 217-222 (in Russian).

KOVACHEV, V. and STRASHIMIROV, S., 1979, Mineral thermometry studies and temperature zonality in the Zidarovo ore field: Bulg. Geol. Druzh., Spis. v. 40, no. 1, p. 101-108 (in Bulgarian).

Indexed under fluid inclusions. (E.R.)

KOVALEVA, K.V. and LEVITSKIY, Yu.F., 1978, Conditions of apatite-rare-metal mineralization* (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 77-78 (in Russian). Authors at VSEGEI, Leningrad, USSR.

The formation conditions were studied by use of decrepitation method. Three temperature intervals of origin of apatite-rare-metal mineralization in Precambrian rocks were distinguished: pre-ore 490-460°C, ore 420-210°C and post-ore 110-60°C. Inclusions in apatite often bear solids (colorless crystals) and up to 10-15% of LCO_2. (From the authors' abstract, transl. by A.K.)

*Deposit name or location not given. (A.K.)

KOVALEVICH, V.M., 1978, Phase changes (liquid-gas) in inclusions in minerals at constant temperature, (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 1, Thermobarogeochemistry in geology: Vladivostok, Akad. Sci. USSR, p. 193-194 (in Russian). Author at Inst. Geol. Geochem. of Mineral Fuels of Acad. Sci. of the Ukrainian SSR, L'vov.

During opening of some inclusions in a neutral liquid, liquid-gas changes were observed under lower pressure. Studies were performed in thermostage permitting the opening of inclusions under controlled, elevated pressure with contemporaneous microscopic observations. Phase change occurs under P equal P of two-phase equilibrium of the studied substance in inclusions at the chosen T. In inclusions filled by $LH_2O + CO_2$, phase change of CO_2 at room T was observed under $P = 55$ atm; when $P > 55$ atm $GCO_2 \rightarrow LCO_2$ and when $P < 55$ atm, $LCO_2 \rightarrow GCO_2$. This operation helps in the identification of gases in inclusions and the determinations of minimum P of mineral-forming solutions. (From the author's abst., transl. by A.K.)

KOVALISHIN, Z.I., 1978, Carbon dioxide content in the gas phase as an indicator of physicochemical conditions of mineral formation of cavity pegmatites in Volyn, in Uglerod Ego Soedin. Endog. Protsessakh Mineral-oobraz., Izd. Naukova Dumka, Kiev, USSR, p. 78-82 (in Russian).

Indexed under fluid inclusions. (E.R.)

KOZYRIN, N.A. and GORBACHEVA, M.A., 1979, Experimentally observed changes in pH of ore-forming solutions: Dokl. Akad. Nauk SSSR, v. 247, p. 202-205 (in Russian; translated in Dokl. Acad. Sci. USSR, v. 247, p. 145-147, 1981).

Proves that the pH of various solutions changes upon reaction with quartz and cristobalite. Of pertinence to the interpretation of the pH of inclusion leachates from quartz. (E.R.)

KRASNOBAYEV, A.A., KRAVTSOV, A.V., SANDLER, G.A., POKROVSKIY, P.V. and SAZONOV, V.N., 1979, Microgeochemical heterogeneity of zircons and its role in the solution of some problems of petrology and geochronology:

Heterogeneity of composition and structure in minerals of the Urals, Trudy Instituta Geology I Geokhimi̇y, 1979, no. 143, Mineralogicheskiy Sbornik no. 14, p. 3-19 (in Russian).

Indexed under fluid inclusions. (E.R.)

KRASOV, N.F., 1978, Crystallization of andesitic lavas from formations in Kamchatka according to data from research on fluid inclusions in the minerals, in Thermobarogeochemistry of the Earth's Crust and Ore Formation, N.P. Ermakov, ed., Izd. Nauka, p. 68-72 (in Russian).

KRASOV, N.F. and CLOCCHIATTI, R., 1979, Liquation of silicate melt and its possible petrogenetic role according to the data of melt inclusion study: Doklady Akad. Nauk SSSR, v. 248, no. 1, p. 201-204 (in Russian; translated in Dokl. Acad. Sci. USSR, v. 248, p. 92-95. 1981).

Plagioclase phenocrysts from andesitic lavas of Kamchatka contain melt inclusions that now consist of 2 glass phases. (Recrystallization of the melts took place at 700-750, but the two melts coexist up to 1280°C, with Th at 1315-1350°C.) (E.R.)

KRAVTSOV, A.I., VOYTOV, G.I., BOBROV, V.A., AKIMOV, A.P., IVANOV, A.N. and SERDYUKOV, L.I., 1979, Gases (chemical and isotopic composition) of the kimberlite pipe "Mir": Akad Nauk SSSR Doklady, v. 245, no. 4, p. 950-953 (in Russian).

Gases in kimberlite were determined from small amount of sample (2g) on crushing by use of gas chromatography. The results, in vol.%, are as follows: violet pyrope H_2 1.92, N_2 97.95, CH_4 0.09, C_2H_6 0.02, C_3H_8 0.01, CO_2, C_2H_4, and C_3H_6 not found; xenolith of the garnet-bearing porphyry peridotite H_2 41.93, N_2 48.91, CH_4 7.46, C_2H_6 0.99, C_2H_4 0.33, C_3H_8 0.38, CO_2 and C_3H_6 not found; apomeymechite-type breccia H_2 1.95, N_2 not found, CO_2 97.53, CH_4 0.33, C_2H_6 0.08, C_2H_4 0.05, C_3H_8 0.04, C_3H_6 0.02. (A.K.)

KREMENETSKIY, A.A., LAPIDUS, I.V. and YUSHKO, N.A., 1978, Temperatures of formation of fluorine-rare-alkali-metal ore mineralization (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 80-81 (in Russian). Authors at IMGRE, Moscow, USSR.

The deposit (name and location are not given, A.K.) occurs in volcanic-sedimentary rocks. Li occurs mostly (98%) in clay mineral of polylithionite type, also Rb (76%) and Cs (86%); the remainder is concentrated in plagioclase as isomorphic admixture. F occurs in clay mineral (61%) and in fluorite (33%). The deposit formed due to hydrothermal-metasomatic alteration of carbonaceous-clay-carbonate rocks, when dioctahedral micas altered into lithium micas. Calcite and fluorite bear G/L (rarely L) inclusions occasionally with solid phase (isotropic and anisotropic). G/L inclusions have Th 105 to 199°C, those with solids - 75 to 202°C, but solid phase remains without dissolution even at T>363°C. (From the authors' abstract, transl. by A.K.)

KRICHEVSKIY, I.R. and LESNEVSKAYA, L.S., 1979, On the limit equation for the volatility of dissolved substances in a double critical solution:

Akad. Nauk SSSR Doklady, v. 246, no. 2, p. 375-379 (in Russian). First author at State Sci.-Research and Project Inst. of Nitrogen Industry and Products of Organic Synthesis, Moscow.

Pertinent to solution models applicable for fluid inclusions. (A.K.)

KRIVOVICHEV, V.G., GALIBIN, V.A. and STAROVA, G.L., 1979, The geochemistry of strontium in low-temperature hydrothermal deposits; for example in the Belorechensk barite deposit: Mineral. Geokhim., Sb. Statei (Leningr. Univ.), v. 6, p. 130-141 (in Russian).

Indexed under fluid inclusions. (E.R.)

KUBOTA, Yasuhiho, 1979, Hydrothermal rock alteration in the northern Hachimantai geothermal field: Chinetsu, v. 16, no. 4, p. 15-31 (in Japanese).

Indexed under fluid inclusions. (E.R.)

KUCHER, M.I. and MATSAPULIN, V.U., 1978, Relation between gases in inclusions and in crystal lattice of quartz and kinetics of their migration (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 1, Thermobarogeochemistry in geology: Vladivostok, Acad. Sc. USSR, p. 206-207 (in Russian). First author at MGRI, Moscow, USSR.

A device for decrepitation linked with a mass-spectrometer permitted the determination of Td and up to 12 gas components. Content of CO_2, N_2 and H_2O in inclusions and in crystal lattice is in the same range, and H_2, CH_4 and He even more in the crystal lattice than in the inclusions. Diffusion coefficients (D) and activation energy coefficients (E) were determined for gases CO_2, N_2, H_2, CH_4 and water of crystallization by means of isothermal calcination of the sample for 6-10 hours at T 600, 700, 800, 900 and 1000°C. All gas components have migration activation energy 40 ± 5 kcal/mol, proving the same diffusion mechanism, probably connected with the low-high quartz inversion. (sic.) Diffusion equations in the crystal lattice for all gases were calculated, e.g., for CO_2 such equation is as follows:

$$D = 5.4 \cdot 10^{-3} \exp(-46000/PT).$$

Using this equation, the amount of gas released from crystal lattice at any T may be calculated; at Td of the studied quartz (240°C), D_{CO_2} will be 10^{-5} cm/sec^2, i.e., during half an hour, the lattice loses 10^{-9} ("nanomillimeters")^3 per gram, hence less than 10^{-10} part of the CO_2 released at that T is from inclusions (310 (nanomillimeters)^3 per gram). At 450°C the respective values are 0.0007 nmm^3/g i.e., 3×10^{-3} part of CO_2 in inclusions, causing error in CO_2 determination of 0.0003%.

At usual T of existence of ore bodies the diffusion coefficients may be as low as 10^{-27} to 10^{-30} cm^2 per sec. - under such conditions inclusions practically do not lose gas components, but with appreciable overheating, e.g., in the neighborhood of intrusions, may essentially change the inclusion filling. (Authors' abstract, transl. by A.K.)

KUDRINA, M.A., KUDRIN, V.S., KHARLAMOV, Ye.S. and KHITAROV, D.N., 1978, Temperatures of scheelite formation in deposits of various types (abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 85-86 (in Russian). Authors at the All-Union Inst. of Mineral Raw Materials, Moscow, USSR.

Wolframite forms in relatively narrow T interval 350-280°C, not depending on its genetic peculiarities. Scheelite forms over a wider Th range 400-160°C, mostly depending in individual deposits on their genetic type, and often forming several generations in one deposit. The typical Th intervals are 400-300°C, 300-200°C and 200-150°C. Commercially very important are deposits of the berezite type contain scheelite that crystallized mostly at 220-180°C. (From the authors' abstract, transl. by A.K.)

KURSHEV, S.A., MAYSKIY, Yu.G., MAYSKAYA, Z.V. and TRUFANOV, V.N., 1978, System "magma-fluid" imitated in casting molds (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 53-54 (in Russian). Authors at Rostov State Univ., USSR.

The content of volatile components decreases strongly at the melted metal/mold boundary due to decrepitation and partial melting of sand-clay mold material, and next volatiles accumulate, reaching a maximum at 5-6 cm from the contact. There are analogies with instrusion of magma in sandy-clay sediments. (From the authors' abstract, transl. by A.K.)

KUSAKABE, Minoru and CHIBA, Hitoshi, 1979, Oxygen isotope geothermometry applicable to sulfate minerals from the Kuroko deposit: Kozan Chishitsu, v. 29, no. 156, p. 257-264 (in English).

Applicability of oxygen isotope geothermometers to sulphate minerals from the Kuroko deposits has been discussed by utilizing oxygen isotope fractionation factors determined for the anhydrite-water and barite-water systems together with the existing isotopic data and models. The oxygen isotopic calibration for the anhydrite-water system has recently been revised. The depositional temperature of the anhydrite-gypsum ore-body at the Shakanai mine is estimated to be about 200°C or so assuming direct precipitation of anhydrite from sea water. At these temperatures about 50% of calcium sulphate originally dissolved in the Miocene sea water was precipitated to form the ore-body. The total volume of sea water required to produce a known amount of the anhydrite-gypsum ore-body was calculated. Barite in the black ore from the Shakanai mine may have been precipitated at temperatures considerably lower than 250°C which is widely accepted as the depositional temperature of the black ores based on the sulphur isotopic data. However, this discrepancy remains to be studied in the future, because the number of oxygen isotopic data of barite and ore solutions is very limited. (Authors' abstract)

KUSHEV, V.G. and MIRONOV, A.G., 1978, The effect of flow of reducing gases in the mantle on the generation of alkalic melts: Akad. Nauk SSR, Doklady, v. 240, p. 431-434 (in Russian).

KUZMINA, T.M., MAKAGON, V.M. and ROSSOVSKY, L.N., 1979, On the temperatures of mineral forming in the kunzite deposit Kulam, Afghanistan: Geokhimiya Endogennykh Protessov, Sib. Inst. Geochem., Irkutsk, 1979,

p. 135-138 (in Russian with English abstract).

Th of fluid inclusions were determined in kunzite, pollucite, tourmaline, beryl, quartz and microcline from chambered pegmatites. Minerals formed there over a wide temperature interval with a regeneration of high-temperature minerals at a low-temperature stage, when kunzite formed. (Authors' abstract)

KUZ'MINA, T.M., ZAGORSKIY, V.Ye. and MAKAGON, V.M., 1978, Characteristic formation conditions of hydrothermal-metasomatic alteration in rocks near veins of rare-metal pegmatites, *in* Thermobarogeochemistry of the Earth's Crust and Ore Formation, N.P. Ermakov, ed., Izd, Nauka, p. 180-182 (in Russian).

Indexed under fluid inclusions. (E.R.)

KUZNETSOV, A.G., 1978a, Mathematical model of temperature fields in the volcanic rocks of the Upper Osetia (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 1, Thermobarogeochemistry in geology: Vladivostok, Acad. Sc. USSR, p. 202 (in Russian). Author at the Symferopol' Geol. Office, Symferopol', USSR.

Temperature field was calculated on the basis of thermobarogeochemical data and the Fourier equation of thermal conductivity. Thermophysical coefficients were accepted as isotropic and constant, and heat loss during radiation and thermic effects of crystallization were taken into account. Th of P melt inclusions in quartz were 680-1230°C. Calculations were made for rocks from Khod-don, Malyi Khod, Nogkau, Sulardon and Tsakhtsiri-khokh. Also the velocity of migration of the melt crystallization line was calculated. (From the author's abstract, transl. by A.K.)

KUZNETSOV, A.G., 1978b, Determination of the location of ancient centers of volcanic eruptions by the methods of thermobarogeochemistry, *in* Thermobarogeochemistry of the Earth's Crust and Ore Formation, N.P. Ermakov, ed., Izd. Nauka, p. 72-79 (in Russian).

KUZNETSOV, V.A., ed. 1979a, The nature of solutions and sources of ore-forming materials of endogenic processes: Novosibirsk, Izdat. "Nauka," 192 pp. (in Russian).

Individual pertinent papers are abstracted in this volume. (E.R.)

KUZNETSOV, V.A., ed., 1979b, Major parameters of natural processes of endogenic ore formation [Dokl. Vses. Soveshch., 1977]: Novosibirsk, Izdat. Nauka, v. 1 - Physical chemical evolution of ore-forming systems. Copper-nickel, iron ores, molybdenum deposits, pp. 270; v. 2 - Tin-tungsten, pyrite-polymetallic, gold ores, antimony-nickel, mercury deposits, pp. 255 (in Russian).

Individual pertinent papers are abstracted in this volume. (E.R.)

KUZNETSOVA, S.V. and KUCHERENKO, Ye.V., 1978, Express method for the chemical determination of CO_2 gas-fluid inclusions, *in* Theory and Practice of Thermobarogeochemistry, N.P. Ermakov, ed., Izd. Nauka, p. 210-213 (in Russian).

KWAK, T.A.P. and TAN, T.H.,1979, Fluids and W-skarn genesis at the King Island scheelite skarn, Tasmania, Australia (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 462.

See abstract in Fluid Inclusion Research--Proceedings of COFFI, v. 11, p. 119-120, 1978. (E.R.)

KYLE, J.R., 1979, Mineralization controls, Pine Point District, Northwest Territories (abst): Program, 108th AIME Annual Meeting, New Orleans, Feb. 18-22, 1979, p. 21.

The Pb-Zn ore bodies in the Pine Point district are localized in paleo-solution structures that developed as the result of post-middle Givetian subaerial exposure of the carbonate barrier complex. Sulfides are concentrated in transgressive paleosolution structures that acted as natural bypasses between aquifers and loci for mixing of fluids of different character, one of which contained metals and the other reduced sulfur. Complex ore textures indicate rapid early sulfide precipitation followed by slower sulfide growth. Evidence for both sulfide-carbonate equilibrium and disequilibrium conditions suggest fluctuations in ore fluid composition. District and ore body metal distribution patterns May reflect the nature and movement of mineralizing fluids (Author's abstract)

LAMOEN, H. Van, 1979, Ferroan dolomite in coronas replacing plagioclase in metamorphosed iron ores from Susimaki and Riuttamaa, Finland: N. Jb. Miner. Mh., 1979, p. 241-252 (in English).

Ferroan dolomite occurs as a rare accessory mineral in coronas replacing plagioclase in metamorphosed iron ores from Susimaki and Riuttamaa in southwest Finland. The coronas formed by reaction of plagioclase with olivine and opaque oxides faciliated by the solvent medium of an intergranular mixed CO_2-H_2O fluid. The stable coexistence of dolomite with orthopyroxene, hornblende, and spinel points to recrystallization under high partial pressures of CO_2 (5 kb) and low partial pressures of H_2O (1-2 kb) at temperatures of 700-750°C. The presence of CO_2-rich fluids in the ores during the retrogressive stage after corona formation is indicated by fluid inclusions contained in apatite plagioclase, and garnet. Fluid densities of the CO_2-inclusions are as high as 0.9 g/cm^3 indicating a maximum fluid pressure of entrapment of about 4.5 kb for the estimated temperature range of 700-750°C. The coronas contain dolomite exclusively in their central parts and often show an increasing orthopyroxene/hornblende ratio towards the inner zones. This mineralogical zoning of the coronas is explained by breakdown of plagioclase involving a fluid that is progressively enriched in CO_2 relative to H_2O towards the central corona parts. Increase of the CO_2/H_2O ratio is attributed to progressive dehydration of the fluid due to extensive formation of hornblende in the outer corona zones. (Author's abstract)

LANDA, E.A., 1978, Metasomatic rocks in massifs of ultrabasic-alkaline rocks and carbonatites, in Metasomatism in Ore Formation, D.S. Korzhinskiy, ed., Izd. Nauka, p. 106-112 (in Russian).

Indexed under fluid inclusions. (E.R.)

LANG, Barbu, 1979, The base metals-gold hydrothermal ore deposits of

Baia Mare, Romania: Economic Geology, v. 74, p. 1336-1351. Author at Geol. Survey Israel, Jerusalem 95501 Israel.

The metalliferous veins form parallel systems generally with constant northeast-southwest and east-west trends. These are grouped in four metallogenic alignments. The mineral assemblages include native elements (Au, Ag, Cu, As, S), sulfides, sulfosalts, oxides, arsenates, antimonates, tellurides, sulfates, carbonates, wolframates, phosphates, and silicates. The richest assemblages occur in the upper mineralized levels and in the center of the ore deposits belt. A generalized scheme for paragenesis begins with iron-bearing minerals and quartz chlorite gangue. With decreasing temperature the base metal sulfides plus other metallic minerals, quartz, adularia, and clay minerals occur. The lowest temperature minerals consist mainly of sulfosalts, native elements, and carbonates. The metallogenic process was polyascendant. Spatial disposition of the ore is sometimes zonal, although telescopic phenomena are frequent. The nature of the most important ore is mesohypothermal. (From the author's abstract.)

Includes thermometric data on 10 deposits, from the literature. (ER)

LAPIN, A.V., 1979, Behavior of fluorine and sulfur in the process of evolution of carbonatites: Geokhimiya, 1979, no. 8, p. 1184-1188 (in Russian).

LAZARENKO, E.A. and LAZARENKO, Ye.K., 1979, Metallogenic significance of igneous and metasomatic migmatite-granite associations: Dok. Akad. Nauk SSSR., v. 248, p. 205-208 (in Russian; translated in Dok. Acad. Sci. USSR, v. 248, p. 96-98, 1981).

Reports Th of dry melt inclusions in the centers of quartz phenocrysts from Beregovo district rhyolite to be ~ 1500°C, whereas melt inclusions in the peripheries of these same phenocrysts have Th <1200°C, presumably indicating a water-saturated melt. (E.R.)

LAZ'KO, E.M., LYAKHOV, Yu.V. and PIZNYUR, A.V., 1979, Principal physicochemical parameters of postmagmatic ore formation: Osnovn. Parametry Prir. Protsessov Endog. Rudoobraz., (Dokl., Vses. Soveshch.), Kuznetsov, V.A. (Ed), v. 1, p. 220-230 (in Russian).

Indexed under fluid inclusions. (E.R.)

LEACH, D.L., 1979, Temperature and salinity of the fluids responsible for minor occurrences of sphalerite in the Ozark region of Missouri: Econ. Geol., v. 74, p. 931-937. Author at USGS, Denver, CO 80225.

Th on many inclusions from 25 localities range from 77 to 110°C; Tm ice range from -10 to -23.6°C, but most are -20 or lower. These occurrences are hence related to a period of epigenetic mineralization in one or more of the major ore districts. (E.R.)

LE BEL, Laurent, 1979, Micas at magmatic and hydrothermal stages in the environment of the Cerro Verde-Santa Rosa porphyry copper type deposit: Bull. Minéral., v. 102, p. 35-41.

LEE, C.A. and SHARPE, M.R., 1979, Spheroidal pyroxenite aggregates in the

Bushveld Complex - A special case of silicate liquid immiscibility: Earth and Planet. Sci. Lett., v. 44, p. 295-310. First author at Johannesburg Consolidated Investment Co., Fundamental Research Unit, P.O. Box 976, Randfontein, Republic of South Africa.

Spherical aggregates of orthopyroxene in a quartz-norite matrix are reported from some parts of the Bushveld Complex in a variety of host rocks. Bulk chemistry shows spheroid to matrix tie-lines orthogonal to those generally accepted for silicate liquid immiscibility, but other chemical information is consistent with the occurrence of immiscibility. The petrology of the process equates with a special case of silicate liquid immiscibility induced by local contamination and ageing of the original magma. (From the authors' abstract)

LEEDER, Otto, 1979, Fluorite: Leipzig, VEB Deutscher Verlag für Grundstoffindustrie, pp.266 (in German).

Contains a 10-p section (63-72) reviewing fluid inclusion studies in fluorite. (E.R.)

LELEK, J.J., 1979, Evidence for magmatic immiscibility in a pyroxenite-syenite complex (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 465.

LEROY, Jacques, 1979, Contribution to the evaluation of internal pressure in fluid inclusions when they decrepitate: Bull. Minéral., v. 102, p. 584-593. Author at Équipe de Rech. sur les Équili. Fluides et Min., E.N.S.G., B.P. 452, 54001 Nancy Cedex, France. et C.R.P.G., C.O. no. 1, 54500 Vandoeuvre-les-Nancy, France.

The pressure inside a fluid inclusion increases with temperature. When this pressure exceeds the strength of the walls of the host mineral, the inclusion decrepitates. Previous data on synthetic or natural quartz crystals, obtained either by decrepitometry or by microthermometry lead to variable values of this decrepitation pressure. The size of the inclusions is one of the factors considered as responsible for the variations of the pressure.

New values have been obtained by microthermometry on two-phase inclusions from synthetic quartz crystals. The thickness of the plates is 0.2 mm. For inclusions larger than 35 µm, the decrepitation pressure is 850 ± 50 bar, as previously determined by Naumov et al. (1966). When inclusions are smaller, the pressure increases up to 1,200 bar for a size of 12-13 µm. For inclusions smaller than 12 µm pressures up to 2.7 kbar were obtained without any decrepitation. The dissolution of the walls of these inclusions is observed. At least two utilizations of decrepitation are discussed. (Author's abstract)

LESKOVETS, G.V. and ABRAMOVA, G.F., 1978, Spectral determination of some trace elements in interstitial solultions with preconcentration extraction: Metody Analia Veshchestv: Sostava Gorn. Porod i Vod pri Geokhim. Issled, p. 90-95, in Ref. Zh., Khim. 1979, Abstr. No. 1G148 (in Russian).

Indexed under fluid inclusions. (E.R.)

LEVITSKIY, V.V., DEMIN, B.G., BARYSHEV, A.S. and KHRENOV, P.M., 1979, Determination of the ore- and sub-ore levels of the quartz-vein and veinlet-impregnated zones in the Lena river province, as indicated by physico-chemical data: Akad. Nauk SSSR Doklady v. 245, no. 6, p. 1442-1447 (in Russian; translated in Dokl. Acad. Sci. USSR, v. 245, p. 102-106, 1981). Authors at the East-Siberian Sci.-Research Inst. of Geol., Geophysics and Mineral Raw Materials, Irkutsk, USSR.

Typical standard quartz-pyrite (with Au) ore field in the central Bodaybo region was studied by means of fluid inclusion methods. On the basis of 80 chromatographic analyses it was found that ore-bearing level is 2.5-3 times richer in total gases than sub-ore one. In the same way CO_2 content increases from 12-20% of total gases to 58-60%, but CH_4 + other hydrocarbons content decreases from 20-25% to 1.5-2.5% due to oxidation in the upper part of the deposit. Those features were used for studies of the other deposits. (Abst. by A.K.)

LEVITSKIY, V.V., DEMIN, B.G., KHRENOV, P.M. and POPIVNYAK, I.V., 1978, Physicochemical conditions of formation of zones of sulfide-quartz stringers, disseminations and veins in the Baikal region: Akad. Nauk SSSR, Doklady, v. 241, no. 5, p. 1190-1192 (in Russian; translated in Doklady Acad. Sci. USSR, Earth Sci. Sec., Apr. 1980, v. 241, p. 216-218, 1980).

Abstract in Fluid Inclusion Research--Proceedings of COFFI, v. 11, p. 125 (1978). (E.R.)

LEVITSKII, V.V., DEMIN, B.G., NAMOLOV, E.A. and BABURIN, L.M., 1979, Distribution of volatile components in gold, sulfides, and quartz of ore zones of the Lena province: Dokl. Akad. Nauk SSSR, v. 249, no. 6, p. 1447-1449 (in Russian).

LI, Yinqing, WEI, Jiaxiu, ZHOU, Xinghan, and MA, Xiujuan, 1979, some features of the fluid inclusions and the ore-forming temperature of a certain porphyrite-type iron deposit: Acta Geol. Sinica, v. 53, p. 50-59 (in Chinese with English abstract).

A study of the inclusions from a porphyrite-type deposit in the middle-lower reaches of the Yantze River, which consists of a group of iron and pyrite ores occurring in the andesitic volcanic rocks and genetically related to gabbrodiorite porphyrites. Various stages of the ore-forming process ranged from 500°C to 175°C, i.e., from pneumato-hypothermal, mesothermal to epithermal mineralization.

The fluid inclusions can be classified as mainly liquid, partially gas, and polyphase inclusions with daughter minerals (NaCl). The features of the inclusions vary with different types of the deposits, and change regularly with the evolution of the ore-forming stages.

The trend analysis of the ore-forming temperature of individual deposits shows directional change in the ore-forming temperatures. Considering the geological features such as structures it is suggested that the ore-bearing solution migrated from NW to SE-S.

Both trend analysis and the correlation analysis indicate that a weakly positive correlation exists between the magnetite-forming temperature and the TiO_2 content. (Authors' abstract)

LILLEY, M.D., 1979, Methane, nitrous oxide, carbon monoxide and hydrogen in the hydrothermal vents of the Galapagos spreading center (abst.): Eos, v. 60, p. 863

LINDBLOM, Sten and RICKARD, D.T., 1978, Fluid inclusions in sphalerite at Laisvall, Sweden: Geol. Foeren. Stockholm Foerh., v. 100(2), p. 177-180 (in English).

LIPPS, J.H., GREEN, H.W., II and SHOWERS, W.J., 1979, Test ultrastructure of Fusulinacean foraminifera (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 88.

These fossils have organic material and/or water inclusions (submicroscopic) in the subgrain boundaries in crystals in their cell walls. (E.R.)

LITVINOVSKII, B.A., LETNIKOV, F.A., KONNIKOV, E.G., GORDIENKO, I.V. and KUZNETSOV, A.N., 1979, Evolution of fluid conditions in subcrustal magmatic chambers of the Baikal mountain region: Dokl. Akad. Nauk SSSR, v. 247, no. 6, p. 1449-1453 (in Russian).

Indexed under fluid inclusions. (E.R.)

LIU, Guo-bin, 1977, Genesis of gas-liquid inclusions and crystal deposits: Kexue Tongbao (Science Journal) 1979, no. 3, p. 115-119 (in Chinese). Author at Inst. Geochemistry, Academica Sinica, Kwei-yang.

LIU, W.K. and MUENOW, D.W., 1979, Volatiles in submarine volcanic rocks from the Mariana Island arc and trough, Geoch. Cosmo. Acta, v. 43, p. 305-312. First author at Geol. Dept., Univ. Hawaii, Honolulu, HI 96822, U.S.A.

High temperature mass spectrometric analyses of glasses from quenched pillow rims of andesites dredged from 1170 m water depth in the northern portion of the Mariana Island arc indicate substantially less H_2O (∿1 wt.%) and more CO_2 (∿0.24 wt.%) than previously reported for volcanic arc rocks. Glass-vapor inclusions within plagioclase phenocrysts from quenched rims have CO_2/H_2O ratios of 1:1. These results are similar to analyses of basaltic samples from the Mariana Trough (a back-arc basin). Generally, F and Cl contents are higher and S lower in the arc rocks compared to the samples from the back-arc basin. These results favor models for the production of island arc magmas which involve melting of the subducted slab, rather than just melting of the overlying mantle wedge because of the high volatile content needed to produce island arc magmas from peridotite (10-15wt.%). The trough samples, although similar in non-volatile composition to mid-ocean ridge rocks, have much higher H_2O, somewhat higher CO_2 and lower S contents. Either near surface addition of volatiles has enriched the magmas or H_2O must be a more important component in the generation and evolution of back-arc basin lavas than in the genesis of mid-ocean ridge basalts. (Authors' abstract)

LONDON, David and BURT, D.M., 1979, Processes of formation and distribution of eucryptite in lithium pegmatites (abst.): Eos, v. 60, p. 417.

Eucryptite, $LiAlSiO_4$, is the rarest of the three lithium aluminosilicates; it is also the most difficult to recognize due to its resemblance to quartz. The following processes have been proposed to account for the formation of eucryptite in lithium pegmatites: (1) Massive eucryptite (as at the Tanco pegmatite, Bernic Lake, Manitoba) may form due to the incongruent solubility of spodumene in an aqueous fluid phase (i.e., silica leaching: Stewart, 1978). (2) Rare intergrowths of eucryptite + quartz (as at Bikita, Rhodesia) led Burt et al. (1977) to propose that this assemblage is stable at relatively low P and T and may form by the isochemical breakdown of spodumene (with decreasing P) or petalite (with decreasing T). (3) More common intergrowths of eucryptite + albite pseudomorphing spodumene (as at Branchville, CT) result from Na-Li ion exchange (Brush and Dana, 1880): $2LiAlSi_2O_6+Na^+ = LiAlSiO_4+NaAlSi_3O_8+Li^+$.

The absence of eucryptite in most lithium pegmatites apparently is due to (1) its instability with quartz at moderate to high P and T, (2) its relative instability in F and P-rich acid fluids, in which the stable assemblage is spodumene + amblygonite (or montebrasite): $2LiAlSiO_4+K^++2H^+ = KAl_3Si_2O_{10}(OH)_2+3Li^+$. When combined with the Na-Li exchange reaction written above, this last reaction yields the albite + muscovite pseudomorphs after spodumene that Brush and Dana called cymatolite. (Authors' abstract)

LONSDALE, Peter, 1979, A deep-sea hydrothermal site on a strike-slip fault: Nature, v. 281, p. 531-534.

Submersible exploration of a young scarp in the San Clemente fault zone, at 1,800 m in the California Borderland, discovered tall piles of hydrothermal barite and dense colonies of large benthic animals. Phenomena along this active strike-slip fault zone resemble those at hot springs along the axes of mid-ocean ridges. (Author's abstract)

LOVELL, J.S., 1979, Gas chromatographic determination of sulfur gases, hydrocarbons, carbon dioxide and water in fluid inclusions (abst.): Program of Fourth Meeting of the Geological Societies of the British Isles, Univ. Sheffield, Sept., 1979 (unpaginated). Author at Imperial College, London SW 7.

Gas chromatography has been applied to the determination of volatiles of fluid inclusions in a suite of foetid barytes samples from Western Australia. The samples smell strongly of hydrogen sulfide when they are broken or scratched and have been shown to contain up to 4100 ppm sulfur gas by volume, by mass spectrometry.

The volatiles were released from the samples by crushing them in a sealed glass and PTFE ball-mill. The gaseous products in the headspace of the mill were transferred to the chromatograph using a gas-tight glass and PTFE syringe. The analysis was performed on a Tracor GC560 machine fitted with either a combined flame photometric/flame ionization detector or a thermal conductivity detector.

Speciation of the sulfur and hydrocarbon gases relied on the use of a specially treated Porapak QS column. The samples showed great variablilty in the sulfur gas detected, both quantitatively and qualitatively. This was presumably due to the observably great variation in the distribution of the inclusions themselves. Hydrogen sulfide was positively identified as the principal sulfur gas, but carbon oxysulfide was detected in appreciable quantities in some specimens. Carbon disulfide was commonly present in very trace amounts. The sulfur gases were not determined quantitatively.

Methane was released from all of the samples and other, higher molecular weight, species were given off when the crushed samples were heated in the mill. However, although the column effectively resolves these components, this is not its normal function and therefore it has not been characterized for hydrocarbons and the species cannot be positively identified. However, it is probable that organic species ranging up to C_7 or C_8 were detected.

The quantities of carbon dioxide evolved from the samples varied between 17 and 468 ppm, by weight. Duplicate analyses showed variations of up to 50% and to obtain a meaningful estimate of the average CO_2 content would require numerous replicate analyses combined with grain size distribution determinations on the crushings.

It is possible to determine water chromatographically using a thermal conductivity detector and a Porapak N column, but the upper limit of detection is restricted by the concentration in the vapor phase of saturated water vapor. It is therefore necessary to ensure that the samples do not release more than 16μ* of water per ml. of headspace. Furthermore, atmospheric air always contains an appreciable concentration of water vapor, further limiting the analytical range and leading to high blanks. In order to eliminate this the head-space above the sample should be filled with dry air. This has yet to be carried out at Imperial College, but the necessary equipment is currently on order.

The study of fluid inclusions is outside the author's normal area of investigation but the object of this paper is to demonstrate the potential of gas chromatography as an analytical tool as a rapid, sensitive and specific method for the determination of volatiles of fluid inclusions. (Author's abstract) *μg?

LU, Huanzhang, YU, Cimei and SHI, Jixi, 1979, Preliminary study of the inclusions in the Jilin Meteorite, in Collected works on the Jilin Meteorite: Beijing, Science Press, p. 134-138 (in Chinese with English abst.).

LUCE, R.W. and HEMLEY, J.J., 1979, Equilibria involving talc, tremolite, diopside, wollastonite, and quartz in chloride solutions at 2 KB, 500-700°C: EOS, v. 89, p. 421.

LUCKSCHEITER, Berthold and PAREKH, P.P., 1979, A new method for the determination of dissolved elements in fluid inclusions: Neues. Jb. Mineral. Mitt., 1979, no. 3, p. 135-144.

The chemical composition of fluid inclusions in fissure quartz crystals from the Tauern Window have been determined by non-destructive neutron activation analysis. Three cylindrical samples were drilled out at pre-selected sites from each of the 4 quartz specimens studied yielding samples with varying amounts of fluid inclusions. After cleaning, the samples irradiated at first for 0.2 hours to determine the elements Na and Cl. After a second irradiation of 2 hours the elements Na, K, Mn, As and Br were analyzed. Reasonably constant ratios Na/Cl and Cl/Br observed in each of the 3 drilled samples indicated that the analyzed elements are almost totally associated with the fluid in the inclusions.

Since neutron activation analysis is not so sensitive for the determination of alkaline earths Mg and Ca at concentration levels generally encountered in the fluid inclusions, these samples were further analyzed destructively for these two elements by the usual "Extraction" procedure. Na and K were additionally analyzed to cross check our neutron activation results. The K/Na ratios determined by the two methods showed good agreement. (Authors' abstract)

LYAKHOV, Yu.V., 1979, On a morphology of near-vein aureoles of hydrothermal steam saturation within ore-fields in Transbaikalia, according to decrepitation data: Mineral. Sbornik, v. 33, pt. 1, p. 41-50 (in Russian).

In the neighborhood of the quartz-sulphide veins were observed decrepitation anomalies of width 50-60 times that of the ore body thickness. The anomaly consists of a decrepitation minimum in the selvage, and a decrepitation maximum in the altered zone. The anomaly intensity is of the greatest prospecting significance, while its structural peculiarities can be used for estimation. (Author's abstract)

LYAKHOV, Y.V. and IVASIV, S.M., 1979, Characteristic physico-chemical formation conditions of the gold-quartz deposits of Transcaucasia: Mineral. Sb. (Lvov. Gos. Univ.), v. 33, pt. 2, p. 99-103 (in Russian; English abstract).

Th for quartz and calcite from various stages were as follows: quartz-pyrite-arsenopyrite-magnesite 275-365°C; quartz-sulfantimonides and tellurides (main ore stage) 195-240°C; quartz-antimonite-carbonate 50-220°C. Highly saline fluids, (high in Na and Cl), at P$\leq$200 atm, with some early boiling. (E.R.)

McDONALD, J.A., 1979, Sourcelines, sourceregions, and pathlines for fluids in hydrothermal systems related to cooling plutons-a discussion: Econ. Geol., v. 74, p. 1511-1513.

A discussion of a paper by Norton (1978; see Fluid Inclusion Research--Proceedings of COFFI, v. 11, p. 154). Reply by Norton on following pages (1513-1517). (E.R.)

MacDONALD, R.H., 1979, Occurrence and characteristics of polymineralic silicate inclusions in chromite grains, Eastern Bushveld complex (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 470.

Chromitites and chromite bearing silicate rocks in the Critical Zone of the Eastern Bushveld complex contain chromite grains with polymineralic silicate inclusions. An individual chromite grain may contain one or more than one inclusion ranging from less than 10 µm to at least 156 µm in diameter. Inclusions occur in all parts of chromite grains, but most commonly are centrally located. Cracks in chromite extend outward from some inclusions. The percentage of chromite grains containing inclusions varies; for most samples, less than 2 percent of chromite grains contain inclusions. Inclusions contain one or more silicate minerals in various proportions, with or without sulfides and rutile. Phlogopite, orthopyroxene, and amphibole are the commonest silicates, but sodic plagioclase and quartz are also present. All minerals found in inclusions also occur as intercumulus minerals in host rocks but in different proportions. Inclusions are richer in phlogopite and amphibole. Four possible mechanisms of origin of the inclusions are examined. 1. Inclusions acted as nucleation centers for chromite crystallization. 2. Inclusions formed from crystallization of fluids trapped during the process of crystal growth. 3. Inclusions are crystallized immiscible silicate-rich liquids isolated in the centers of chromite grains by crystallization of chromite from the outside inward. 4. Inclusions formed by replacement. Replacement is the only mechanism which is consistent with all of the observed features of the inclusions. (Author's abstract)

McDUFF, R.E. and EDMOND, J.M., 1979, Sulfate and chloride in Galapagos Rift hydrothermal vent waters (abst.): Eos, v. 60, p. 864.

MACER, R.J., 1978, Fluid inclusion studies of fluorite around the Organ Cauldron, Dona Ana County, New Mexico: Master's thesis, Univ. of Texas at El Paso, El Paso, TX, USA.

MacGEEHAN, P.J., 1978, The geochemistry of altered volcanic rocks at Matagami, Quebec: a geothermal model for massive sulphide genesis: Canad. J. Earth Sci., v. 15, p. 551-570.

Suggests a geothermal model for massive sulphide genesis, where Fe, Mg, Ti, Cu and Zn were leached from footwall rocks, flushed through a geothermal system, and then precipitated at the discharge point to form chlorite alteration zones in the overlying rhyolite and exhalite deposits at the sediment-seawater interface. (From the author's abstract)

MACK, Seymour and FERRELL, L.M., 1979, Saline water in the foothill suture zone, Sierra Nevada Range, California: Geol. Soc. Amer. Bull., Pt. 1, v. 90, p. 666-675.

Thirty-one wells yielding sodium chloride water and dissolved solids averaging 1,300 mg per liter have been drilled into granitic rocks of the western Sierra Nevada foothills of Fresno and Madera Counties, California. Their chemistry contrasts sharply with that of thousands of other wells tapping granitic rocks in the area which yield good quality bicarbonate water that is low in dissolved solids. The sodium chloride wells are along a N30°W, 85-km-long trend, herein referred to as the "foothill lineament." (From the authors' abstract)

McKENZIE, W.F. and HELGESON, H.C., 1979, Calculation of the dielectric constant of H_2O and the thermodynamic properties of aqueous species at temperatures to 900°C (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 476.

Experimental quartz solubilities (Anderson and Burnham, 1965) together with the equation of state for aqueous species proposed by Helgeson and Kirkham (1976), Walther and Helgeson (1977), and Helgeson, Kirkham, and Flowers (1979) were used to calculate the dielectric constant of H_2O (ε_{H_2O}) at pressures and temperatures greater than those for which experimental measurements (Heger, 1969) are available ($0 \leq T \leq 550°C$). Estimates of ε_{H_2O} computed in this way for 2 kb range from 9.6 at 600°C to 5.4 at 800°C. These values are ~ 0.5 greater than those calculated by Quist and Marshall (1965). The estimates of ε_{H_2O} and its partial derivatives with respect to pressures and temperature permit provisional calculation of the thermodynamic properties of Mg^{++}, Ca^{++}, and other ionic species at temperatures to 900°C. These properties were combined with experimental buffer data (Chou and Frantz, 1977; Frantz and Popp, 1978; Gunter and Eugster, 1978) to generate dissociation constants (K) for HCl, $MgCl_2$, and $CaCl_2$ at high pressures and temperatures. As expected, log K for these species decreases with increasing temperature and/or decreasing pressure. The calculations permit estimation of the total concentrations of magnesium and calcium in hydrothermal fluids coexisting with high-grade metamorphic rocks and/or silicate melts at high pressures and temperatures. Conversely, they can be used to relate fluid inclusion analyses to equilibrium activity diagrams generated from thermodynamic data for minerals and the estimated thermodynamic properties of ionic species at temperatures ≤ 900°C. (Authors' abstract)

McKIBBEN, M.A., 1979, Sulfide minerals in the Salton Sea geothermal system, Imperial Valley, California (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 91.

A discussion of the mineralogy and S isotopic data in light of the temperatures and compositions of the Salton Sea metal-rich chloride brines. (E.R.)

McLAUGHLIN, R.J., SORG, D.H., MORTON, J.L., BATCHELDER, J.N., LEEQUE, R.A., HEROPOULOS, C., OHLIN, H.N. and NORMAN, M.B., II, 1979, Timing of sulfide mineralization and elimination of the San Andreas Fault at Point Delgada, Calif.: Eos, v. 60, n. 46, p. 883.

Fluid inclusions in the vein quartz have low to moderate salinities and filling temperatures of 230° to 270°C. Based on the curves of Haas, depth of mineralization must have been greater than 600 meters. Adularia in the vein assemblage has a K-Ar age of 13.8 ± 0.4 m.y., which is also a minimum age for the northeast-striking fault set. (From the authors' abstract)

McLIMANS, R.K., 1979, Geologic, fluid inclusion, and stable isotope studies of the Upper Mississippi Valley zinc-lead deposits of southwest Wisconsin (abst.): Program, 108th AIME Annual Meeting, New Orleans, Feb. 18-22, 1979, p. 21.

Sphalerite in the ores studied is multibanded. Based on color and textures, bands in samples separated by a few kilometers may be correlated. Darkness of color is directly related to iron content. Isotopic and fluid inclusion data indicate that temperatures of ore deposition were 225°C-50°C. The agreement between these two sets of data suggests that chemical and isotopic equilibrium were established. The salt content and hydrogen and oxygen isotopic compositions are similar to present day values of oil field brines suggesting a similar mode of origin. Ore transport and deposition are not adequately explained by either chloride or bisulfide complexing. Necessarily, other mechanisms were involved. (Author's abstract)

MCLIMANS, R.K.,1979, Geologic, fluid inclusion, and stable isotope studies of the upper Mississippi valley zinc-lead deposits of southwest Wisconsin. A.I.M.E. preprint 79-91, 4 p.

See McLimans, 1977b, in Fluid Inclusion Research--Proc. COFFI v. 10, p. 165-166.

MACQUEEN, R.W. and THOMPSON, R.I., 1978, Carbonate-hosted lead-zinc occurrences in northeastern British Columbia with emphasis on the Robb Lake deposit: Can. J. Earth Sci., v. 15, no. 11, p.1737-1762.

Several thermometric methods give rather discordant data for this Mississippi Valley-type(?) deposit: bitumen analysis, illite crystallinity, Th of fluid inclusions in "associated" quartz, and estimates from assumptions as to depth of burial and geothermal gradient. Two discussion papers (and following replies) published: Haynes, 1979, v. 16, p. 1641-1642; and Sangster, 1979, v. 16, p. 2063-2066. (E.R.)

MACQUEEN, R.W. and THOMPSON, R.I., 1979a, Carbonate-hosted lead-zinc occurrences in northeastern British Columbia with emphasis on the Robb Lake deposit: Reply: Can. J. Earth Sci., v. 16, p. 2067-2068.

A reply to Sangster, 1979 (this volume) concerning Macqueen and Thompson, 1978, (this volume). (E.R.)

MACQUEEN, R.W. and THOMPSON, R.I., 1979b, Carbonate-hosted lead-zinc occurrences in northeastern British Columbia with emphasis on the Robb Lake deposit: Reply: Can. J. Earth Sci., v. 16, p. 1643-1644.

A reply to Haynes, 1979 (this volume) concerning Macqueen and Thompson, 1978, (this volume). (E.R.)

MAKAGON, V.M., 1978, Role of carbon dioxide in formation of muscovite and rare-metal pegmatites: Uglerod Ego Soedin. Endog. Protsessakh Mineraloobrz., Izd. Naukova Dumka, Kiev, USSR, p. 82-85 (in Russian).

Indexed under fluid inclusions. (E.R.)

MAKRIGHINA, V.A., 1979, The evolution of fluid composition in processes of metamorphism, granitization and pegmatite origin in the central Khamar-Daban: Geokhimiya Endogennykh Protessov, Sib. Anst. Geochem., Irkutsk, 1979, p. 97-102 (in Russian with English abstract).

This was an investigation of the fluid regime in a zoned metamorphic complex in central Khamar-Daban. It was found that a small amount of abyssal reduced fluids, and tectonic peculiarities, promoted degasing, and determined the incomplete reworking during metamorphism and low-level granitization, even at high P-T parameters. (Author's abstract)

MALEEV, M., 1979, Revealing of dislocations(?) in sphalerite by decoration: Univ. Sofia, Geol. Geogr. Fak., 1977-1978 (pub. 1979), v. 70, no. 1, p. 335-343 (in Russian).

Electron microscopy of crystals (of halite, sylvite and gypsum) formed on dislocations(?) on sphalerite surface (from fluid inclusions?). (E.R.)

MALININ, S.D. and KUROVSKAYA, N.A., 1979a, Experimental study of solubility of fluorite (CaF_2) in water solutions of HCl-NaCl at 25 to 90°C: Geokhimiya, 1979, no. 5, p. 693-703 (in Russian with English abstract; translated in Geochem. Internat., v. 16, no. 3, p. 40-49, 1979).

MALININ, S.D. and KUROVSKAYA, N.A., 1979b, A laboratory study of equilibria in the CaF_2-HCl-NaCl-H_2O system under hydrothermal conditions: Geokhimiya, 1979, no. 11, p. 1030-1036 (in Russian; translated in Geochem. Internat., v. 16, no. 6, p. 27-32, 1979).

MALINKO, S.V., LISITSYN, A.E., RUDNEV, V.V., MIRONOVA, O.F., SEMENOV, Yu.V. and KHODAKOVSKII, I.L., 1979, Physicochemical parameters of the formation of commercial borosilicate ore mineralization, in Major parameters of natural processes of endogenetic ore formation, V.A. Kuznetsov, ed.: Novosibirsk, Izdat. Nauka, v. 1, p. 98-106 (in Russian). [Dokl. Vses. Soveshch., 1977]

Borosilicate mineralization in the Maritime Territory and Tadzhikistan is localized in calcareous skarns but had a post-skarn hydrothermal origin. The fluid inclusions in borosilicate and quartz of these deposits contained CH_4 traces-63 and CO_2 0.2-26.5 mol/LH_2O. IR spectroscopy of carbonaceous matter in danburite and datolite indicate salts of org. acids, either mixed with or contg. aliph. hydrocarbons. Based on fluid-inclusion studies the mineral-forming solns. in general had a Cl-HCO_3-$Na+$ compn., and the mineral-forming temps. were danburite 285-424, datolite 265-420, quartz 210-395, and calcite 165-365°C. Calcns. of the thermodn. equil. between datolite and danburite at 25-300°, show widening of the stability field of danburite with increasing acidity and of datolite with increasing Ca^{2+} activity in soln. Maintenance of geochem. conditions for borosilicate formation developing large com. deposits can only occur in a high-temp. skarn setting. (C.A. 92:61973r)

MAL'KOV, B.A., 1978, Principles of calculation of thermodynamic conditions of diamond formation on the basis of studies of the system diamond-crystalline inclusion, (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 1, Thermobarogeochemistry in geology: Vladivostok, Acad. Sci. USSR, p. 181-182 (in Russian). Author at the Ukhta Industrial Inst., Ukhta, USSR.

"Mineral-prisoners" (crystal incs.) in diamonds yield the remnant tension equal 0.9-22.7 kbar at room T, connected with different elasticity and thermal expansion of diamond and crystal incs. Analysis of epitaxy of diamond and syngenetic crystal inclusions resulted in crystallophysic method of calculation of thermodynamic conditions of diamond formation. Calculations show that diamonds crystallized under P70-90 kbar (i.e. depth 220-280 km), where diamond might form epitaxial intergrowths with forsterite, pyrope, chromite etc. Diamonds crystallized from ultramafic or mafic (eclogitic) melt that consolidated in upper mantle under conditions of the diamond-pyrope facies. Appropriate melt might exist at $T > 1500°C$, probably at 1700-2000°C. Crystallophysical calculation of time of formation of crystal inclusions with octahedral habit, very frequent in diamonds, revealed that those inclusions might have formed during unlimited time, even as long as 10^9 years, under mantle conditions. The mineral assemblage of eclogite type found in crystal inclusions proves that diamonds are xenocrysts in kimberlites. (From the author's abst., A.K.)

MAL'KOV, B.A. and ASKHABOV, A.M., 1979, Nitrogen segregations (platelets) in diamond crystals, produced by diamond annealing in the mantle: Dokl. Akad. Nauk SSSR, v. 248, p. 1420-1423 (in Russian; translated in Dokl. Acad. Sci. USSR, v. 248, p. 179-181, 1981).

MAL'KOV, B.A. and BOBOLOVICH, G.N., 1979, Genesis of kimberlite as shown by study of inclusions in calcite and apatite: Akad. Nauk SSSR, Doklady, v. 234, no. 2, p. 436-439 (in Russian; translated in Dokl. Acad. Sci. USSR Earth Sci. Sect., v. 234, p. 181-184, 1979).

Abstract in Fluid Inclusion Research--Proceedings of COFFI, v. 10, p. 170, 1977. (E.R.)

MANAKOV, A.V., 1979a, On mechanism of liquation in silicate systems: Akad. Nauk SSSR Doklady, v. 246, no. 4, p. 942-946 (in Russian; translated in Dokl. Acad. Sci. USSR, v. 246, p. 102-105, 1981). Author at the Tomsk

State Univ., USSR.

The paper is almost identical to one published Akad. Nauk SSSR Doklady, v. 244, no. 6, p. 1461-1464, 1979 (but not referenced here). (See next item.) (E.R.)

MANANKOV, A.V., 1979b, On the mechanism of microliquation in silicate melts and glasses: Dokl. Akad. Nauk SSSR, v. 244, p. 1461-1464 (in Russian; translated in Dokl. Acad. Sci. USSR, v. 244, p. 128-131, 1981).

Five melts were studied, that were stoichiometrically equal to pyroxene solid solutions bearing Ca-tschermakite molecule from 10.7 to 31.1 mol.%. Chemical compositions of melts were in wt. %: SiO_2 41.4-50.1, TiO_2 0.3-1.3, Al_2O_3 9.9-14.9, Fe_2O_3 2.8-8.9, Cr_2O_3 0.1-1.97, FeO 0.7-3.1, MgO 3.5-12.3, CaO 16.4-30.1, Na_2O 0.1-4.3, K_2O 0.8-1.0. Melting was made in alumina vessels of volume 50-700 cm^3. Melts after 1.5-2 hour run at 1400°C reach optical homogeneity. Refractive indices of the obtained glasses were 1.604-1.658 depending on compositions. By IR absorption bands were found, attributable to the strongest bands in monoclinic pyroxenes, proving the achievement of some degree of long distance order. Electron microscopy studies (magn. 55,000x) revealed point and spheroidal immiscibility structures 200-600Å in size. Structural microdifferentiation and liquidus temperature increase when the melt become more basic. Calcination of glass between 500°C and softening T equal 700-750°C, causes metastable pre-crystallization liquation. (Abst. by A.K.)

MANON, M.A., SANCHEZ, A.A., FAUSTO, L.J., JIMENEZ, S.M.E., JACOBO, A.R. and ESQUER, P.I., 1979, Preliminary geochemical model of the Cerro Prieto geothermal field: Geothermics, v. 8, p. 211-222. Authors at Comision Federal de Electricidad, Coordinadoro Ejecutiva de Cerro Prieto, Mexicali, B.C., Mexico.

The distribution of the Na-K-Ca index values in the geothermal aquifer of Cerro Prieto indicates a probable cold-water recharge in the northern and western parts of the present producing field. In the central part of the field, the distribution of Na-K-Ca values is very irregular, due to the effect of percolation of the vertical descending flow of colder waters caused by apparent over-exploitation.

The large area with indices varying between 0.5 and 0.7 to the east, southeast, and south of the field confirm the presence of hotter geothermal waters than those observed in the present producing field. The limits of this hot aquifer have not yet been determined toward the east and southeast.

The temperature distribution in the Cerro Prieto aquifer confirms the conclusions reached using the Na-K-Ca index. The maximum temperature calculated was well M-53 (350°C) and the minimum was in M-9 (250°C), when wells M-6 and M-1A, which have lower temperatures, are not taken into account.

The chloride distribution in the aquifer confirms the recharge of colder, less saline waters in the northern and western parts of the field. It was surprising to find that the chloride content in the aquifer was lower in the eastern part (M-53) than in the present field, even though the temperature is higher. Another interesting fact is the extremely low chloride content found in well M-101, with temperatures around 290°C.

The distribution of potassium and silica in the aquifer was not as useful for the interpretation of fluid movement as originally expected.

Discrepancies were found with respect to the interpretations based on the Na-K-Ca index and the chloride content.

In regard to the changes in the Na-K-Ca index, in temperature, and in chloride content during the exploitation of the field, a gradual increase in Na-K-Ca index values was observed in wells with high and low enthalpy. In exceptional cases these values decrease or remain constant. This increase in the index has represented a 10 to 20°C temperature decrease with respect to the original values existing at the beginning of the exploitation of the field (1973). The chloride content in the aquifer has decreased at different rates, from 670 mg/l per year in M-26 to 371 mg/l per year in well M-42, even though in some wells (M-20) it has increased and in others (M-5) it has remained almost constant.

In order to decrease the rate of temperature and pressure reduction in the present producing field, it is recommended that production of low enthalpy wells be suspended and be replaced by new wells located in the periphery of the field, preferably to the southwest and northeast. Thus, the production area would at least be doubled, in an attempt to avoid the percolation or vertical flow, which is apparently causing the cooling of the reservoir.

Another measure, which could help prevent a rapid drawdown, is to exploit the deeper hot aquifers that apparently exist in the center of the field. This would first have to be confirmed by an exploratory well or by deepening one of the present wells. (Authors' abstract)

MANUCHARYANTS, B.O., PRUSHINSKAYA, E.Ya., and VLADIMIROV, V.G., 1979, Some data on the nature of hydrothermal solutions forming gold and gold antimony ore mineralization in Yakutia, in Major parameters of natural processes of endogenetic ore formation, V.A. Kuznetsov, ed.: Novosibirsk, Izdat. Nauka, v. 2, p. 210-220 (in Russian). [Dokl. Vses. Soveshch., 1977]

Fluid inclusion studies, including chromatog. anal. of the gas (CO_2 and CH_4) in the inclusions, were done on quartz from Au quartz-stibnite and Au quartz-low sulfide formations. The former originated at 170-320° and 500-1800 atm. In this ore formation early stage quartz veins formed at 230-320° and 700-1800 atm, whereas mineral assocns. of the stibnite stage formed at 170-250° and 500-1250 atm, and quartz veins with stibnite and native Sb crystd. at 250-350°. The ore mineralization of the A quartz-low sulfide formation originated at 170-370° and 900-2100 atm. The productive mineral assocns. of both formations were sepd. at 170-280°, in general agreement with the formation temp. of Au deposits in the Soviet Far East, as given by V.G. Moiseenko (1976). The minerals formed from slightly oxidizing nearly neutral solns. at Eh -0.05 to -0.08 and -0.45 to -0.6 for the Au quartz-low sulfide and Au quartz-stibnite formations, resp. (C.A. 92:62003m)

MARAKUSHEV, A.A., IVANOV, I.P. and RIMKEVICH, V.S., 1979, The significance of liquation in the genesis of magmatic rocks: Vestnik Moskovskogo Universitetta. Geologiya, v. 34, no. 1, p. 3-22 (in Russian; translated Moscow Univ. Geol. Bull., v. 34, no. 1, p. 1-19, 1979).

This article presents the experimental results of dissociation of acidic and alkalic melts with the addition of fluoride components to them (without water and with water pressure). These experiments, along with petrographic materials and a survey of the literature lead to the conclusion that liquational phenomena are more common in petrogenesis than has previously been thought. Liquation is characteristic of fluid magmatic systems, in contrast to silicate systems lacking volatile components. The course of magmatic evolution is marked by the differentiation of melts rich in fluid components, in which ore metals are concentrated. Their subsequent crystallization leads to separation of the fluid and the rise of hydrothermal ore-forming systems. (Authors' abstract)

MAR'IN, A.A. and DOROGOVIN, B.A., 1978, Influence of mineralizer on the homogenization temperature of inclusions, (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 1, Thermobarogeochemistry in geology: Vladivostok, Acad. Sci. USSR, p. 194 (in Russian). Authors at All-Union Sci.-Research Inst. of Synthesis of Artificial Raw Materials, Alexandrov, USSR.

Hydrothermal crystallization in the system $LiOH-Bi_2O_3-SiO_2-H_2O$ was carried out under isothermal and isochoric conditions. Following crystals were obtained: $Bi_{12}SiO_{20}$, bismite $\alpha-Bi_2O_3$, and Li_7BiO_6 (the original text has erroneous formulae: "$B_{12}SiO_{20}$, $-B_2O_3$ and $LiBo_6$" - A.K.). Bismuth silicate crystallized first, and next (contemporaneously) bismite and lithium bismuthate. Th of inclusions in bismuth silicate is constant at 280°C, in bismite and lithium bismuthate Th changes from 275°C in the center of crystals to 240°C in the marginal parts. That decrease may be explained by linking of mineralizer in lithium bismuthate, connected with decrease of solution concentration. Similar effect of concentration decrease may appear in natural crystals grown under isothermal and isochoric conditions. (Authors' abst., transl. by A.K.)

MARKHININ, Ye.K., URAKOV, V.A. and PODKLETNOV, N.Ye., 1977, Hydrocarbons in gases of basalt lava streams of the Tolbachik fissure eruption in 1975 and 1976: Doklady Akad. Nauk SSSR, v. 236, no. 5, p. 1214-1217 (in Russian; translated in Doklady Acad. Sci. USSR, Earth Sci. Sects., v. 236, p. 211-214).

Abstracted in Fluid Inclusion Research--Proceedings of COFFI, v. 10 p. 172. (E.R.)

MATKOVSKIY, O.I., 1978, Estimate of the temperature of metamorphic mineral formation by means of various methods of thermometry, in Thermobarogeochemistry of the Earth's Crust and Ore Formation, N.P. Ermakov, ed., Izd. Nauka, p. 89-96 (in Russian).

Indexed under fluid inclusions. (E.R.)

MATKOVSKIY, O.I., YASINSKAYA, A.A., STEPANOV, V.B., ZAYTSEVA, V.N., PUKACH, B.V. and SKATYNSKIY, Y.P., 1979, Gold-telluride-sulfide mineralization in ancient metamorphic formations: Mineral. Sb. (L'vov. Gos. Univ.), v. 33, Pt. 2, p. 37-43 (in Russian).

Indexed under fluid inclusions. (E.R.)

MATSUHISA, Yukihiro, GOLDSMITH, J.R., and CLAYTON, R.N., 1979, Oxygen isotopic fractionation in the system quartz-albite-anorthite-water: Geoch. Cosmo. Acta, v. 43, p. 1131-1140.

MATTHEWS, Alan and BECKINSALE, R.D., 1979, Oxygen isotope equilibration systematics between quartz and water: Amer. Min. v. 64, p. 232-240.

First author at Dep. Geol. Hebrew Univ. of Jerusalem, Israel.

The $^{18}O/^{16}O$ fractionation accompanying the hydrothermal crystallization of quartz from silicic acid at 265°-465°C has been studied in order to assess the influences of (a) rate of quartz formation, (b) the nature of the reaction mechanism, and (c) temperature. At 360° and 465°C there are no indications of rate effects influencing isotope partitioning, but at 265°C (where fractionation factors show an unusually large scatter) the evidence is inconclusive in this respect. All reaction appears to occur through solution-precipitation processes, with the intermediate phases, cristobalite and silica K, giving identical fractionation factors (within experimental errors) to quartz samples formed at the same temperature. The temperature-dependence of fractionation in the range 265°-465°C is given by the equation

$$10^3 \ln \alpha (SiO_2-H_2O) = 3.05 \times 10^6 T^{-2} - 2.09$$

The data are in good agreement with other experimental calibrations of the quartz-water fractionation. (Authors' abstract)

MAZOR, E. and MANON, M.A., 1979, Geochemical tracing in producing geothermal fields: a case study at Cerro Prieto: Geothermics, v. 8, p. 231-240. First author at Weizmann Inst. Sci., Rehovot, Israel.

Over 750 detailed chemical analyses of fluids, collected from 30 geothermal wells over 12 years of operation, were accumulated at Cerro Prieto, Mexico. These results are used as a case study to establish the physical and chemical processes taking place and to construct a geochemical model of the resource. A knowledge of these processes is a prerequisite for conducting successful isotope studies.

The following regularities and correlations were observed in the geothermal wells of Cerro Prieto.

1. The concentrations of Cl, Na, K, Li, Ca, B, HCO_3, and SiO_2 in individual wells vary by factors of up to 2. (A common range for Cl is, for example, 10,000-20,000 mg/l). A similar range is observed when the maximum ion contents of all the wells are compared.

2. A positive correlation is observed between the Cl content and the concentrations of Na, K, Li, Ca, B and SiO_2 in individual wells and throughout the field. Comparison of all the wells also revealed positive correlations of the concentrations of Cs, Rb and Br.

Patterns (1) and (2) are due to concentration - dilution processes, such as steam loss or mixing with condensed steam and possibly fresher water from a shallow aquifer.

3. In most wells a consistently lower Cl content (about 10,000 mg/l) is observed. This value suggests the salinity of the deep-seated brine, all higher values being caused by steam losses. These steam losses seem to occur both in the aquifer and in the wells.

4. The plots of the various ions vs Cl reveal a conservative pattern in the data of the individual wells (i.e., best-fit lines extrapolate to zero). This indicates that no significant chemical reactions occur during the ascent of the fluids in the wells. In contrast, K and SiO_2 plots of the different wells reveal a reactive pattern both when plotted against the Cl content and enthalpy. Hence, these ions are reactive in the aquifers, responding to temperature zonations. This pattern makes the K (or Na/K) and the SiO_2 values useful as geothermometers in the Cerro Prieto system.

5. The above regularities are best ascribed to one type of brine existing at Cerro Prieto, with a Cl content of around 10,000 mg/l, and a

temperature zonation. The variety in the observed samples is caused by steam losses (partially caused by production conditions such as diameter of the well orifice) and by K and SiO_2 equilibrations at different temperatures in the geothermal system. (Authors' abstract)

MEL'NIKOV, F.P. and MITIN, S.N., 1978, Studies of gas-liquid inclusions in halite from Upper Jurassic evaporite formations in East Kuban' and Chernoles depressions (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 50-51 (in Russian). Authors at Moscow State Univ., Moscow, USSR.

The studied areas are intraplatform depressions and the evaporite formation is a huge lens of rocks consisting of anhydrite and intercalations of halite and limestone. The beds outcrop in the southern part but they are as deep as 5 km in the northern part. Grain size of halite reaches 2 cm, and halite is completely recrystallized. Over 500 slides from 70 samples collected in 8 areas were investigated. One-, two- and three-phase inclusions were found in halite. Samples from a given depth bear approximately the same G/L phase ratio. Th of 200 inclusions range from 50 to 90°C for salts in East Kuban' and from 75 to 100°C for halite from Chernoles. Repeated Th measurements gave essentially the same results. Th reflects T of halite recrystallization. At the site inclusions from deep are homogeneous. (From the authors' abstract, transl. by A.K.)

MELTON, D.C., Jr. and PROCTOR, P.D., 1979, Minor fringe Mississippi Valley-type mineral deposits, south-central Missouri (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 163.

Small base metal deposits in south-central Missouri are intermediate to the Tri-State district and the New Lead Belt. Intermittent mining from the late 1800's until the present resulted in insignificant production. The deposits occur in carbonate rocks of Mississippian (Kinderhookian) and Ordovician (Canadian) age. Fractures and breccias associated with northwest trending high-angle normal faults are the dominant mineral controls, and locally prepared the host rock for mineralization. A definite spatial change occurs in metal values and host rock preference. Simple mineralogy of the deposits is dominated by sphalerite and galena with gangue of pyrite, marcasite, calcite, dolomite and quartz. Minor amounts of chalcopyrite, bornite, covellite and greenockite are also present. Oxidation products include smithsonite, cerussite, geothite and hemimorphite. Typically, sphalerite deposition was followed closely by galena, then the iron sulfides. Calcite usually terminated deposition. Major host rock alteration is absent. Fluid inclusions in sphalerite yielded homogenization temperatures from 61-161°C, but mainly in the 70-110°C range. The temperatures suggest both spatial and temporal changes in ore fluids. Simple mineralogy and paragenesis, dominant structural control, weak mineralization and alteration, and relatively low homogenization temperatures suggest possible fringe-type mineralization. (Author's abstract)

MERCHANT, R.J., 1978, Metallogenesis in the Thames-Tapu area, Coromandel peninsula NZ. Ph.D. Thesis Univ. Auckland, NZ.

The Thames-Tapu area is conventionally regarded as a gold-silver province, within the Hauraki gold-silver province; other metals present have been regarded as minor constituents. However, within this area, a regional metallogenic zonation of lead, zinc and copper about molybdenite bearing centers is recognized. This mineralization is interpreted as a manifestation of a high level porphyry molybdenum deposit which formed at the depth of approximately 2km in a greywacke dacite-andesite pile. The proposed mechanism of mineralization is as follows:-

(1) Molybdenum ore shells were emplaced at shallow depths after intrusion of the dacite-quartz diorite porphyry stocks. Molybdenum was deposited at temperatures of around 350°C and at pressures above 0.3 kb, from fluid of unknown salinity.

(2) Distal to the molybdenite-bearing shells haloes of pyrite-magnetite and pyrite-hematite formed.

(3) Base metal bearing quartz veins were deposited in fissure zones above the ore shell. In these, copper-bismuth mineralization took place at 350-450 (typically 370) °C at a depth of about 1.5 km under a pressure of 0.3kb (this pressure was in part lithostatic). The ore fluids were dilute Na-K-Ca-Cl brines of 2-3 wt % NaCl salinity, and were commonly boiling.

(4) Lead-zinc-telluride ore formed at temperatures of 250-320°C from slightly more saline fluids (~3% NaCl) at comparable and shallower depths under lower pressures which were dominantly hydrostatic in origin. This mineralization was telescoped upon the earlier mineralization as thermal decline took place in the system.

(5) After the main mineralization a period of uplift and erosion followed. A second mineralizing event superimposes the first. This mineralization is characterized by zoned antimoniferous assemblages occurring in cryptocrystalline quartz veins which follow a northwest fracture orientation. These crosscut, or infill open spaces in the earlier quartz veins. The deepest levels of this later event are characterized by tetrahedrite together with several sulfosalts which were deposited at least in part above 320°C. Tetrahedrite commonly replaces earlier sulfides. Gold (electrum)-pyrargyrite is found at intermediate levels and occurs in flat lying zones at depth of less than 300-400m below the present surface. Temperatures of 200-250°C are indicated for the gold deposition, and a mechanism of deposition above a boiling zone is invoked. Within this zone rich accumulations gave rise to the Thames bonanzas. These bonanzas were clearly related to faults in the area, and these faults probably provided the mechanisms by which mixing of fluids and pressure releases took place. This disequilibrium was probably responsible for the rapid and massive gold deposition. Stibnite and barite are found at shallower levels in the system and also occasionally telescoped with a gold bearing assemblage.

A zoned acid-stable aluminous alteration cap is found in rhyolitic pyroclastics of ? Whitianga Group age that mantle the highest elevations, northeast of Thames. Assemblages of natroalunite-quartz, pyrophyllite-dickite-pyrite-quartz, dickite-pyrite-quartz and marginal zones with interlayered clay minerals comprise this cap. Andalusite and diaspore are also rarely found.

This cap is believed to be the near surface expression of a geothermal system that was responsible for the gold mineralization. A model of deep reintrusion is developed. Above these more recent plutons geothermal systems are thought to have been initiated and these were responsible for the late vein mineralization and associated alteration. In conclusion, the Thames-Tapu area is regarded as being part of a molybdenum as well as a gold-silver province; this conclusion might also apply to the entire Hauraki gold province. (From the author's abstract)

MERCOLLI, Ivan, 1979, Fluid inclusions in nodules of quartz from dolomitic marble of the Campolungo region (Ticino): PhD dissertation, Federal Polytechnic School, Zurigo; (in Italian with English abstract).

Alpine metamorphic mineralization has caused rims of tremolite, talc, and calcite to form on quartz nodules in the Campolungo dolomite marbles and a number of rare minerals to grow in the marbles. Fluid inclusions in the quartz core of the nodules have been studied with the purpose of determining the relationship between growth of new minerals and development of fluid during alpine metamorphism. Microthermometry analysis show that CO_2/H_2O in the inclusions decrease with time and that four generations of fluid inclusions have developed.

These data and studies of textural relationships and mineral chemistry permit the following reconstruction of the mineralogical evolution of the nodules:

Formation of the quartz cores in the dolomitic sediment.

Boudinage and partial remobilization of the nodules together with the formation of tremolite in siliceous layers within the dolomite during the climax of Alpine metamorphism.

Formation of postkinematic reaction rim of calcite and tremolite around the quartz cores caused by a drastic decrease in pressure and a gradual decrease in temperature.

Formation of talc pseudomorphs after tremolite.

Local formation of coarse talc grains.

Fluorine partitioning between talc and tremolite permit a revised modelling of progressive metamorphism of siliceous dolomites in the Central Alps.

Fluid inclusions and mineral paragenesis studies allow the alpine uplift history of the Campolungo area to be understood in terms of pressure and temperature. (Author's abstract)

Also includes a diagram of the physical appearance of elongated to almost equant inclusions with 10 to 90% vapor bubble, in 10% increments. (ER)

METRICH, Nicole and CLOCCHIATTI, Robert, 1979, Primary melts trapped in phenocrysts of a pantelleritic lava from Ethiopian Rift: a study of crystallization and setting processes of the flow: C.R. Acad. Sc. Paris, v. 289, p. 57-60 (in French).

The crystallized phases of the pantellerite studied: quartz, anorthoclase, hedenbergite and aenigmatite are characterized by two-phase glassy inclusions.

Optic and thermo-optic studies show that leucocrate minerals crystallized between 740 and 830°C.

The composition of the glass trapped in phenocrysts is very similar to that of the bulk rock and of the groundmass. The volatilc content is lower than 3%.

The very low temperature of crystallization can be explained by fluorine and chlorine content in initial melt (glass inclusion). (Authors' abstract)

MEYER, H.O.A., 1979, Kimberlites and the mantle: U.S. National Report, 17th General Assembly, IUGG, Canberra, Australia, Dec. 1979, Papers in volcanology, geochemistry, and petrology: Reviews of Geophysics and Space Physics, v. 17, no. 4, p. 776-787.

MEYER, H.O.A. and TSAI, Hsiao-Ming, 1979, Inclusions in diamond and mineral chemistry of the upper mantle, in Origin and distribution of the elements, Proc. of the Second Symposium, Paris, May 1977, L. H. Ahrens, ed.: Oxford, Pergamon Press, p. 631-644.

MILOVSKIY, G.A., ZLENKO, B.F. and GUBANOV, A.M., 1978, Conditions of formation of scheelite ores in the Chorukh-Dayron mineralized area (as revealed by a study of gas-liquid inclusions): Geochem. Internat., v. 15, no. 1, p. 45-52 (in English).

See Fluid Inclusion Research--Proceedings of COFFI, v. 11, p. 140, 1978. (E.R.)

MIROSHNIKOV, A.Ye., OKHAPKIN, N.A. and PROKHOROV, V.G., 1978, Decrepitation properties of rocks as indicators of their hydrothermal-metasomatic alteration, in Theory and Practice of Thermobarogeochemistry, N.P. Ermakov, ed., Izd. Nauka, p. 173-179 (in Russian).

MISHINA, N.B. and KHITAROV, D.N., 1978, Aureoles from low-temperature steaming; their correlation with endogene geochemical anomalies and the importance of their exploration, in Theory and Practice of Thermobarogeochemistry, N.P. Ermakov, ed., Izd. Nauka, p. 180-183 (in Russian).

Indexed under fluid inclusions. (E.R.)

MITIN, S.N., 1979, New data confirming the theory of sedimentary migration origin of oil: Akad. Nauk SSSR Doklady, v. 245, no. 4, p. 924-926 (in Russian. Author at the Moscow State Univ.

Th of inclusions in halite from E.-Kuban' basin are 50-90° and from Chernoles depression - 75-100°C, the T of halite recrystallization under action of water released from gypsum altering into anhydrite; P ranged from 50 to 100 atm. Clayey inclusions in halite have hydrocarbon haloes (as hydrocarbon inclusions in halite), most extensive at T≈150°C in the Koshekhabl'skaya area. (Abst. by A.K.)

MITRYAEVA, N.M., PARILOV, Yu.S. and MIKHALEVA, V.A., 1979, Conditions for the formation of Zhairem sulfide ores: Metallog. Rudoobraz., Kunaev, A.M., and Yanshin, A.L. (eds.): Alma-Ata, Izd. Nauka Kazakhskoi SSR, p. 197-209 (in Russian).

Indexed under fluid inclusions. (E.R.)

MOELLER, P., SCHNEIDER, H.J., WILKE, A., KUBANEK, P., GERMANN, K. and MORTEANI, G., 1979, Use of nuclear analysis methods for treatment of geochemical characteristic quantities for exploration of deposits: Hahn-Meitner-Inst. Kernforsch. Berlin, No. HMIOB 302, 97 pp (in German).

Indexed under fluid inclusions. (E.R.)

MOGK, D.W., 1979, Contact metamorphism of carbonate rocks at Cave Ridge, Snoqualmie Pass, Washington (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 117.

Contact metamorphism of pre-Tertiary Denny Fm marbles by the epizonal Miocene Snoqualmie Batholith (qtz monozonite) produced cc-per-(br), cc-do-fo-clinohumite ± sp, and cc-di-wo ± gar parageneses in a 1/2 mile wide aureole. These mineral assemblages show no regular spatial distribution. There is no textural evidence for prograde reactions, but retrograde reactions are common. These parageneses, together with calcite-dolomite geothermometry, indicate temperatures reached at least 600°C. Fluid inclusion analyses yield freezing points of -7 to -19°C; decrepitation studies of fluid inclusions revealed that $CO_2(g)$ constituted <30 vol% of the fluid phase. Water-rich fluids are required for brucite, grossularite, and cc-chl-bearing assemblages. A new invariant point involving the phases fo-sp-chl-br-cc-do=H_2O-CO_2 has been derived, as well as phase relations involving clinohumite. Infiltration is believed to be the primary metamorphic agent. Anastomosing veins of do, gar, gar-wo, and fo indicate at least local mass transfer of Si and Al has occurred along fractures and grain boundaries. The presence of uniform, highly saline aqueous solutions, and the ubiquitous occurrence of the fluorine-bearing phase, clinohumite, suggests that the composition of the fluid phase was externally controlled. The development of skarns at marble-metabasalt contacts, and of rodingitized mafic dikes also indicate the presence of water-rich fluids. The infiltrating fluid phase probably was responsible for: 1) early formation of dolomite veins, 2) attainment of periclase-zone thermal maximum, 3) introduction of Si and Al at high T, directly forming high-grade calc-silicate assemblages, and 4) retrogression of high-grade assemblages. (Author's abstract)

MOISEENKO, V.G., LAVRIK, N.I. and KARAULOV, S.S., 1978, Comparison of composition of gas-liquid inclusions in cassiterite of deposits associated with plutonic and volcanic rocks (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 63 (in Russian). First author at Far East Geol. Inst. of Far East Sci. Center of Acad. Sci. USSR, Vladivostok, USSR.

Gas-liquid inclusion fillings in cassiterite vary widely even in one deposit, but on the basis of many salts and gas analyses common features may also be revealed.

Two types of deposits were compared: cassiterite deposits connected with plutonic, and with volcanic rocks. The plutonic-type deposits formed by solutions low in Ca and Al and with high pH, with prevailing anions HCO_3 and Cl. In plutonic deposits reduced C compounds are most common, but in volcanic ones CO_2 prevails. (Authors' abstract)

MOISEENKO, V.G. and MALAKHOV, V.V., 1979, Physico-chemical conditions of endogene ore-formation: Moscow, "Nauka" Publishing House, 200 pp (in Russian). Authors at Acad. Sci. USSR, Far-East Sci. Center, Far-East Geol. Inst. Contents (transl. by A.K.; pages in parentheses).

Part I: METHODS OF ESTIMATION OF PHYSICO-CHEMICAL PARAMETERS OF ORE-FORMATION (5)

Chapter 1. Possibilities and limits of methods of determination of physico-chemical parameters of hydrothermal solutions by inclusions of minerals: Evaluation of temperatures and pressures of mineral-formation (from inclusions in minerals) (9); Studies of the salt composition of inclusions in minerals (11); Analysis of gas phase in inclusions in minerals (19).

Chapter 2. Analysis of gas phase of inclusions in minerals of endogene deposits by gas chromatography: Use of optimum conditions for separation of gases, typical of hydrothermal solutions, and their determination (23); Opening of inclusions and putting of the sample into chromatograph (32); Quantitative determination of gas phase in minerals (44); Emission of CO_2 from inclusions in minerals for isotope analysis (46).

Chapter 3. Determination of the salt composition of gas-liquid inclusions in minerals and calculation of the redox potential and pH of solutions from analytical data: Possible errors in determinations of liquid phase under various conditions of opening of inclusions (48); Analysis of cation and anion composition of solutions, obtained by extraction of salts from thermally opened inclusions (57); Calculation of redox potential and pH of solutions from analytical data for temperature 25-300°C (62); complex studies of chemical composition of gas-liquid inclusions in minerals (68).

Part II: ESSENTIAL TYPES AND PHYSICO-CHEMICAL PARAMETERS OF ENDOGENE ORE-FORMING SOLUTIONS (72)

Chapter 4. Thermodynamic factors and ore-forming processes: Influence of temperature and pressure on character of ore-forming fluids (73); Solubility and forms of migration of some ore components and their compounds (77); Possible forms of migration of gold and silver (78); Tin in hydrothermal solutions (83); Migration of tungsten and other metals by mineralized waters (98).

Chapter 5. Thermobarogeochemical conditions of formation of gold and gold-silver deposits: Peculiarities of hydrothermal solutions forming deposits (99); Essential causes of inhomogeneity of native gold and certain peculiarities of its chemical composition (117).

Chapter 6. Thermobarogeochemical conditions of formation of deposits of tin, tungsten, lead and zinc: Tin (128); Tungsten (152); Lead and zinc (157).

Chapter 7. Some problems of endogene ore formation and metallogeny: Role of various chemical elements in the ore-forming process (165); Anion-forming elements (166); Approximate calculation of gas equilibria in the system H-O-C (169); Alkaline and alkaline-earth metals (173); Influence of main physico-chemical parameters on endogene ore formation and metallogeny of the Pacific belt (176).

Conclusions (183); Literature (185).

MOLLER, P., MORTEANI, G., HOEFS, J. and PAREKH, P.P., 1979, The origin of the ore-bearing solution in the Pb-Zn veins of the western Harz, Germany, as deduced from rare-earth element and isotope distributions in calcites: Chem. Geol., v. 26, p. 197-215. First author at Hahn-Meitner-Inst. fur Kernforschung G.m.b.H. Berlin, D-1000 Berlin 39, ERG.

Rare-earth element (REE) and stable-isotope distribution patterns in calcites from the mining areas of St. Andreasberg, Clausthal and Bad Grund, western Harz, Germany, have been determined. Three types of REE distribution patterns were found: type I is characterized by high amounts of light REE without any Ce and Eu anomalies and relatively homogeneous C- and O-isotopic composition. Type II displays conspicuous Ce and Eu anomalies at lower levels of concentration of the light REE. Type III has very low amounts of REE. Types II and III exhibit a more variable C-isotopic composition than type I.

The calcite with type I patterns is assumed to be derived mainly from magmatic waters. A possible source for the magmatic waters seems to be the Brocken-Oker granite. Type II calcites and the sulfides are probably derived from heated country rock whereas calcite with type III pattern mineralized from relatively cold descending solutions.

The calcite with type I pattern turns out to be not in equilibrium with sulfides, although both are in intimate contact, e.g., in banded ores. This non-equilibrium indicates two independent sources for this calcite with type I pattern and the sulfides. (Authors' abstract)

MOORE, D.J., 1979, An unusual calcite from Muirshiel, Renfrewshire: Mineral. Mag., v. 43, p. 446-448.

Calcite from a barite mine near Glasgow shows various (up to 6) dms and high Th (440-480°C), and evidence of boiling. Tm ice (?) -6 to -36°C. Na/K (atomic) of water leach = 13 (in the range shown by the barite, which has low temperature, monophase inclusions. No CO_2 detected by mass spectrometry. Dms are apparently anisotropic. On SEM study, some dms show Ca-Fe-Mn, Ca-Ti-REE, Ba-S, and silicates of various composition. (E.R.)

MOORE, F. and MOORE, D.J., 1979, Fluid-inclusion study of mineralization at St. Michael's Mount, Cornwall: Trans. Inst. Min. Mettal., Sect. B, p. B57-B60. Authors at Dept. Geol., King's College, London.

Tin-tungsten mineralization shows Tm ice(?) of 2.3 to 16.0°C and Th of ~ 300-400°C. Greisen quartz and cassiterite gave the highest values of Th. Na/K (atomic) for leachates ranged from 0.55 for cassiterite to 19.6 for quartz associated with wolframite. "Daughter crystals" of a platy K-Al-Si mineral were found by SEM. (E.R.)

MOORE, J.G., 1979, Vesicularity and CO_2 in mid-ocean ridge basalt: Nature, v. 282, p. 250-253. Author at U.S. Geol. Survey, Menlo Park, California 94025.

Vesicles and included CO_2 are enriched in deep-sea basalts that are also enriched in light rare earth and incompatible elements. This enrichment probably results from a unique deep mantle origin of such melts but may have been modified by CO_2 bubbles rising in shallow magma chambers. (Author's abstract)

MORTON, R.D., AUBUT, A. and GANDHI, S.S., 1978, Fluid inclusion studies and genesis of the Rexspar uranium-fluorite deposit, Birch Island, British Columbia (Canada): Geol. Surv. Pap. (Geol. Surv. Can.), v. 78-1B, p. 137-140.

MOSKALYUK, A.A., 1979, Fluorite formation conditions, in Major parameters of natural processes of endogenetic ore formation, V.A. Kuznetsov, ed.: Novosibirsk, Izdat. Nauka, v. 2, p. 236-241 (in Russian). [Dokl. Vses. Soveshch., 1977]

A review of fluid inclusion data on fluorite deposits in the USSR. (E.R.)

MOSKOVSKIY, G.A., SIROTIN, K.M. and RUMYANTSEVA, O.P., 1978, Elucidation of geochemical conditions of formation of salt rocks of some regions in Prikaspiye on the basis of studies of inclusions in minerals (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 45-46 (in Russian). Authors at Sci.-Research Inst. of Geology of the Saratov Geol. Office, Saratov, USSR.

Inclusions were studied in salts from the potassium deposit El'ton of Kungur age, from the Baskunchak salt dome and from other regions of the Prikaspiye (i.e., outlining Caspian Sea) depression. Salts bear relics of primary hopper structures with P liquid inclusions both in deep deposits (over 5000 m) and in salt domes. The relics are preserved best in brecciated salts with anhydrite cement. Fluid inclusions proved that SO_4 concentration in brine was low (<15 or 20 g/l). Only rarely were SO_4 concentrations high enough to precipitate kieserite. Dms in hopper salt indicate possibility of occurrence of K-Mg salts. P solid-liquid inclusions yielded following Th for halite: El'ton 60°C, Baskunchak 50°C, marginal zone of the basin 48°C. Some rocks bear inclusions with dms sylvite or bischoffite and Th are then 48-70°C. Maximum Th of S inclusions are 140-179°C are probably T of maximum sinking in Earth's crust. (Authors' abstract, transl. by A.K.)

MOSKOVSKII, G.A., SIROTIN, K.M., RUMYANTSEVA, O.P. and FAINITSKII, S.B., 1979, Characteristics of the composition of halogen brine of the Kungur Basin determined from the results of the ultramicrochemical analysis of fluid inclusions: Vopr. Geol. Yuzhn. Urala i Nizhn. Povolzh'ya, Saratov, 1979, no. 18, p. 59-62 (in Russian).

See previous item. (E.R.)

MOTORINA, I.V., 1978, Temperature conditions of crystallization of some allochthonous granitic plutons according to data from a study of fluid inclusions, in Thermobarogeochemistry of the Earth's Crust and Ore Formation, N.P. Ermakov, ed., Izd. Nauka, p. 79-82 (in Russian).

MUENOW, D.W., GRAHAM, D.G., LIU, N.W.K. and DELANEY, J.R., 1979, The abundance of volatiles in Hawaiian tholeiitic submarine basalts: Earth Planet. Sci. Lett., v. 42, p. 71-76. First author at Chem. Dept., Univ. Hawaii, Honolulu, HI 96822 U.S.A.

High-temperature mass spectrometric studies have been made to determine the distribution of volatiles within glassy rims of submarine pillow basalts dredged from the east rift zone of Kilauea volcano, Hawaii. The CO_2/H_2O mole ratio for glass-vapor inclusions within olivine phenocrysts in the glassy rims is greater than 30:1 compared to 0.06 for matrix glasses. Enclosing matrix glasses contain 0.53-0.74 wt. % H_2O, 0.02-0.04 wt. % carbon, 0.08-0.12 wt. % sulfur, 0.012-0.028 wt. % chlorine and 0.012-0.077 wt. % fluorine. (Authors' abstract)

MULLIS, Josef, 1979, The system methane-water as a geologic thermometer and barometer from the external part of the Central Alps: Bull. Minéral., v. 102, p. 526-536. Author at Inst. Mineral. Petrog., Univ. Freiburg, Freiburg, Switzerland.

Fluid inclusion studies from synkinematic quartz crystals gave new insight into the fluid composition and P-T distribution of the external part of the Central Alps. Knowing the densities of methane and the minimum temperature of formation, fluid inclusions of the system CH_4-H_2O and CH_4 have been used as geothermometers and barometers. For the regional distribution the following conclusions can be drawn:

1. Fluids trapped in inclusions define zones of different fluid composition related to the zones of metamorphism:

- non-metamorphic zone: >1 mol-% higher hydrocarbons, CH_4, H_2O,

CO_2 ...

- low and medium grade anchizone: CH_4, <1 mol-% higher hydrocarbons, H_2O, CO_2 ...
- high grade anchizone and epimetamorphic zone: H_2O, CO_2 ...

2. The minimum conditions of formation for mineral clefts and their quartz crystals from the low and medium grade anchizone are 200-270°C and 1,200-1,700 bar, with geothermal gradients of 25-45°C/km.

3. From the fluid inclusion studies the following minimum P-T conditions were deduced with respect to metamorphic grade:

- non-metamorphic zone - low grade anchizone:
  $T > 200°C - P > 1,200$ bar
- medium grade anchizone - high grade anchizone:
  $T > 270°C - P > 1,700$ bar

4. The evolution of the fluids is a product of progressive metamorphism. But the fluids were trapped in quartz crystals towards the end of the nappe overthrust and during the uplift of the Alps (middle to final Miocene era). As rocks with fluid inclusions of higher grade metamorphism are found above rocks with fluid inclusions of lower grade metamorphism, their metamorphism must have taken place before the final transport of the nappes. (Author's abstract)

MURAMATSU, Y., and WEDEPOHL, K.H., 1979, Chlorine in Tertiary basalts from the Hessian Depression in NW Germany: Contrib. Mineral. Petrol., v. 70, p. 357-366. Authors at Geochem. Inst. Univ. Gottingen, D-3400 Gottingen, F.R.G.

The chlorine concentration has been determined by a chemical method in 7 quartz tholeiites, 19 alkali olivine basalts, 9 basanitic alkali olivine basalts and 11 olivine nephelinites to be on average 80, 280, 720, and 400 ppm Cl respectively. If these basalts are products of decreasing degrees of partial melting of mantle rocks a regular increase of chlorine is to be expected in this sequence. The actual chlorine abundances are a function of partial losses of gases during rock consolidation and optimum stabilities of sodalite group minerals as major chlorine traps in alkalic basalts. The occurrence of sodalite and sodalite nosean solid solutions has been detected by microprobe in 7 out of 10 alkalic basalt species in grains smaller than 70 µm. Quantitative analyses of 4 sodalite group minerals from the olivine nephelinites are listed. One contains the sodalite and the nosean molecule in a proportion one to one and must be formed above 1,050°C according to the experimental results of Tomisaka and Eugster (1968) in the respective system. In the majority of the samples apatite contains less than 20% of the total chlorine of the basalts. Biotite as a chlorine containing phase (about 900 ppm Cl) is rare. The proportion of chlorine which could be extracted from rock powders by boiling water is small. No general correlation between the element pairs Cl/S and Cl/K could be observed. Excluding tholeiites a tendency of a reversed correlation between chlorine and 'potential primary water' (as indicated by the Fe_2O_3/FeO ratio) and between chlorine and silica can be derived. (Authors' abstract)

MURARIU, Titus, 1979, Mineralogical, geochemical, and structural study of pegmatites from the Rodna mountains (Roumania): Inst. Geol. Geofiz., Studii Tehnice Econ., Ser. 1, no. 15, 264 pp + plates; (in Roumanian with short English abstract and 24 p. French resume.)

Includes a short section (p. 173-179) dealing with fluid inclusion studies. Many in quartz show liquid CO_2, some with high density of fill. Inclusions in tourmaline, garnet, and muscovite were also studied for Th and Td. Th CO_2-H_2O ranges from 278-365° (quartz), and 237-320° (tourmaline); Th (muscovite 283-318°). Inclusions in garnet contain mainly solids and only Td determined (202-620°C). (Abst. by E.R.)

MYSEN, B.O. and VIRGO, D., 1979, Influence of melt structure on REE and Ni partitioning between diopside and melt, (abst): EOS, v. 89, p. 402.

NAMBU, Masateru, and HAYAKAWA, Norihisa, 1979, Fluid inclusion study of quartz from Sendachiyama hydrothermal clay deposit, Fukushima Prefecture: Mining Geology (Japan), v. 29, p. 75-82; (in Japanese with English abstract).

Sendachiyama clay deposits which consist of kaolinite, halloysite, sericite and associated quartz, occur in hydrothermally argillized zone of andesite and green tuff of Miocene age. Since quartz veining seems to be genetically related with the clay minerals, filling temperatures, salinities and chemical compositions of fluid inclusions in quartz were studied by means of the heating- and cooling-stage and IMA.

Filling temperatures range from 200°C to 300°C and salinities are less than 6 wt.% NaCl equivalent concentration. Ratios of K/Na of solutions in inclusions are in order of from 0.1 to 1.0. Average value of filling temperatures of the samples from kaolinite-rich zone is 261°C and the one from halloysite-rich zone is 236°C. Judging from the fact that the thermal variation with depths is not recognizable, ascending thermal waters were not diluted with meteoric water of low temperatures as far as the present level of the deposit is concerned. The data obtained suggest not only the conditions of the formation of this deposit, but also the conditions of wall-rock alteration of kaolinite-halloysite-sericite-quartz combination. (Authors' abstract)

NAMBU, Masateru, HAYAKAWA, Norihisa, and OKA, Hideyuki, 1979, Fluid inclusion study of the Kaneuchi tungsten deposit, Kyoto Prefecture: Mining Geology (Japan), v. 29, p. 43-47 (in Japanese with English abstract).

The ore deposits of the Kaneuchi mine are wolframite and scheelite bearing quartz veins occurring in slate, sandstone and chert of Permian period. Filling temperature and salinity of fluid inclusions in quartz and some scheelite were measured with the heating-cooling stage and compressing-heating stage investigated by Hayakawa and Nambu (1973, 1978). Leakage of fluid from the inclusions in the case of brittle samples were prevented by the use of the compressing-heating stage.

Filling temperature of primary inclusions of quartz is similar to that of scheelite. Thus quartz can be useful to estimate temperature and salinity condition of the mineralization. The filling temperature of quartz varies from 200 to 300°C and is positively correlated with the salinity (Fig. 5). CO_2-bearing inclusions are not uncommon. Both filling temperature and salinity of the primary inclusions increase from west to east in the vein swarm indicating the ore solution flowed out from east which supports the hidden granitic cusp proposed by Imai et al. (1972) in that area. (Authors' abstract)

NAMIOT, A.Yu., SKRIPKA, V.G. and ASHMYAN, K.D., 1979, Influence of water-dissolved salt upon methane solubility under the temperatures 50 to 350°C: Geokhimiya 1979, no. 1, p. 147-148 (in Russian).

NARSEYEV, V.A. and BAKHANOVA, Ye.V., 1978, Thermometric methods for detailed predictions of ore deposits, Termobarogeokhimiya Zemnoy Kory I Rudoobrazovaniye, N.P. Ermakov, ed.: Moscow, Izd. Nauka, p. 222-228 (in Russian).

Indexed under fluid inclusions. (E.R.)

NAUMOV, G.B., MIRONOVA, O.F. and NAUMOV, V.B., 1976, Carbon compounds in fluid inclusions of hydrothermal quartz: Geokhimiya 1976, no. 8, p. 1243-1251 (in Russian; tranlated in Geochem. Intern., v. 13, no. 4, p. 164-171, 1976).

Abstracted in Fluid Inclusion Research--Proceedings of COFFI, v. 9 p. 95, 1976.

NAUMOV, G.B. and NAUMOV, V.B., 1977, The influence of temperature and pressure on the acidity of endogenetic solutions and the stages of ore-formation: Geol. Rudnykh Mestor., 1977, no. 1, p. 13-23 (in Russian; abstract made by H.A. Stalder from German summary in Z. angew. Geol, v. 24, no. 5, p. 227-228, 1978).

The three most important conclusions are:

(1) In all natural solutions, CO_3^{--}, SO_4^{--}, Cl^-, and F^- show the same tendency to change their pH-value; at high temperatures they are more alkaline, then (with decreasing temperatures) neutral or slightly acid and, after reaching a minimum, they become acid again.

(2) Unlike the effect of temperature, whose decrease causes a wave-like change of acidity, a decrease of pressure favors a systematic increase of alkalinity.

(3) The tectonics of an ore deposit may cause several changes of acidity in the ore-forming fluids and therefore precipitation of ore during the alkaline stage. (Authors abstract)

NAUMOV, G.B., SALAZKIN, A.N., MOTORINA, Z.M., MIRONOVA, O.F., NIKITIN, A.A. and SAVEL'EVA, N.I., 1979, Composition and properties of ore-containing fluids of hydrothermal deposits in Eastern Transbaikal, in Major parameters of natural processes of endogenetic ore formation, V.A. Kuznetsov, ed.: Novosibirsk, Izdat. Nauka, v. 2, p. 75-80 (in Russian). [Dokl. Vses. Soveshch., 1977]

The title region has zonal distribution of rare metal (RM), polymetallic (PM), and fluorite (Ft) mineralization. Based on fluid-inclusion Th, the hydrothermal veins in the different metallogenic belts have Tt which follow the order RM >PM > Ft. Using a special method for detg. the total amt. of gases sepd. from quartz heated at 500°, secondary hydrothermal inclusions were detd. to be widespread not only in the ore veins and their wall rocks but also in the quartz of granitic rocks over a broad area in the ore region. The Cl and CO_2 contents of the inclusions in the ore veins and granitic rock quartz are not statistically different. A broad front of hydrothermal fluid moved into the ore region, and heterogeneity in the flow of this fluid was detd. by the phys. (structural) features of the enclosing medium. (C.A. 92:79631n)

NAUMOV, V.B., 1979, Determination of concentration and pressure of volatiles in magmas from inclusions in minerals: Geokhimiya, 1979, no. 7, p. 997-1007 (in Russian; translated in Geochem. Internat., v. 16, no. 4, p. 33-40, 1979). Author at Vernadskiy Inst. Geochem. Anal. Chem., Acad. Sci. USSR, Moscow.

A method is given for determining the concentrations and pressures of volatiles in a magma from inclusions; the water concentrations vary from 0.5 to 6.9 wt. %, and those of CO_2 from 1.9 to 2.3 wt. %. The pressures of the volatiles are in the range 0.3-5.5 kbar for water and 0.7-8.0 kbar for CO_2. (Author's abstract)

(The method involves optical measurement of inclusion plus P-V-T properties of assumed fluid comp. E.R.)

NAUMOV, V.B., IVANOVA, G.F. and MOTORINA, Z.M., 1979, Conditions for the formation of tungsten, tin-tungsten, and molybdenum-tungsten deposits, in Major parameters of natural processes of endogenetic ore formation, V.A. Kuznetsov, ed.: Novosibirsk, Izdat. Nauka, v. 2, p. 53-62 (in Russian). [Dokl. Vses. Soveshch., 1977]

The W, Sn-W, and Mo-W deposits of eastern Transbaikalia and Mongolia belong to the same metallogenic province and had similar conditions of formation. The greisen deposits of these ores are topaz-zinnwaldite and quartz-muscovite types. The vein deposits formed in early and late stages, developing different mineral assocns. Fluid inclusion studies indicate formation of high-temp. (350-450°) rare metal assocns. from chloride solns. and low-temp. (250-350°) ore assocns. from CO_2-rich solns. The pressure of endogenic ore formation varied greatly (~100-1800 bars), indicating involvement of tectonic activity. (C.A. 92:61996a)

NAUMOV, V.B. and NAUMENKO, B.N., 1979, Conditions of formation of the tin-tungsten deposit Svetloe (Chukotka): Geol. Rudnikh Mestor. v. 21, no. 5, p. 84-92 (in Russian). First author at Inst. Geochemistry and Anal. Chemistry, Moscow, USSR.

The deposit Svetloe in the Tultin ore region occurs in hornfels of Lower and Middle Triassic cut by Cretaceous dikes, and consists of quartz and quartz-topaz veins. The composition of ore veins is as follows: Quartz (90-95% vol.), muscovite, topaz, albite, arsenopyrite, löllingite, wolframite, cassiterite. Th (1300 P and PS inclusions in 66 samples) were measured with accuracy ±2°C, Tm - ±0.2°C. The Th values obtained were as follows in °C, (no of samples/no of measurements): anhedral cassiterite from veins 331-295 (6/178), euhedral cassiterite from druses 314-271 (6/184), gray coarse-grained vein quartz and smoky crystals 360-275 (4/82), drusy quartz from regeneration voids 339-252 (6/100), drusy quartz overgrowing albite 308-231 (3/66), sceptre-like quartz 242-220 (2/15), colorless topaz 332-300 (6/82), yellow topaz 338-323 (7/181), blue topaz 335-334 (1-30), colorless topaz from vein in hornfels 338-308 (3/88), drusy albite 271-198 (3/19), scheelite 262-234 (3/86), fluorite with zonal color 303-196 (8/105), fluorite overgrowing albite 179-160 (2/54), the latest fluorite 115-70 (1/36), white tabular calcite 98-68 (3/28). All inclusions freeze in metastable region -30 to -60°C; Tm for high-T inclusions are from -4.1 to -1.8°C, i.e. 7-3% NaCl equiv.) In the lowest-T fluorite and calcite Tm was in metastable range +1.5 to +4.1, sometimes to +10°C due to high negative pressure in frozen inclusions. Also coeval inclusions homogenizing in L and G phase proved occasional crystallization from boiling solution at 355-360°C, thus vapor pressure of 5% solution is ~150 bars. The same samples bear inclusions homogenizing in L at 312-322°C; since true Tt is close to 360°C, the T = 50-40°C is caused by P 700-600 bars. Such P variations (700-150 bars) were caused by tectonic activity. Fluorite contained in 2 inclusions ~1% isotropic dm; Th_1 L+G→L was 188 and 267°C, Th_2 L+dm→L 237 and 297°C, respectively. The difference Th_2-Th_1 yield P 700-450 bars. (sic) (Abst. by A.K.)

NAUMOV, V.B. and SHAPENKO, B.V., 1978, Iron concentration in high-temperature chloride solutions (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 1, Thermobarogeochemistry in geology: Vladivostok, Acad. Sci. USSR, p. 208 (in Russian). Authors at GEOKHI, Moscow.

Iron concentration in solutions at T>400 or 500°C are high and this fact caused presence of numerous iron dms in fluid inclusions, but homogenization of dms such as magnetite or hematite was not reached. Fluorite from pyroxene-garnet skarns from Tyrnyauz W-Mo deposit (Caucasus) bear inclusions filled by G (20±1%) LH_2O (32±4%) dms: halite, sylvite, etc. (45±5%) dm, magnetite 3±0.4% (all by volume). Sylvite Tm - 190-200°C, Tm halite - 435-455°C, Th G-L - 615-645°C, Tm magnetite - 625-655°C. Magnetic features of magnetite were observed up to 450-470°C. Magnetite dissolves in 5-10 min., but it does not dissolve even after 2-hour-long run at 600°C (sic). It crystallizes again in inclusions at 450-400°C when cooling rate was 5°C/min. Calculated fluid density was 1.5±0.2 g/cm^3, chloride concentration 60 wt.%, iron concentration 7.5±1.5 wt.%. (From the authors' abstract, transl. by A.K.)

NAYBORODIN, V.I. and TRUSHIN, A.V., 1978, Formation temperature of Kandykchan tin ore deposit (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 68 (in Russian). Authors at NE Complex Sci.-Research Inst. of Far East Sci. Center of Acad. Sci. USSR, Magadan.

The deposit occurs in the N part of Middle Arman volcanic-tectonic depression (Okhotsk-Chukotka volcanic Belt). Vein ore bodies formed in propylitised liparites. Veins consist of three stage mineral sequence: 1) cassiterite-chlorite-quartz, 2) sulfide, 3) carbonate (+fluorite). Th in quartz 315-365°C, and for S inclusions - 220-275°C; the latter Th are close to Td of sulfides (250-290°C). Carbonate stage yielded Th 110-145°C. (From the authors' abstract, transl. by A.K.)

NAYDENOV, B.M., POLYVYANNYI, E.Ya. and BOGOLEPOV, V.G., 1978, Present state and prospects of research on variations of the isotopic composition of the argon of gas-liquid mineral inclusions: Geochem. Internat., v. 15, no. 6, p. 182-187 (in English).

See Fluid Inclusion Research--Proceedings of COFFI, v. 11, p. 150, 1978. (E.R.)

NCUBE, A.N., HORN, E.E. and AMSTUTZ, G.C., 1979, The fluorite deposit Käfersteige in the Buntsandstein near Pforzheim, Black Forest: N. Jb. Miner. Mh. 1979, Pt. 2, p. 49-61.

The fluorite ore deposit at Käfersteige lies approximately 2 km SE of Pforzheim, on the eastern bank of the Wurm river. The fluorite ore-body is a brecciated vertical vein, 12-18 m thick, striking approximately EW and cutting across almost horizontal sandstone beds of the Buntsandstein formation. The fragments of the brecciated vein consist of greenish-blue fluorite, zoned quartz and plagioclase. Breccia fragments from deeper levels of the mine contain pyrite, chalcopyrite, emplectite and fahlore as subsidiary components. Constituting the cementing material of the breccia are fluorite, quartz, barite, malachite, calcite and limonite, which commonly form pronounced cockade structures around the breccia fragments. Studies of the vein/sandstone contact zone established only very little "mineralization" of the sandstone within the first 20-40 cm from the contact. Thermomicroscopic fluid-inclusion studies carried out on fluorite and barite of the brecciated vein and on detrital quartz of the Buntsandstein (secondary fluid inclusions) revealed crystallization temperatures of 370-65°C and a salinity range of 27-1 wt.% NaCl equivalent. (Authors' abstract)

NEHRING, N.L. and FAUSTO, L.J.J., 1979, Gases in steam from Cerro Prieto geothermal wells - with a discussion of steam/gas ratio measurements: Geothermics, v. 8, p. 253-255. First author at U.S. Geol. Survey, Menlo Park, CA.

As part of a joint USGS-CFE geochemical study of Cerro Prieto, steam samples were collected for gas analyses in April 1977. Analyses of the major gas components of the steam were made by wet chemistry (for H_2O, CO_2, H_2S and NH_3) and by gas chromatography (He, H_2, Ar, O_2, N_2 and hydrocarbons).

The hydrocarbon gases in Cerro Prieto steam closely resemble hydrocarbons in steam from Larderello, Italy, and The Geysers, California, which, although they are vapor-dominated rather than hot-water geothermal systems, also have sedimentary aquifer rocks. These sedimentary geothermal hydrocarbons are characterized by the presence of branched C_{4-6} compounds and a lack of unsaturated compounds other than benzene. Relatively large amounts of benzene may be characteristic of high-temperature geothermal systems. All hydrocarbons in these gases other than methane most probably originate form the thermal metamorphosis of organic matter contained in the sediments. (Authors' abstract)

NEKRASOV, I.J. and BESMEN, N.I., 1979, Pyrite-pyrrhotite geothermometer. distribution of cobalt, nickel and tin, in Origin and distribution of the elements, Proc. of the Second Symposium, Paris, May 1977, L.H. Ahrens, ed.: Oxford, Pergamon Press, p. 767-771.

NEKRASOV, I.J., SOROKIN, V.I. and OSADCHII, E.G., 1979, Fe and Zn partitioning between stannite and sphalerite and its application in geothermometry, in Origin and distribution of the elements, Proc. of the Second Symposium, Paris, May 1977, L.H. Ahrens, ed.: Oxford, Pergamon Press, p. 739-742.

NIKANOROV, A.M., KAVELADZE, M.Sh., TARASOV, M.G., SIANISYAN, E.S., and FEDOROV, Yu.A., 1978, Genesis and conditions of formation of the deep brines on the basis of data of isotopic composition of bedrock waters and inclusion solutions (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 39-41 (in Russian). First author at the Rostov State Univ., USSR.

Chemical and isotopic studies of pore and fissure waters and inclusion fillings in minerals of sedimentary rocks (water leachate method) yielded the following data: in fluid inclusions total salt content 17-70 g/l, δD from -10 to -70% (sic.*) (-8 to -26% for pore waters). The minimum D contents are typical of inclusions in hydrothermal minerals, being very close to shallow (δD = -67%) and surface waters (δD = -78%) in the studied region. This proves the essentially infiltration type of hydrothermal waters, and that infiltration had to reach a depth of ~ 7 km, as concluded from Th of inclusions (160-250°C). Inclusions in sedimentary minerals have the same range of δD as pore waters. (From the authors' abstract, transl. by A.K.)

*Editor's note - these probably should be ‰, not %.

NIKANOROV, A.M., SIANISYAN, E.S., FEDOROV, Yu.A. and TARASOV, M.G., 1978, Fluid inclusions in salts of the Jurassic deposits in the NE Caucasus as indices of gas and oil bearing sedimentary complexes (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 38-39 (in Russian). Authors at the Rostov State Univ., USSR.

The salt-bearing deposits are the cover for the possible (sic.) gas and oil deposits. Numerous types of inclusions were found in salts. Chemical analyses of individual inclusions and cryometric determinations yielded total salt concentrations in fluids from 25 g/l to several hundreds g/l. Hydrocarbon inclusions were studied by luminescence and IR method. Maximum heating of salts, determined on the basis of Th and Td of carbonate wallrocks were 160-250°C; salts bear inclusions with maximum Th 140-150°C. This proves the possibility of preservation of hydrocarbons in rocks underlying salts. Presence of essentially gaseous inclusions may prove the hydrothermal recrystallization of salts and trapping of G phase from gas and oil deposits. (From the authors' abstract, transl. by A.K.)

NORMAN, D.I. and TRANGCOTCHASAN, Y., 1979a, The Yod Nam tin mine, southern Thailand (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 488.

The Yod Nam deposit consists of fracture fillings in Cretaceous or Tertiary-aged, biotite granite strock. In paragenetic order, mineralization is cassiterite, hematite, quartz, chlorite, pyrite, chalcopyrite, fluorite, adularia, and magnetite with cassiterite and quartz predominating. Wolframite occurs sporadically in upper parts of the veins.

Fluid inclusion studies on cassiterite, quartz, and fluorite indicate depositing fluids of erratically varying salinity 0 to 8 eq. wt. % NaCl. Carbon dioxide content of the mineralizing fluids was low during deposition of cassiterite but ranged to greater than 10% during quartz mineralization. Studies of CO_2-rich inclusions indicate a pressure of ~1 Kb during mineralization. Pressure corrected filling temperature data indicate depositing fluids at 490-220°C with temperature decreasing through the paragenesis.

The data suggest that mineralizing fluids were either low salinity, meteoric-connate waters or distillates from boiling, saline, magmatic solutions. Further, the data suggest that the f_{CO_2} of hydrothermal fluids may exert a control on the transport or deposition of tin. (Authors' abstract)

NORMAN, D.I., and TRANGCOTCHASAN, Y., 1979b, Fluid inclusion study of the Yod Nam Tin Mine, Southern Thailand (abst.): Geological Society Newsletter (G.B.), v. 8, no. 6, p. 17-18.

The Yod Nam deposit consists of fracture fillings, predominantly of cassiterite and quartz, in a Cretaceous or Tertiary, biotite-granite stock. Fluid inclusion studies indicate depositing fluids of erratically varying salinity 0 to 8 eq. wt % NaCl, low CO_2 content of the fluids during cassiterite mineralization but ranging to >10% during quartz deposition temperatures falling through the paragenesis, 490-222°C; and a pressure of ~1 Kb. The data suggest that mineralizing fluids were either low salinity, meteoric-connate waters or distillates from boiling, saline, magmatic solutions. Further, the data suggest that the f_{CO_2} of hydrothermal fluids may exert a control on the deposition or transportation of tin. (Authors' abstract) (See previous item.)

NORMAN, D.I., HOLT, L.E. and LANDIS, G.P., 1979, Chemistry of post-magmatic fluids associated with alkalic intrusives, Oslo, Norway (abst.): Eos, v. 60, p. 974.

Fluid inclusions in miarolitic quartz from the Grefsen Syenite and Drammen Granite provide good samples for studying the evolution and chemistry of post-magmatic fluids.

Microscopic study indicates similar conditions for both instrusives, boiling with T-P decreasing from a maximum of 580°C and 700 bars. Fluid dominent inclusions fall into two distinct salinity populations. They are 40 and 20% NaCl for the syenite; 50 and 6% for the granite. These are attributed to high P-T boiling. Rb-Sr isotopes of inclusion fluids plot on the whole rock isochron and indicate the dissolved solids are derived from the intrusive. $\delta D(H_2O) = -42, -45$ and $\delta^{18}O$ (quartz) = 7.1, 8.3 respectively from the syenite and granite suggest a common genesis but not a unique source. The lower salinity fluid of the syenite is a Na-Cl brine with high concentrations of base metals and 1.5 mol% gases (CO_2, H_2, N_2). Lower salinity granite fluids are Ca-Na-Cl-F solutions having a low concentration of base metals, and 2.1% gases (CO_2, H_2, CH_4, He). Sulfur species are not detected in either fluid. Calculated f_{O_2} indicates solutions near the py-po-mg buffer.

The Grefsen Syenite is associated with hydrothermal base metal deposits, and the Drammen Granite is associated with hydrothermal Mo-F mineralization. Chemical similarities between inclusion fluids and hydrothermal mineralization associated with the intrusives suggests a strong genetic link between post-magmatic fluids and ore deposits. Data suggest the fluids evolved within the intrusives, and their chemistry was influenced by depth of boiling and/or nature of the intrusive. We conclude that both the presence and evolution of magma-associated fluids may profoundly influence the nature of post-magmatic ore mineralization. (Authors' abstract)

NORONHA, F., 1979, Fluid inclusions; their utilization in determining the physicochemical conditions of rock and mineral formation: II Semana de geoquimica, Port., Serv. Geol., Comun., v. 64, p. 257-259 (in English).

NORRIS, T.L. and SCHAEFFER, O.A., 1979, Total nitrogen content in deep sea basalts, (abst): EOS, v. 89, p. 408.

The total nitrogen content was measured by neutron activation analysis: $N^{14}(n,p)C^{14}$. The C^{14} was extracted with a CO_2 carrier gas at various temperatures (max. 1300°C) and measured with low level proportional counters. The abundance of quench glass and associated matrix ranged from ~30 to ~40 ppm N, which is similar to the ordinary chondritic meteorites. The nitrogen content is too high by a factor of ~1000 to be from adsorption from seawater. The noble gas and nitrogen data can be explained by preferentially incorporating chemically bound nitrogen (e.g., NH_4^+) into the mantle during planetary formation. The noble gases, not being chemically bound, were initially degassed while the Ar^{40} and nitrogen have slowly degassed over the last 4.5 BY. (From the authors' abstract)

NORTON, D., 1979, An analysis of relationships among thermal, mechanical and chemical processes in hydrothermal ore forming systems (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 488.

Coupled processes in hydrothermal systems that transport thermal and mechanical energy, fluid mass, momentum, and chemical components through fractured media have been evaluated on the basis of system analysis, transport theory, thermodynamic calculations, and numerical models. Conductive and convective cooling rates disperse thermal energy away from the magma chamber, alter the state of stress, and change the chemical and mineral composition of rocks in these systems. Large strain rates caused by differential thermal expansion of host rocks around the magma chamber and of pore fluids within host rocks, together with the separation of a fluid from the magma, produce sets of shear and tensile fractures whose orientations, abundances, and effective apertures determine the magnitude and heterogeneity of rock permeability. Spatial and temporal variations in permeability control the transport rates of thermal and mechanical energy and chemical components within the aqueous phase. Concurrently, the irreversible and reversible chemical reaction rates between fluids and rocks alter the apertures and continuity of fractures and heat content of the system as a consequence of volumes and heats of reactions. Changes in permeability as a result of chemical reactions affect pore fluid pressures and the state of stress. Concentration of ore forming components requires permeable rocks between source regions and the ore deposit. Crystallizing hydrous-magmas are necessary and sufficient to produce permeable stocks and host rocks; the advection of components from source-regions along the flow channels together with irreversible and reversible reactions between fluids and rocks are sufficient to form mineral deposits in these environments. Numerical analyses of these processes define the characteristics of rocks contiguous with the ore zones and provide exploration criteria for deeply buried ore deposits. (Author's abstract)

NYUSSIK, N.M., PYOTROVSKIY, V.A. and YANULOV, K.P., 1978, Gas inclusions in technical mineralogy (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 56-57 (in Russian). Authors at Geol. Inst. of Komi Division of Acad. Sci. USSR, Syktyvkar.

Formation and metamorphism of G inclusions due to redox processes is discussed. Electrons released in redox processes may join with various ions forming new phases and various defects in crystal structure including vacuoles bearing G inclusions. Such secondary process causes turbidity of crystals of diamond, beryl, quartz, etc. because of the huge member of submicroscopic vacuoles. (A.K.)

OHTA, Eijun, 1979, Occurrence and geochemical environment of berthierite from Toyoha Mine. Mining Geology (Japan), v. 29, p. 97-102; (in Japanese with English abstract).

Berthierite, a rather uncommon mineral, was found in geodes of quartz-manganocalcite vein at the 450 mL, W 42 point of Toyoha Mine, Hokkaido. This vein crosses the Tajima vein with almost the same trend as that of the Soya vein, representative of so called NW-SE system.

Berthierite and co-existing minerals were investigated by means of ore microscope, transmission microscope with heating stage, X-ray diffractometer and EPMA, and three stages of mineralization were discriminated as follows: 1: Pyrrhotite stage (pyrrhotite-quartz); 2: Pyrite stage (pyrite-arsenopyrite-quartz-calcite); 3: Berthierite stage (berthierite-arsenopyrite-native arsenic-Pb, Sb Sulfosalt-quartz-calcite).

Filling temperatures of fluid inclusions in the quartz of the first stage were within the range from 175°C to 210°C. On the basis of these data and the thermochemical data given by Barton (1969, 1971), it is suggested that the formation temperature of the vein was about 200°C at the first stage and decreased to about 150°C at the last stage, and that the sulfur fugacity in the vein was approximately 10^{-17}atm during the mineralization. (Author's abstract)

OLANDER, D.R. and MACHIELS, A.J., 1979, Thermal gradient brine inclusion migration in salt study: Gas-liquid inclusions-preliminary model: Off. Nuc. Waste Isolation Report ONWI-85, 49 pp.

A mathematical treatment of the fluid mechanics in the liquid, the temperature distribution in various models, and the calculated velocities. (E.R.)

OLSON, E.R., 1979, Oxygen and carbon isotope studies of calcite from the Cerro Prieto Geothermal field: Geothermics, v. 8, p. 245-251. Author at Inst. Geophys. Plan. Physics, Univ. of California, Riverside, CA.

The inferences derived from oxygen and carbon isotope data for calcite samples from the Cerro Prieto geothermal field depend on the sample type. The $\delta\ ^{18}O$ values for calcite in sandstone provide a reliable basis for estimating stable reservoir temperatures and the $\delta\ ^{18}O$ values for calcite in shale can be related to the extent and spatial distribution of subsurface flow. The $\delta\ ^{18}O$ values for vein calcite record short-lived polythermal fracture-filling episodes at temperatures that may differ from those in the adjacent stable reservoir. The oxygen isotope data for shales indicate a minimum water-rock volume ratio of 2:1. Even this high flow was greatly exceeded in sandstones, with the result that the reservoir fluids are isotopically well-mixed and of relatively low salinity. (Author's abstract)

O'NEIL, J.R., 1979, Stable isotope geochemistry: U.S. National Report, 17th General Assembly, IUGG, Canberra, Australia, Dec. 1979, Papers in volcanology, geochemistry, and petrology: Reviews of Geophysics and Space Physics, v. 17, no. 4, p. 829-849.

O'NEIL, J.R. and BAILEY, G.B., 1979, Stable isotope investigation of gold-bearing jasperoid in the Central Drum Mountains, Utah: Economic Geology, v. 74, p. 852-859. First author at USGS, Menlo Park, CA.

The oxygen, hydrogen, carbon, and sulfur isotope relationships in gold-bearing jasperiod and associated carbonate and pyrite from the Drum Mountains, Utah, have been studied for the purpose of determining certain genetic relationships of these mineral occurrences. Relative deuterium depletion in inclusion fluids and ^{18}O depletion in quartz and carbonates indicate participation of large quantities of heated ground waters in the formation of these bodies. The $\delta\,^{13}C$ values near zero imply a sedimentary source but allow a minor component of magmatic carbon for the carbonates, whereas $\delta\,^{34}S$ values near zero suggest a magmatic source of sulfur for the pyrite. Oxygen isotope and fluid inclusion temperatures of 125° to 225°C establish a hypogene origin for the jasperiod, and this finding has important economic implications relative to the possible occurrence of additional quantities of gold-bearing jasperiod at depth in the Drum Mountains. (Authors' abstract.)

ONTOYEV, D.O., KANDINOV, M.N. and KORYTOV, F.Ya., 1977, Temperatures of mineral formation in apatite-fluorite-rare earth ores of southern Mongolia: Doklady Akad. Nauk SSSR, 1977, v. 234, no. 5, p. 1164-1166 (in Russian; translated in Doklady Acad. Sci. USSR, Earth Sci. Sects., v. 234, p. 117-119, 1979).

Abstract in Fluid Inclusion Research--Proceedings of COFFI, v. 10, p. 201-202 (1977).

ONTOEV, D.O., KANDINOV, M.N. and KORYTOV, F.Ya., 1978, Thermobaric conditions of formation of fluorine-rare earth-iron ore deposits (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 62 (in Russian). Authors at IGEM, Moscow, USSR.

Numerous deposits in Central Asia have common features: each stage starts at high Th and finishes at low Th, P inclusions bear NaCl, KCl, glass, silicates, carbonates and sulfates. Laser analysis revealed significant content of Sr and REE in inclusions. Total salt concentration is up to 70-75 wt.%, hydrocarbons, CO and CO_2 occur in G phase. By cryometry of CO_2-bearing inclusions P was evaluated; early stage (REE apatite) Th 1100-600°C, P 1000 atm; intermediate stage (fluorite, REE fluocarbonates) - very wide P and T ranges; hypabysal fluorite - Th 450-150°C, P 500-1000 atm; subsurface fluorite Th 600-500°C, P >2000 atm. Final calcite, celestite, etc. formed from L solutions, Th 150-80°C, P n x 10 to n x 100 atm. (From the authors' abstract, transl. by A.K.)

ONTOEV, D.O., KANDINOV, M.N., KORYTOV, F.Ya. and GUNDSAMBUU, Ts., 1979, Temperature conditions for the formation of fluorine-rare earth-iron ore deposits, in Major parameters of natural processes of endogenetic ore formation, V.A. Kuznetsov, ed.: Novosibirsk, Izdat. Nauka, v. 1, p. 199-206 (in Russian). [Dokl. Vses. Soveshch., 1977]

Similar to Ontoev, et al., (1977), abstracted in Fluid Inclusion

Research--Proceedings of COFFI, v. 10, p. 201-202 (1977). (See also previous item; E.R.)

ORLOV, Y.L., DUDENKOV, Y.A. and SOLODOVA, Y.P., 1978, Fibrous growth, infrared rays and inclusions of carbonates in cubic diamond crystals: Tr. Mineral Muz. Akad. Nauk SSSR Novye Dannye Miner, p. 109-112 (in Russian).

ORLOVA, I.M., 1978, Change in the chemical composition of the liquid phase of inclusions in the formation of rare-metal pegmatites: Genet. Mineralogiya. po Vklyucheniyam v Mineralakh, Novosibirsk, 1978, p. 100-108 (in Russian).

OSTAFIICHUK, I.M. and MOLYAVKO, V.G., 1979, Composition of the fluids in late orogenic volcanic series from the Carpathians and Greater and Lesser Caucasus: Vopr. Prikl. Geokhim. Petrofiz., (1979) p. 97-108 (in Russian).

Indexed under fluid inclusion. (E.R.)

OTKHMEZURI, Z.V. and DOLIDZE, I.D., 1979, Composition and properties of ore-forming solutions of antimony-mercury-arsenic deposits (as illustrated by Georgia), in Major parameters of natural processes of endogenetic ore formation, V.A. Kuznetsov, ed.: Novosibirsk, Izdat. Nauka, v. 2, p. 221-226 (in Russian). [Dokl. Vses. Soveshch., 1977]

Similar to Otkhmezuri and Dolidze, (1977), Fluid Inclusion Research--Proceedings of COFFI, v. 10, p. 203 (1977). (E.R.)

OVCHINNIKOV, L.N. and KREMENETSKY, A.A., 1979, The thermobarogeochemistry of ore forming processes: Geol. Rudnykh Mestor., v. 21, no. 2, p. 122-124 (in Russian).

A summary of papers given at the Sixth All-Union Conference on Thermobarogeochemistry in Vladivostok in 1978. (E.R.)

PADOVANI, E.R., SHIREY, S.B. and SIMMONS, Gene, 1979, Microcracks in amphibolite and granulite facies grade rocks from southeastern Pennsylvania (abst.): Eos, v. 60, p. 424-425.

Observations of the microcracks in a dozen samples of amphibolite and granulite facies rocks of variable compositions show that (a) most cracks are partly healed or completely sealed with quartz, feldspar or calcite, (b) the crack porosity of most samples is related to bulk composition rather than metamorphic grade, and (c) materials sealing microcracks are unrelated to phase equilibria under metamorphic conditions. The cracks appear to have been formed in response to the post-metamorphic tectonic stresses associated with uplift of the metamorphic terrain to the earth's surface. No cracks were observed that could have been present during metamorphism. Thus, the crack sealing minerals reflect post-metamorphic fluid circulation and cannot be used as indicators of fluid composition during the peak of metamorphism. (Authors' abstract)

PAGEL, Maurice and RUHLMANN, Francois, 1979, Mineralogy and fluid inclusions in mineralized veins (Cu, Mo, Ag, U) from the Château-Lambert district (Southern Vosges): Bull. Minéral., v. 102, p. 654-664 (in French with English abstract). First author at Équipe de Recherche sur les Équilibres entre Fluides et Minéraux. Centre de Recherches Pétrographiques et Géochimiques, Case officielle no. 1, 54500 Vandoenvre-les-Nancy (France).

A detailed study of mineralized veins (Cu, Mo, Ag, U) of Château-Lambert (Southern Vosges) has shown that they consist of five main stages of crystallization: 1) pegmatite, 2) potassic alteration, 3) sulfide succession, 4) carbonate veins,+5) supergene remobilization, which are superimposed in space. Carbonic fluids, related to a deeply fractured zone, are contemporaneous with the uranium remobilization. Brannerite breakdown into uraninite and anatase is described. (Authors' abstract)

PAL'MOVA, L.G., 1978, Utilization of decrepitation methods for the evaluation of characteristics of complex fine-aggregate ores, in Theory and Practice of Thermobarogeochemistry, N.P. Ermakov, ed., Izd. Nauka, p. 184-186 (in Russian).

PAL'MOVA, L.G., KOPNEVA, L.A., IVANOV, P.A. and PRUSAKOV, A.M., 1978, Physical-chemical characteristics of gold-bearing solutions, in Theory and Practice of Thermobarogeochemistry, N.P. Ermakov, ed., Izd. Nauka, p. 101-106 (in Russian).

PANINA, L.I. and KOSTYUK, V.P., 1978, Inclusions of mineral-forming materials in minerals from alkaline rocks of carbonatite complexes, in Theory and Practice of Thermobarogeochemistry, N.P. Ermakov, ed., Izd. Nauka, p. 80-86 (in Russian).

PANTALEO, N.S., NEWTON, M.G., GOGINENI, S.V., MELTON, C.E. and GIARDINI, A.A., 1979, Mineral inclusions in four Arkansas diamonds: their nature and significance: Am. Min., v. 64, p. 1059-1062.

PARILOV, Yu.S. and MIKHALEVA, V.A., 1979, Physicochemical parameters of the formation of pyrite-lead-zinc ores in some deposits of Kazakhstan, in Major parameters of natural processes of endogenetic ore formation, V.A. Kuznetsov, ed.: Novosibirsk, Izdat. Nauka, v. 2, p. 118-126 (in Russian). [Dokl. Vses. Soveshch., 1977]

Tf and ore forming solns. compn. of Pb Zn pyrite deposits are estd., on the basis of fluid inclusion studies. Two hydrothermal sedimentary deposits formed at 60-80° in the presence of brines with ~12-27% salt and a compn. including Na^+, Mg^{2+}, Fe^{2+}, NH_4^+, Cl, SO_4^2, F, Br, and HCO_3. Sulfides formed in fissures and cavities as a result of dislocation metamorphism pptd. at ~100-20° in brines with high salt and gas concns. At the Tekeli deposit dynamothermal metamorphism causing sulfide pptn. in brecciated rocks occurred in 2 stages and involved fluids heated to ~300 and 500° and relatively low in H_2O but with high gas (H_2S and CO_2) and salt contents. During the formation of metasomatites synchronous with disseminated and veinlet mineralization the fluids were hydrothermal solns. at 400-500° and often weakly satd. with salts. In general, 3 varieties of fluids are preserved in the massive sulfide ores: (1) solns. with similar content of H_2O, gases, and salts, and characteristic for high-temp. (~500°) ores; (2) essentially gas-salt fluids with low

H_2O content and in medium-temp. (300-400°) ores; (3) fluids essentially of dissolved salts and in low-temps. (150-300°) ores. (C.A. 92:79633q)

PARK, H.P. and PARK, H.I., 1979, Studies on the fluid inclusions of Useok polymetallic mineral deposits: Chijil Hakhoe Chi, v. 15, p. 282-294 (in Korean).

The Useok polymetallic ores formed adjacent to a granite batholith, in 3 stages: (1) mainly pyrrhotite, chalcopyrite, and fluorite, replacing Cambrian-Ordovician limestones; (2) molybdenite, scheelite, and wolframite in northwest trending fractures; and (3) pyrite, calcite, fluorite veins. The fluid inclusion studies show that the ore fluids of the 1st and 2nd stages were complex CO_2-rich brines; during the main ore deposition CO_2- and H_2O-rich phases coexisted. The 1st and 2nd stages formed at 235-340° the predominant ores and 243-360° resp. The polyascendance of compositionally different ore fluids led to vertical zoning of the polymetallic deposits. (C.A. 93:98708c)

PASHKOV, Yu.N., 1978, Decrepitation pressure-sounding apparatus, <u>in</u> Theory and Practice of Thermobarogeochemistry, N.P. Ermakov, ed., Izd. Nauka, p. 244-248 (in Russian).

PATERSON, S. and KEKULAWALA, K.R.S.S., 1979, The role of water in quartz deformation: Bull. Minéral., v. 102, p. 92-98. Authors at Research School of Earth Sciences, Australian National University, Canberra 2600, Australia.

This review of the experimental studies in quartz deformation since the discovery of hydrolytic weakening concentrates on defining the role of the water more closely. The experiments show some apparently inconsistent features that are clarified in the light of new results from a joint mechanical, infrared and electron microscopical study of a number of different quartzes, natural and synthetic, and of OH-rich quartzes heat-treated in various ways. The results indicate that the diffusivity of the effective OH species is probably concentration dependent and low enough up to 300 MPa to explain the failure to weaken strong quartz by heating with water at these pressures. The occurrence of hydrolytic weakening at 1,500 MPa may involve both the higher degree of ionization of the water and the concentration dependence of the diffusivity. The equilibrium solubility of OH is also discussed and the implications for further experimental work examined. (Authors' abstract)

PAVLOV, A.V., 1978, Laser microspectral analysis of the composition of the glassy phase of fluid inclusions, <u>in</u> Thermobarogeochemistry of the Earth's Crust and Ore Formation, N.P. Ermakov, ed., Izd. Nauka, p. 104-109 (in Russian).

PAWLIKOWSKI, M., 1978, Amethysts from Lower Silesia: Zesz. Nauk. Akad. Gorn.-Hutn. Stanislawa Staszica, Geol, v. 4, no. 1, p. 81-90 (in Polish with English summary).

Indexed under fluid inclusions. (E.R.)

PÊCHER, Arnaud, 1979, Composition and density of the fluid phase through a major crustal shear-zone: data on fluid inclusions of quartz from the

Himalayan Main Central Thrust zone, Central Nepal: Bull. Minéral., v. 102, p. 537-554 (in French). Author at Univ. Grenoble I, I.R.I.G.M., B.P. 53, Centre de Tri, 38041 Grenoble Cedex, France.

The Main Central Thrust - between the Higher and Lesser Himalaya - is a thick shear zone (more than 10 km) where deformation is accompanied by the well-known Himalayan "reverse metamorphism." The composition and density of the fluid phase in this particular tectono-metamorphic zone has been studied utilizing the fluid inclusions of in-schistosity exsolution quartz; a study of about 40 samples shows that: 1) CO_2 nearly always present in the M.C.T. zone (in addition to H_2O and salt), is much more abundant in samples collected nearest the thrust (i.e., where the metamorphic intensity is the strongest); and 2) apparent fluid pressures, as deduced from fluid density and temperature data (respectively given by Th and mineralogical data) is surprisingly low (2.5 to 4.5 kbar) versus the medium to high pressure environment (3 to 8.5 kbar). These results are discussed. (Author's abstract)

PEDAN, M.V., GRITSAY, Yu.L. and KOVAL'CHUK, Kh.U., 1978, Gas-liquid inclusions as source of salt in water during dressing process of ferruginous quartzites in the Krivoy Rog basin (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 47-48 (in Russian). Authors at "Mekhanobrchermet," Krivoy Rog, USSR.

Minerals of ferruginous quartzites bear fluid inclusions with total mineralization (mostly salts of Na) up to 40 g/kg H_2O. The ore is ballmilled by wet method to 200 mesh, that causes opening of most of fluid inclusions and accumulation of salt in circulating process waters. Water leachate method proved that from 1 kg of quartz water may remove 75 mg of Na, 150 mg of K (sic.), 72 mg of Ca, 195 mg of HCO_3, 387 mg of Cl, and minor amounts of other constituents. If each cycle of water circulation gets 10% of new water, total salt concentration due to inclusions may easily reach 900-1000 mg/LH_2O, but even more if water losses are lower. This may cause serious problems in technological process. (From the authors' abstract, transl. by A.K.)

PERCHUK, L.L. and LINDSLEY, D.H., 1979, Liquid immiscibility in model carbonate-silicate systems (abst.): Eos, v. 60, p. 412.

PERSIKOV, E.S. and EPEL'BAUM, M.B., 1979, Pressure influence on the viscosity of water-bearing magmatic melts: Akad. Nauk SSSR Doklady, v. 245, no. 5, p. 1198-1200 (in Russian). Authors at Inst. Exper. Mineral. Acad. Sci. USSR, Chernogolovka near Moscow, USSR.

Increasing P causes viscosity decrease in water-bearing magmatic melts; pertinent to silicate melt inclusion studies. (A.K.)

PETERSIL'E, I.A., FEDKOVA, T.A. and PAVLOVA, M.A., 1979, Gases and organic matter in rocks of granulite complex of the Archaean of the Kola Peninsula: Geokhimiya, 1979, no. 12, p. 1883-1887 (in Russian).

PETERSILJE, I. A. and PRIPACHKIN, W. A., 1979a, Hydrogen, carbon, nitrogen and helium in gases of igneous rocks, in Origin and distribution of the elements, Proc. of the Second Symposium, Paris, May 1977, L. H. Ahrens, ed.: Oxford, Pergamon Press, p. 541-545.

The gases of closed pores of igneous rocks were investigated. Research of this kind offers a new geochemical method that can be used for the elucidation of complicated petrogenetic problems of the gaseous regime of the earth's crust and for practical geological problems.

In the igneous rocks of calc-alkaline series the content of gases varies from 0.4-9.5 cm^3/kg of rock. Granitoids contain a minimum quantity of gases. In the composition of gaseous phase hydrogen evidently prevails (up to 60-88% of gaseous mixture), hydrocarbon gases, nitrogen, helium, argon and sometimes carbon dioxide are the rest of the species.

Agpaitic alkaline rocks (Khibiny, Lovosero, Illimaussak, Middle-Tatarien and other massifs) in their gaseous phase amounts and in composition differ sharply. The predominating component of the composition of these gases is not hydrogen, as in the previous case, but methane which amounts to 92% of the whole volume of gases; maximal quantity of gases in rocks reaches up to 150 cm^3/kg of rock. Agpaitic alkaline rocks by gaseous phase composition resemble the rocks of sedimentary formation, but methane of alkaline rocks differ from methane of sedimentary rocks in the carbon isotopic composition. The average isotopic composition of methane carbon expressed in per cent of δC^{13}, is 0.85 for the Khibini massif, 0.53 for the Lovosero massif and 0.77 for Illimaussak (PDB etalon).

The carbon isotope distribution between different fractions of hydrocarbon gases (methane-ethane-propane) is the reverse of that by sedimentary rock gases. The former allows the confirmation with a sufficient degree of certainty the abiogenetic origin of hydrocarbons in agpaitic alkaline rocks.

The prevailing part of non-carbonic carbon in the igneous rocks is concentrated not in hydrocarbon gases, but in so-called dispersed carbon ($C_{disp.}$), which represents, presumably, carbon-graphite matter, uniformly disseminated in the rocks. The content of C_{disp}) varies from 0.008 to 0.09 wt.% on the rock.

In the fracture zones the filtration of helium is revealed. The content of helium in water-dissolved gases of bore-holes in these zones is up to 4%. Such differences in helium content permit us to reveal and trace the fracture zones by superficial gaseous and water-helium mapping. (Authors' abstract)

PETERSIL'YE, I.A. and PRIPACHKIN, V.A., 1979b, Hydrogen, carbon, nitrogen, and helium in gases from igneous rocks: Geokhimiya, 1979, no. 7, p. 1028-1034 (in Russian; translated in Geochem. Internat., v. 16, no. 4, p. 50-55, 1979).

See previous item. (E.R.)

PETRICHENKO, O.I., 1973, Methods of study of inclusions in minerals of saline deposits: Kiev, "Naukova Dumka" Pub. House, 92 pp. (in Ukrainian; see translations).

PETRICHENKO, O.I., 1978, Nature of carbon dioxide inclusions in halite from metamorphosed salt-bearing beds (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 46-47 (in Russian). Author at Inst. of Geol. Geochem. of Natural Fuels of Acad. Sc. of Ukrainian SSR, L'vov.

Some salt deposits (Dnepr-Donets basin with Devonian salts, Kan-Taseevo depression with Cambrian salts) bear an anomalously high CO_2 content, causing huge blowouts. Halite from those deposits bear P and S LCO_2 and LCO_2 + LH_2O inclusions occurring in a zonal groups or individually. Inclusion size ranges from 5 to 200 μm. By mass spectrometry, gas composition (%) is as follows: CO_2 66-94, N_2 3-13, H_2 0.1-19, CH_4 1.5-40, H_2S 0.1-2.5. Ratio LCO_2:LH_2O varies greatly. LH_2O bears Ca to 150 g/l, Mg to 40 g/l, K to 10-15 g/l, pH <3.5. Halite rich in CO_2 formed during recrystallization of chemical sediments when intruded by basalt magma. Metamorphism of evaporites is confirmed by presence of authigenic accessory chlorite, talc, stilpnomethane, seapolite, etc. in salts. Apatite, fluorite, quartz, calcite, anhydrite, and halite in contact zones bear a complete sequence of salt-bearing inclusions from salt melt to G and G/L ones. (From the author's abstract, transl. by A.K.)

PETROV, P.P., and HRISTOV, M., 1978, Decreptometric studies on quartz from the Zlata deposit, Tran District: Ann. de l'Univ. de Sofia, Fac. de Geol. et Geog., v. 70, no. 1, p. 329-333 (in Russian with English abstract).

Quartz from the gold ore paragenesis in the Tigan section, Zlata deposit, District of Tran, was studied by the decrepitation method. The deposit occurs in the core of an anticline built up of Precambrian gneiss-schists and is generally related to the Hercynian Lyuskan pluton. The bulk of the ore occurs in veins.

The quartz examined is considerably fractured. Decreptograms of individual samples are characterized by the varying intensity of decrepitation of the inclusions which does not depend on the depth at which the sample has been taken. The onset of intensive decrepitation falls within the interval of 290-310°C. After introducing a correction of 20°C, taken from experimental studies, the temperature range 270-290°C is accepted as the best estimate of the actual temperature of mineral formation in the deposit. Comparing this result with the temperature of mineral formation in the gold ore associations in a number of multistage vein plutonogenic deposits in the USSR and in the Collar deposit in India, it is concluded that the main gold ore association in the Zlata deposit belongs to the higher-temperature gold mineral parageneses. The relative uniformity of the temperatures measured over a vertical distance of more than 200 m justifies the conclusion that in the section examined, as far as temperature conditions are concerned, there is no reason to believe that gold ore deposits will be absent from greater depths. (Authors' abstract)

PETROV, P. and SLAVILOV, I., 1979, Inclusions of mineral-forming solutions in quartz from pegmatites in from the Rosen pluton, Burgas District: God. Sofii. Univ., Geol.-Geogr. Fak. 1977-1978, v. 70, no. 1, p. 323-328 (in Bulgarian).

Th was detd. of gas-liq., liq., and multiphase inclusions in quartz crystals. from the pegmatite veins and lenses in the monzonites of the Rosen pluton. The processes of their formation and crystn. of the quartz were discussed in relation to Th values. Th of gas-liq. inclusions - 340-280°; the secondary inclusions at <170°. (C.A. 92:150218r)

PETROVSKAYA, S.G. and KUZ'MINA, T.M., 1978, Temperatures of formation of mineral associations of molybdenum ore mineralization (abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 88-89 (in Russian). Authors at Geochem. Inst. of Siberian Branch of Acad. Sci. USSR, Irkutsk.

Zhodzhertuy ore mineralization in the W. Transbaikalia is mostly of Mo type; granitoids (syenites, granites, granosyenite porphyries) are the wall-rocks. These are partly greisenized with molybdenite and pyrite, and moreover this ore mineralization occurs in vein-like quartz-muscovite (sericite) greisens. The sequence of formation of mineral associations is as follows: 1) quartz-sericite greisen without ore minerals, 2) quartz-sericite greisen with pyrite, 3) greisen with dispersed molybdenite, 4) quartz-molybdenite veins and veinlets. Quartz of the greisen (1) bears G/L inclusions with Th 340-300°C, quartz of the greisens (2) and (3) yields Th 480-345°C. Quartz-molybdenite veins bear P inclusions with Th intervals: 510-460°C, 400-360°C, 465-420°C and 390-360°C, the inclusions typically contain dms (KCl, NaCl) and LCO_2. Greisens surrounding those veins yield Th 365-300°C and 320-250°C. (Authors' abstract, transl. by A.K.)

PETROVSKAYA, S.G. and KUZ'MINA, T.M., 1979, Formation conditions and geochemical features of mineral associations in the Khodzherty molydenum deposit: Geokhimicheskiye Metody Poiskov; Metody Analiza, Akad. Nauk SSSR, Irkutsk, p. 48-53 (in Russian).

Indexed under fluid inclusions. (See also previous item.) (E.R.)

PETROVSKIY, V.A., 1979, Formation of flawed crystals in boiling heterogeneous solutions; Termobarogeokhimiya Zemnoy Kory I Rudoobrazovaniye, N.P. Ermakov, ed.: Moscow, Izd. Nauka, p. 61-64 (in Russian).

Indexed under fluid inclusions. (E.R.)

PIPEROV, N.B., PENCHEV, N.P. and ZIDAROVA, B.P., 1979, The analysis of the volatiles from fluid inclusions in hydrothermal fluorite: Chem. Geol., v. 27, p. 215-231. First author at Inst. Gen. Inorg. Chem., Bulgarian Acad. Sci., 1040 Sofia Bulgaria.

Volatiles from primary fluid inclusions in hydrothermal fluorite were studied. The gases released were analyzed with a mass spectrometer using an internal standard; water-vapor pressure was measured manometrically.

To extract the volatiles, both heating and grinding in vacuum were used. In the thermal treatment, volatiles from other sources besides the inclusions were also found: H_2 and hydrocarbons, as well as additional amounts of H_2O and CO_2. The vacuum grinding, on the other hand, leads to volatile deficiency, especially with respect to H_2O and CO_2, due to retention of these components on the ground material.

The study of the dependence of amount of volatiles released upon heating, on the grain size of the mineral fractions, was used as additional information for evaluating the amounts of volatiles coming from a source other than inclusions.

The thermal studies were supplemented by decrepitophonic measurements.

It is concluded that the volatiles from inclusions are represented practically only by CO_2 and H_2O in a 1:100 molar ratio. Conclusions about the conditions of mineral formation are drawn. (Authors' abstract)

PIZNYUR, A.V., 1979, The combination physico-chemical (thermobarogeochemical) factors in the development of the commercial mineralization - the basis of the additional criteria for predicting molybdenum deposits: Mineral. Sb. (L'vov. Gos. Univ.), v. 33, pt. 2, p. 27-32 (in Russian).

The significance of the thermobarogeochemical facts concerning the formation of commercial mineralization on the example of the Gireken and East-Kounrad deposits is discussed. The conformity of the exposed molybdenum mineralization to the different formations is recommended. The scheme of the development of ore-forming fluids in time is proposed. (Author's abstract)

PLYUSNINA, L.P. and LIKHOYDOV, G.G., 1977, Stability of prehnite in the system $Ca_2Al_2Si_3O_{12}$-H_2O-CO_2-NaCl from experimental data: Dokl. Akad. Nauk SSSR, v. 236, p. 719-721 (in Russian; translated in Dokl. Acad. Sci. USSR, v. 236, p. 142-144, 1979).

POHL, D.C. and DICKSON, F.W., 1979, Basalt-seawater reaction at 400° and 500°C and 1 kb; implications as to depositional processes at spreading centers (abst.): Eos, v. 60, p. 973.

POKALOV, V.T., VOLOKHONTSEVA, S.V. and VASIN, V.V., 1979, Thermobarogeochemical conditions for the formation and the stage nature of the Malyi Oinogor tungsten-molybdenum deposit, *in* Major parameters of natural processes of endogenetic ore formation, V.A. Kuznetsov, ed.: Novosibirsk, Izdat. Nauka, v. 1, p. 252-259 (in Russian). [Dokl. Vses. Soveshch., 1977]

The W-Mo, discrimination-veinlet mineralization of the title deposit (Transbaikalia) occurs as a linear-elongate stockwork zone above the apical part of a leucocratic granite pluton. The quartz veinlets have inclusions of gas, multiphase, gas-liq., H_2O-CO_2, homogeneous CO_2, and liquid types; Th 60-440°C. Mineral formation occurred over this temp. range in 8 stages, each with characteristic formational temps. The Mo-quartz stage formed at 320-80° and pressure >1000 atm. The quartz veinlets with scheelite, pyrite, chalcopyrite, and fluorite, formed directly after the Mo mineralization, developed from CO_2-enriched solns. at 280-350° and 400-1000 atm. The $\delta^{18}O$ values of the quartz from different stages indicate a magmatic origin of the water involved in ore formation but diln. by meteoric waters in late, low-temps. stages. (C.A. 92:61984v)

POLACK, F., LOWENTHAL, S., PETROFF, Y. and FARGE, Y., 1978, Selective x-ray absorption microanalysis with synchrotron radiation: Nucl. Instrum. Methods, v. 152(1), p. 289-91.

POMÂRLEANU, V. and FILIP, D., 1976, Contributions to the method of thermoacoustic research of inclusions from minerals: Rev. Roum. Geol., Geophys. et Geogr., Geologie, v. 20, no. 2, p. 299-306 (in English).

A description of a thermoacoustic sounder for the simultaneous measurement of the temperature of complete filling of the inclusions and frequency of the vibrations produced by the decrepitation of inclusions is described. The decrepitation curves obtained with this device, for several minerals, show the nature of the inclusions and the paragenetic character of some mineral associations. (Authors' abstract) Editor's note: The device measures the temperature of the sample, not Th.

POPIVNYAK, I.V. and LAZ'KO, Ye.Ye., 1979a, Inclusions of solidified melts in minerals of the kimberlite rocks in Western Yakutia (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 1, Thermobarogeochemistry in geology: Vladivostok, Acad. Sci. USSR, p. 194-197 (in Russian). First author at the L'vov State Univ., USSR.

Deep-seated xenoliths and phenocrysts from the kimberlite cement from the pipes "Mir" and "Udachnaya" were studied. The minerals bear glass, and G-glass, crystallized, and rare gas inclusions. Inclusions were most abundant in the two generations of olivine phenocrysts from the "Udachnaya" pipe, and rarer in orange-red garnet of the titanium association. Also minerals of the deep-seated garnet peridotite xenoliths bear melt inclusions. Inclusions were not found in minerals of eclogite and pyroxenite. Inclusions distributed in growth zones are almost absent; extremely rare zonal melt inclusions were found in olivine of the second generation in the "Udachnaya" kimberlite. However, azonal primary inclusions were found, as well as rare anomalous decrepitated inclusions and PS inclusions. Most frequent are S inclusions in healed fractures. Glass inclusions bear numerous tiny G bubbles throughout the whole vacuole, G-glass ones have one or few bubbles occupying ~20 vol.% of the vacuole. Inclusion size is up to 0.001 mm. (sic.), Th 900-1020°C. Crystallized inclusions bear G, glass and four kinds of crystals: 1 - transparent, elongated with orange tint, 2 - colorless cubic or prismatic, 3 - opaque aggregates, 4 - opaque cubic or cubooctahedral crystals. Phases 3 and 4 may occupy up to 90% of vacuole volume. Crystallized inclusions are relatively large (up to 0.01 mm). Th usually is 1150-1200°C, but sometimes opaque phases did not dissolve even at 1400 C - the latter inclusions are the earliest ones or opaque phases are trapped solid inclusions, not dms. The data obtained prove the magmatic origin of kimberlites. Melt inclusions in garnet peridotites with Th 1220-1270°C characterize the final stages of crystallization of the ultrabasic melts generated in the upper mantle. Crystallization of the protokimberlite melt was at T 1400°C. Final portions of such magma consolidated at 900-1020°C, the crystallization solidus of the volatile-saturated ultrabasic melts. (Abstract by A.K.)

POPIVNYAK, I.V. and LAZ'KO, Ye.Ye, 1979b, Inclusions of solidified melt in minerals of kimberlitic rocks of western Yakutia: Dokl. Akad. Nauk SSSR, v. 244, p. 194-197 (in Russian; translated in Doklady Acad. Sci. USSR, v. 244, p. 86-89, 1981).

See previous item for abstract. (E.R.)

POPIVNYAK, I.V. and MYAZ', N.I., 1979, The possibility of using the decrepitation method in exploring for hidden kimberlite bodies: Mineral. Sb. (L'vov. Gos. Univ.), v. 33, Pt. 2, p. 103-106 (in Russian).

POPOV, V.A. and BARKHUDARYAN, N.B., 1979, The formation conditions of gold ore occurrences of various types; Termobarogenokhimiya Zemnoy Kory I Rudoobrazovaniye, N.P. Ermakov, ed.: Moscow, Izd. Nauka, p. 202-205 (in Russian).

Indexed under fluid inclusions, geothermometry, geobarometry. (E.R.)

POPP, R.K., and FRANTZ, J.D., 1979a, An experimental study of mineral solubilities and the thermodynamic properties of aqueous $CaCl_2$ in the system $CaO-SiO_2-H_2O-HCl$: Carnegie Inst. Wash. Yearbook 78 (1978-1979), p. 586-591.

POPP, R.K. and FRANTZ, J.D., 1979b, Mineral solution equilibria - II. An experimental study of mineral solubilities and the thermodynamic properties of aqueous $CaCl_2$ in the system $CaO-SiO_2-H_2O-HCl$: Geochim. Cosmo. Acta, v. 43, p. 1777-1854.

POTTER, R.W.,II, 1979, Computer modeling in low temperature geochemistry: U.S. National Report, 17th General Assembly, IUGG, Canberra, Australia, Dec. 1979, Papers in volcanology, geochemistry and petrology: Reviews of Geophysics and Space Physics, v. 17, no. 4, p. 850-859.

POTTER, R.W., II and CLYNNE, M.A., 1978, The solubility of the noble gases He, Ne, Ar, Kr, and Xe in water up to the critical point: J. Solu. Chem., v. 7, no. 11, p. 837-844.

The solubility of the noble gases Ar, He, Ne, Kr, and Xe in pure water was measured from 298 to 561°K. These data in turn were extrapolated to the critical point of water, thus providing a complete set of Henry's law constants from 274 to 647°K when combined with the existing literature data. Equations describing the behavior of the Henry's law constants over this temperature range are also given. The data do not confirm extrapolations of empirical correlations based on low-temperature solubility data. (Authors' abstract)

POTTER, R.W.,II and FOURNIER, R.O., 1979, Physical chemical properties of multi-component brines applied to the genesis of Mississippi Valley-Type ore deposits (abst.): Program, 108th AIME Annual Meeting, New Orleans, Feb. 18-22, 1979, p. 19.

The physical chemical properties of multi-component brines must be considered in genetic models of Mississippi Valley-Type deposits in order to account for the transport, deposition, and resolution of metal sulfides as well as the time and place of quartz and carbonate deposition. The solubility of sulfate in chloride-rich brines at 150°-250°C is drastically decreased by high Ca and Mg concentrations. If the fluid inclusions are assumed to be pure sodium chloride solutions, estimated salinities from freezing points will be too low by several percent and pressure corrections applied to homogenization temperatures will be correspondingly too small. (Authors' abstract)

POVILAYTIS, M.M., 1979, Endogene deposits of tungsten and conditions of their formation: "Nedra" Publishing House, Moscow, 152 pp. (in Russian).

The book contains numerous Th and Td data of minerals from wolframite and scheelite parageneses, taken from literature sources. (A.K.)

POWERS, L.S., BRUECKNER, H.K., and KRINSLEY, D.H., 1979, Rb-Sr provenance ages from weathered and stream transported quartz grains from the Harney Peak Granite, Black Hills, South Dakota: Geoch. Cosmo. Acta, v. 43, p. 137-146. First author at Dept. Earth and

Envir. Sci., Queens College, Flushing, NY 11367, USA.

Weathered quartz grus and stream transported quartz of the Harney Peak Granite, Black Hills, South Dakota, contain low concentrations of Rb (generally 0.3-6.8 ppm) and Sr (0.2-2.0 ppm) and variable Sr isotopic ratios (0.759-1.070).

Six of seven single grains of large composite quartz grus which recently entered the weathering environment define an apparent isochron age (about 1800 Myr) and initial $^{87}Sr/^{86}Sr$ ratio (0.7066) that approximate the whole-rock isochron age (1707 Myr) and initial ratio (0.7143) of the Harney Peak Granite. Apparently the Rb-Sr systematics of these grains were not significantly altered during initial weathering. Leached fluid inclusion material from a ca. 2 g aggregate of composite quartz grains contains very little Rb or Sr (0.019 and 0.17μg, respectively) and has a very low $^{87}Sr/^{86}Sr$ ratio (0.739). The Rb and Sr content of the quartz grains appears to be concentrated in minute, heterogeneously-distributed mineral inclusions. (From the authors' abstract)

POZDNYAKOVA, N.V., 1979, Physicochemical conditions characterizing the formation of the ores in the Kamyshinskoe deposit: Vestnik Moskovskogo Universiteta. Geologiya, v. 34, no. 1, p. 86-88 (in Russian; translated in Moscow Univ. Geol. Bull, v. 34, no. 1, p90-92, 1979).

The temperature determined from the sulfide mineral assemblage is compared with fluid inclusion data. Th max. in sphalerite 280-300°C; most >200°C. Some contain CO_2 liq., yielding pressure 150-200 atm. Th in quartz (with chalcopyrite) ≤ 320°C, min. 170°C; inclusions with CO_2 yielded P = 300 atm. Th of quartz veinlets cutting sulfobismuthite assemblage = 150-160°C. (E.R.)

PREECE, R.K. and BEANE, R.E., 1979, Studies of mineralization and alteration at the Sierrita porphyry copper deposit, Arizona: I. Paragenetic relations and associated fluid characteristics (abst.): Program, 108th AIME Annual Meeting, New Orleans, Feb. 18-22, 1979, p. 27.

Petrographic and fluid inclusion studies were employed to monitor temperature and salinity variations in fluids associated with evolving vein-controlled hydrothermal alteration. Minerals characteristic of both potassic and propylitic assemblages accompany early veins forming in the temperature range 370° to 300°C. In felsic rocks, these are cut by weak quartz-muscovite veining with temperatures decreasing to 200°C. Fluid salinities varied between 10 and 20 wt % NaCl equivalent with the exception of a brief period during earlier alteration, when hypersaline brines (~40 wt% NaCl) were present. Main stage sulfide minerals were deposited from the lower salinity fluids accompanying the earlier alteration, while late stage, possibly remobilized, mineralization formed in the center of quartz-muscovite veins at temperatures as low as 140°C. (Authors' abstract)

PRESTON, R.M.F. and DUNCAN, A.M., 1979, Electron-microprobe investigation of melt inclusions in plagioclase phenocrysts from Mount Etna: Mineral. Mag., v. 43, p. 181-183.

Inclusions in plagioclase seem, from the description, to have trapped an immiscible mixture of sulfide liquid and silicate liquid, though the authors believe a homogeneous phase was trapped, yield, on cooling, a subcritical silicate and a supercritical fluid (that precipitated a mass of Cu and Fe sulfides). (E.R.)

PRICE, L.C., 1979, Aqueous solubility of methane at elevated pressures and temperatures: AAPG Bull., v. 63, p. 1527-1533.

This study reports the solubility of methane in distilled water from 150° to 350°C and from 100 to 28,600 psi (689.5 to 197,197 kPa). Methane solubility greatly increases with increasing temperature above 250°C to maximum values of over 800 standard cu ft (22.66 cu m) of methane per barrel of water at 354°C and 28,600 psi (197,197 kPa). These high methane solubilities suggest that dissolved methane in the pore waters of sediments buried at 20,000 ft (6.10 km) and deeper in the Gulf Coast and other sedimentary basins could be a significant energy resource. These solubilities are also consistent with the concept of primary migration of natural gas and crude oil by molecular solution from the deep sediments of petroleum basins. (Author's abstract)

PROKHOROV, V.G. and KAZ'MIN, B.N., 1978, Decrepitometer using the heated sample as immediate source of electric signals, (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 1, Thermobarogeochemistry in geology: Vladivostok, Acad. Sci. USSR, p. 200 (in Russian. Authors at KO SNIIGGIMS, Krasnoyarsk, USSR.

The changing electroconductivity of sample on grain breaking when heated, provides the signal registered. (From the authors' abst., transl. by A.K.).

PROKIN, V.A., BOLOTIN, Yu.A., SHIGAREV, V.G. and ISMAGILOV, M.I., 1979, Polol'skoe copper sulfide deposit in the Southern Urals: Geol. Rudnikh Mestor. v. 21, no. 5, p. 3-17 (in Russian). First author at Sverdlovsk Mining Inst., USSR.

The deposit, connected with volcanites of spilite-keratophyre group, formed at 100-350°C. (A.K.)

PROKOPTSEV, N.G., 1979, Quasi-superliquid state in liquating magmatic melt: Akad. Nauk SSSR Doklady, v. 246, no. 3, p. 694-697 (in Russian). Author at the Southern Division of the Oceanology Institute of Acad. Sci. of the USSR. Gelendzhik.

Coefficient of internal friction (viscosity) of magmatic melts in the state of immiscibility (consisting of two components: leucocratic and melanocratic) is very low. The viscosity calculated for leucocratic component of alkaline-basaltic magma is 10^{-2} poise, and for melanocratic component 10^{-4} poise. Pertinent to melt inclusion studies. (A.K.)

PROKOPTSEV, N.G., VAKHRUSHEV, V.A. and PROKOPTSEV, G.N., 1979, On the mechanism of ore-silicate liquation of basalt magma: Akad. Nauk SSSR Doklady, v. 246, no. 5, p. 1206-1210 (in Russian). First author at Southern Division of the Oceanology Inst. of Acad. Sci. of the USSR, Gelendzhik.

Magmatic melt split to melanocratic and leucocratic fractions, and tiny sulfide (mostly pyrrhotite) and spinel droplets. Liquation may occur only under presence of volatiles. Pertinent to melt inclusion studies. (Abst. by A.K.)

PROSKURYAKOV, A.A., KHRENOV, V.A. and PASHKOVA, L.B., 1979, Physicochemical parameters of ore-forming solutions in Charmitan gold-ore deposits: Tr. Inst. Geol. Geofiz., Akad. Nauk SSSR, Sib. Otd., 1979, no. 449, p. 147-157 (in Russian).

The Charmitan Au ore deposits in the Severnoe Nuratinsk anticlinorium are assocd. with the Hercynian granitic rocks. Assemblages corresponding to 4 ore-forming stages are recognized: (1) Au-Bi-telluride, (2) pyrite-arsenopyrite, (3) Au-sulfide-polymetallic, and (4) quartz-carbonate. Based on thermobarometric studies on the fluid inclusions in quartz, the compn. and other parameters were detd. of the ore-forming solns. responsible for Au ore mineralization in each stage. (C.A. 92:218164c)

PUCHKOV, E.V., 1979, Parameters of the formation of copper-porphyry deposits in Kazakhstan, in Major parameters of natural processes of endogenetic ore formation, V.A. Kuznetsov, ed.: Novosibirsk, Izdat. Nauka, v. 1, p. 230-236 (in Russian). [Dokl. Vses. Soveshch., 1977]

Based on fluid-inclusion studies of vein quartz the temp. of the 3 main ore stages of the Kazakhstan Cu porphyry deposits was: quartz-chalcopyrite-molybdenite 360-430, quartz-chalcopyrite-enargite-tennatite-tetrahedrite 220-340, and bornite-chalcocite-polymetallic ores 160-220°. The chem. (ionic) compns. of fluid inclusions in the quartz are tabulated. The basic parameters (crit. temp. and pressure, T and P) of ore formation occurring in fracture cavities are calcd., assuming fracture formation by the contractive force of an intrusive hydrodynamic system, with disruption of the thermodn. equil. The thermodn. system describing the state of the hydrothermal solns. of the fracture formation is: max. velocity ≤1100 m/s, T ≥477°, and P ≥542 atm. (C.A. 92:61983u)

PUZANOV, L.S., 1977, Origin of fluorite mineralization in carbonatite of the Bolsha Ya Tagna pluton, eastern Saya: Dokl. Acad. Sci. USSR, Earth Sci. Sect., v. 233, p. 134-136 (1978).

Abstract in Fluid Inclusion Research--Proceedings of COFFI, v. 10, p. 222, 1977. (E.R.)

PUZANOV, L.S., 1979, Pneumatolytic fluorite of the central part of the Aldan Shield: Dokl. Akad. Nauk SSSR, v. 249, p. 1213-1216 (in Russian; translated in Dokl. Acad. Sci. USSR, v. 249, p. 192-194; 1982).

For similar(?) work, see Puzanov, 1977, Fluid Inclusion Research--Proceedings of COFFI, v. 10, p. 221-222. (E.R.)

PUZANOV, L.S., PARTSEVSKIY, A.I. and BEBIK, A.N., 1977, Fluorite mineralization of magmatic type on the Aldan Shield: Dok. Akad. Nauk SSSR, v. 236, no. 3, p. 704-707 (in Russian; translated in Dokl. Acad. Sci. USSR, v. 236, p. 73-75, 1979).

Abstract in Fluid Inclusion Research--Proceedings of COFFI, v. 10, p. 223, 1977. (E.R.)

RAKHMANOV, A.M., 1978, Thermobarogeochemistry of the skarn-formation process (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis:

Vladivostok, Acad. Sci. USSR, p. 72-73 (in Russian). Author at Tadzhikistan State Univ., Dushanbe, USSR.

The deposits of rare metal skarn type in the Central Tadzhikistan: Maykhura, Kabuty, Kanyaz, Sarymat and Takfon, are characterized by Th in stages: skarn 620-360°C, quartz-rare metal 420-220°C, quartz-sulfide 340-180°C, quartz-carbonate 220-160°C. Early stage associations formed from G solutions, late stage ones - from hydrotherms. Garnets, scheelite and quartz often bear CO_2-rich inclusions (80-100 vol. %); especially in high-T (skarn and quartz-rare metal) associations. P calculated by the Nacken-Kalyuzhnyi method are 800-600 atm. Water leachates for skarn stage yielded HCO_3-F-Cl-Na-K-Ca composition of inclusion fluids, with presence of Al and Si, and for quartz-rare metal- F-type or F-Cl-HCO_3-Ca solutions. (From the author's abstract, transl. by A.K.)

RAKHMANOV, A.M., ISKANDAROV, F.Sh. and DUROV, S.I., 1978, Thermo- and cryometric studies of gas-liquid inclusions in quartz crystals of the rare-metal deposit Mushiston (Zeravshan Ridge) (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 78-80 (in Russian). Authors at the Tadzhikistan State Univ. Dushanbe, USSR.

The Mushiston deposit consists of quartz-cassiterite and quartz-sulfide (stannite-chalcopyrite-galena) veins occurring in metamorphic Middle Paleozoic carbonate-schist complexes. Quartz from voids in cassiterite-quartz veins bears P inclusions of composition $LH_2O>G>LCO_2$, $LH_2O>G$ and $LH_2O<G$; Th of the P inclusions in the earliest zones of quartz crystals was 410-350°C, in intermediate zones 350-320°C and in the latest zones 266-226°C; PS inclusions in the outer zones of quartz crystals yielded Th 196-142°C. Te of P inclusions was as high as -5.2 to -6.7°C, suggesting K_2CO_3 as the main salt dissolved; Tm decreases from early to late zones from +4.7 (sic.) to -5.1°C showing the decreasing concentration from 20 to 17 wt.%. (Authors' abstract shortened and transl. by A.K.)

RAMBOZ, Claire, 1979, A fluid inclusion study of the copper mineralization in Southwest Tintic District (Utah): Bull. Minéral., v. 120, p. 622-632.

The microthermometric study of the fluid inclusions from the southwest Tintic district has confirmed that the copper mineralization can be considered to be a porphyry type deposit. In addition, the major stages of the hydrothermal activity have been determined. At the late magmatic-early hydrothermal stages (700°C and about 2 kbar), high salinity brines circulated, containing mostly KCl and NaCl, with high copper contents (1000 to 2000 ppm Cu). The adiabatic decompression resulted in the boiling of the fluids, starting at about 600°C and 800 bar. The fluid phases became supersaturated with respect to chalcopyrite, yielding the deposit. The fluids continued to boil as pressure and temperature decreased rapidly, and the brines became supersaturated in halite as well. Boiling stopped as the pressure decreased to about 100 bar. Liquids of lower salinity were finally trapped at and below 400°C. (Author's abstract)

RAMSDEN, A.R. and RYALL, W.R., (eds.) 1979, The Lachlan fold belt; contributions to mineral exploration: CSIRO Mineral Res. Lab. (Australia), Invest. Rept. no. 128, 112 pp.

Indexed under fluid inclusions. (E.R.)

RANKIN, A.H., 1979, Sorby's work on fluid inclusions. Lecture at Plenary Session, Program of Fourth Meeting of the Geological Societies of the British Isles, Univ. Sheffield, Sept., 1979 (unpaginated). Author at Imperial College, G.B. (No abstract available.)

RANKIN, A.H. and ALDOUS, R.T.H., 1979, Tritolyl phosphate - a suitable immersion oil for fluid inclusion freezing-state studies: Mineral. Mag., v. 43, p. 315-316.

This compound has $n = 1.55$, and hence can be used as a mounting medium for examination of quartz grains without polishing. It remains optically clear even at -100°C. (E.R.)

RANKIN, A.H. and SHEPHERD, T.J., 1978, Hydrogen sulfide-bearing fluid inclusions in baryte from the North Pole deposit, Western Australia: Mineral. Mag., v. 42(323), p. 408-410.

REBROVA, K.P. and MOSKALYUK, A.A., 1978, Influence of gas-liquid inclusions on chemical composition of quartz raw material (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 52-53 (in Russian). First author at Geol. Sci.-Research Inst. of Quartz Raw Material, Leningrad, USSR.

G/L inclusions affect the quality of silica glass by the formation of G bubbles, and contamination by salts from inclusion solution. K, Na, Ca and Mg contents in inclusions equal 30-70% of total concentration in quartz. (From the authors' abstract, transl. by A.K.)

REHTIJARVI, Pentti, and KINNUNEN, Kari A., 1979, Fluid and mineral inclusions and inclusion zones of cave calcite from Korsnas Mine, western Finland: Bull. Geol. Soc. Finland, v. 51, p. 75-79. (In English.)

Inclusions and crystal forms of calcite crystals from a cave in the Korsnas lead-lanthanide mine in western Finland have been studied. The primary fluid inclusions in the scalenohedral yellowish calcite show homogenization temperatures of 79^{o} to 103^{o}C and salinities of 3.6 to 4.9 eq. wt.^{o}/o NaCl. The prevailing crystal form is scalenohedron. In some specimens it reveals a rhombohedral phantom. Four mineralization stages are proposed on the basis of correlation between inclusion zones in multiple-zoned calcite crystals. (Authors' abstract)

REKHARSKIY, V.I., PASHKOV, Yu.N., IGNAT'YEVA, I.B. and VAR'YASH, L.N., 1978, Composition of ore forming solutions of certain molybdenum deposits (abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 87-88 (in Russian). Authors at IGEM, Moscow, USSR.

Typical features of ore-forming fluids of various Mo ore formations are as follows: feldspar-quartz Mo formation has high CO_2 and F content and Th 360-270°C, greisen W-Mo formation - similar CO_2 and F contents as above and Th 350-260°C, feldspar-quartz W-Mo formation - same solutions, Th 420-340°C, quartz-sericite Cu-Mo formation - high concentrations of NaCl and KCl, Th 300-220°C. For feldspar-quartz and greisen formations the most likely forms of Mo migration are as thiomolybdates and halide-molybdates; for W migration, as halide-wolframates; for quartz-sericite formations, Mo as halide-molybdates and silicomolybdates, and Cu as polychloride complexes, mostly of monovalent copper. (From the authors' abstract, transl. by A.K.)

REYF, F.G., 1978, Causes of different homogenization systems in fluid inclusions, Termobarogeokhimiya Zemnoy Kory I Rudoobrazovaniye, N.P. Ermakov, ed.: Moscow, Izd. Nauka, p. 34-39 (in Russian).

Indexed under fluid inclusions, geothermometry and geobarometry. (E.R.)

REYNOLDS, T.J. and BEANE, R.E., 1979, The evolution of hydrothermal fluid characteristics through time at the Santa Rita, New Mexico, porphyry copper deposit (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 502.

Fluid inclusions were used to determine thermo-saline characteristics of hydrothermal fluids associated with a progression of alteration-mineralization events at the Santa Rita porphyry copper deposit. Identification of an evolutionary character of fluids and a relationship of such to mineralization may have important application to mineral exploration. From samples showing K-feldspar stable assemblages collected at four localities in and near the base of the Whim Hill breccia pipe, a temporal framework for fluid generations was established using primary and secondary inclusions in both crosscutting veins and growth zones in quartz crystals. Preliminary results indicate the earliest fluid to have been a high-temperature (> 800°C), hypersaline (10-30m NaCl+KCl eq) brine associated with quartz+K-feldspar+biotite+apatite veining. This was followed by a cooler (~ 300-450°C), but still highly saline (10-20m NaCl eq) fluid associated with a quartz+K-feldspar+biotite vein assemblage. Chalcopyrite, pyrite, magnetite, and hematite have been tentatively identified as daughter products in both generations of hypersaline fluid inclusions using scanning electron microscopy and observable physical properties. A later, lower temperature (275-350°C), low salinity (<4m NaCl eq) fluid is associated with quartz+K-feldspar+chlorite deposition, and also appears to be responsible for chloritization of earlier biotite deposited from the hypersaline fluids. Temperatures determined by fluid inclusion homogenization correlate well with previous isotopic and mineral thermometric studies. Although the three fluids of highly contrasting thermochemical character are associated with similar gangue mineral assemblages, primary copper sulfide mineralization is found only in association with the latest generation. (Authors' abstract)

RICH, R.A., 1979, Fluid inclusion evidence of Silurian evaporites in southeastern Vermont: Geol. Soc. Am. Bull., v. 90, no. 10, Pt. 2, p. 1628-1643 (summary on microfiche, Bull. Geol. Soc. Amer., Pt. 1, v. 90, no. 10, p. 901-902).

For abstract, see Rich, 1975, Fluid Inclusion Research--Proceedings of COFFI, v. 8, p. 151 (1975). (E.R.)

RICHARDSON, K. and HOLLAND, H.D., 1979a, The solubility of fluorite in hydrothermal solutions, an experimental study: Geoch. Cosmo. Acta., v. 43, p. 1313-1325.

The solubility of fluorite in NaCl solutions increases with increasing temperature at all ionic strengths up to about 100°C. Above this temperature, the solubility passes through a maximum and possibly a minimum with increasing temperature at NaCl concentrations of 1.0M or less, and increases continuously with increasing temperature at NaCl concentrations above 1.0M. At any given temperature, the solubility of fluorite increases with increasing salt concentration in NaCl, KCl and $CaCl_2$ solutions. The solubility follows Debye-Huckel theory for KCl solutions. In NaCl and $CaCl_2$ solutions, the solubility of fluorite increases more rapidly than predicted by Debye-Huckel theory; the excess solubility is due to the presence of NaF°, CaF^+, and possibly of Na_2F^+. The solubility of fluorite in NaCl-$CaCl_2$ and in NaCl-$CaCl_2$-$MgCl_2$ solutions is controlled by the common ion effect and by the presence of NaF°, CaF^+, and MgF^+. The solubility of fluorite in NaCl-HCl solutions increases rapidly with increasing initial HCl concentration; the large solubility increase is due to the presence of HF°. It seems likely that complexes other than those identified in this study rarely play a major role in fluoride transport and fluorite deposition at temperatures below 300°C. (Authors' abstract)

RICHARDSON, K. and HOLLAND, H.D., 1979b, Fluorite deposition in hydrothermal systems: Geoch. Cosmo. Acta., v. 43, p. 1327-1335.

During the formation of fluorite deposits fluorite is precipitated either as a consequence of changes in temperature and pressure along the flow path of hydrothermal solutions or due to fluid mixing, or as the result of the interaction of hydrothermal solutions with wall rocks.

A decrease in temperature in the flow direction is the most appealing, though still unproven, mechanism of fluorite deposition in Mississippi Valley fluorite deposits.

Mixing can produce solutions which are either undersaturated or supersaturated with respect to fluorite. The most important parameters are the temperature, the salinity, and the calcium and fluoride concentration of the fluids prior to mixing.

A variety of wall rock reactions can lead to fluorite precipitation. Among these reactions which increase the pH of initially rather acid ($pH \leq 3$) hydrothermal solutions are apt to be particularly important. (Authors' abstract)

RICKARD, D.T. and LINDBLOM, S., 1979, Fluid inclusion and related studies of sphalerite from the Laisvall sandstone lead-zinc deposit, Sweden: Ann. Soc. Geol. Belg. (Liege), v. 102, no. 2, p. 485-495 (in English).

See Lindblom, 1978b, Fluid Inclusion Research--Proceedings of COFFI, v. 11, p. 126 (1978). (E.R.)

RICKARD, D.T., WILLDEN, M.Y., MARINDER, N.-E. and DONNELLY, T.H., 1979, Studies on the genesis of the Laisvall sandstone lead-zinc deposit, Sweden: Econ. Geol., v. 74, p. 1255-1285. First author at Geol. Inst., Stockholm Univ., Box 6801, 11386 Stockholm, Sweden.

A fluid inclusion study on the sphalerites shows that the ore was precipitated from a concentrated Na-Ca-Cl brine at around 150°C. No evidence for boiling is found. Sulfur isotopic ratios of the sulfides are not in equilibrium, indicating sequential deposition. The sulfide-sulfur is isotopically heavier than the barite sulfate-sulfur. This indicates that two solutions were involved in the formation of the ore, a sulfidic solution and a low sulfide sulfate solution. Thermodynamic and mass balance considerations suggest that the metals were contained in the sulfate solution.

Calcite carbon and oxygen isotope ratios reveal the presence of both sedimentary and hydrothermal carbonate, suggesting partial reaction of hydrothermal solutions with the sedimentary carbonate. Oxygen isotopic ratios are consistent with the fluid inclusion data.

The distribution of the ore is mainly controlled by permeability variations in the sandstones caused by the distribution of shale layers and sedimentary structures. Sharp ore contacts in some areas of the deposit indicate that the ore was formed after the deposition of the sandstones. The ore formation temperature, similarities of fluid inclusion properties in sphalerite in probable Caledonide-related joints with bulk ore, and increased crystallinity of illites when in contact with the ore suggest that ore formation was nearer to the arrival of Caledonide nappes in the area.

Trace hydrocarbons have been detected in the sphalerite and evidence is presented as to their primary origin, rather than from recent contamination. These observations, together with the fluid inclusion data, suggest that the ore solutions were similar to oil field brines.

The accumulated data suggest that pulses of metalliferous, low sulfide brines encountered sulfidic waters in the Laisvll area, leading to precipitation of the ore. Sulfur isotopic evidence indicates that the sulfate was derived from oxidative leachng of sedimentary sulfides and the sulfide possibly from oil-field waters. The metalliferous brines varied in gross chemistry, being zinc-rich initially, lead-rich in the main phase of ore formation, and becoming metal-poor in the later stages. The sulfide solution seems to have been more homogeneous in character.

Precipitation occurred at around pH 5 at 150°C from a concentrated chloride solution.

Subsequent loading by the nappes effectively sealed the Laisvall sandstone aquifer, leading to the preservation of the ore during the remaining, relatively peaceful, 400 million years of its history. (From the authors' abstract.)

RIPLEY, E.M., Mineralogic, fluid inclusion, and stable isotope studies of the stratabound copper deposits at the Raul mine, Peru, South America: Ph.D. dissertation, Penn State Univ.

Similar to Ripley (1976), Fluid Inclusion Research--Proceedings of COFFI, v. 9, p. 114 (1976). (E.R.)

RIPP, G.S., 1979, Analysis of the formation conditions of pyrite lead-zinc deposits of Buryat, in Major parameters of natural processes of endogenetic ore formation, V.A. Kuznetsov, ed.: Novosibirsk, Izdat. Nauka, v. 2, p. 109-118 (in Russian). [Dokl. Vses. Soveshch., 1977]

Indexed under fluid inclusions. (E.R.)

ROBIN, P.-Y.F., 1979, Stress distribution and location of fluid phases in banded migmatites (abst.): Eos, v. 60, p. 425.

ROBINSON, B.W. and INESON, P.R., 1979, Sulphur, oxygen and carbon isotope investigations of lead-zinc-barite-fluorite-calcite mineralization, Derbyshire, England: Trans. Inst. Min. Metall., Sect. B, v. 88, p. 107-117. First author at Instit. Nucl. Sci., DSIR, Lower Hutt, New Zealand.

The isotopic compositions of oxygen and sulphur in barite, oxygen and carbon in calcite and limestones and of sulphur in galena and sphalerite were determined on samples from the Derbyshire (south Pennine) orefield. Galena $\delta\ S_{CDT}$ values range from -23 to + 7‰, with an increase to the east and with time of deposition. The isotopic compositions of the barite also show a wide range of values ($\delta\ ^{34}S_{CDT}$ value +4 to +23‰ and $\delta\ ^{34}O_{SMOW}$ value +9 to -25‰). They do not change with time, but the $\delta\ ^{34}S$ values tend to increase eastwards. The observed spread in the barite analyses is explained partly by the mixing of fresh-water sulphate (low $\delta\ ^{34}S$ values) with connate sea-water sulphate ($\delta\ ^{34}S \sim +19‰$). Only the barite that has more positive isotopic values is thought to approach isotopic equilibrium, probably with a fluid of high $\delta\ ^{18}O$ values, or, in other words, evolved connate water.

It is thought that the reduced sulphur has a dual source and that mixing has produced the spread of galena $\delta\ ^{34}S$ values. Biogenic sulphur from kerogens in the limestones probably supplied the isotopically light sulphur, whereas a dominant supply of heavier sulphur was afforded by reduction of the connate sea-water sulphate.

Carbon isotope values from vein calcites and limestones lie between +1‰ and +4‰ PDB. The isotope values in the limestones adjacent to the veins show a small shift to lower values.

Some of the isotope trends are unique to the Derbyshire area and reflect a high degree of mixing of fluids and components from many different sources. (Authors' abstract)

ROBSON, R.N., 1979, Geology of a mineralized porphyry system, Whangapoua, Coromandel Peninsula, N.Z.: M. Sc. thesis, Univ. Auckland, N.Z. 1979.

The igneous rocks in the Whangapoua Valley, situated on the eastern flank of the Coromandel Range, consist of hornblende and two-pyroxene andesites, volcaniclastites and diorite porphyries and are correlated with the Miocene Beesons Island Volcanics and Whangapoua Andesite, both of the Coromandel Group. Petrologically, these rocks follow a calc-alkalic trend and bear close similarity to suites associated with mineralized porphyry-Cu deposits of the S.W. Pacific.

Hydrothermal alteration contemporaneous with mineralization has produced a zoned pattern of pervasive alteration. Detailed petrographic study enabled a finer subdivision of the traditional four-fold zonation. This can be related on a regional basis to porphyry-type alteration as well as locally to systems of veins and closely spaced fractures. The variation in the composition of the minerals and their assemblages is discussed, providing data pertaining to the changing physico-chemistry that existed during the prograde alteration events. Both fO_2 and fS_2 increased from 10^{-29} atm to $10^{-26.4}$ atm and 10^{-9} atm to $10^{-5.4}$ atm respectively in parallel to alteration rank. $M\ CO_2$ level was significant in the weak propylitic environment but decreased to 0.15 in the advanced propylitic zone. The metasomatic behavior of the principal cations, Ca^{2+}, K^{+}, Na^{+}, Mg^{2+} and Fe is discussed and the hydrothermal fluid is considered in terms of cation activities and pH.

Mineralized epithermal veins located marginally to the Whangapoua area contain the following sequence of minerals: An early iron sulfide generation deposited at temperatures 432°C was followed by a silver-base metal association precipitated around 300°C. At moderate temperatures an arsenic association preceded the final stibnite-quartz deposition. Microprobe analyses and optical descriptions are given for the Cu-Ag-Sb sulfosalts, base-metal sulfides and native metals.

Both the regional geochemical zonation and the epithermal vein mineralization are related to the existence of a high level intrusive porphyry system. (Author's abstract)

Fluid inclusions in quartz from a 1m. wide barren epithermal vein within the propylitic fringe, together with unmineralized float from a silver- sulfosalt vein was studied. In both veins, primary fluid inclusions homogenized from 270-360° with possible grouping at ~350°. Secondary inclusions homogenized at 220-230°. All temperatures were corrected for 0.1 kb.

The hysteresis temperature range averaged 35°C. No vapor-rich inclusion or daughter minerals were observed. Immiscible CO_2 liquid was not observed. (J. Hedenquist).

RODZYANKO, N.G., SAFAROV, Yu.A. and VEKILOV, V.S., 1978, Thermobarogeochemical criteria of tungsten ore mineralization in the Central Caucasus (abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 84-85 (in Russian). Authors at the Rostov State Univ., USSR.

The following genetic types of tungsten mineralization occur in the Central Caucasus: 1) skarn - Tyrnyauz, 2) hydrothermal-metasomatic quartz-scheelite connected with amphibole rocks - Ktiteberda, Kargashelli-Kol, 3) hydrothermal - Blyb, Ilipsar, Ullu-Kam. Skarn deposit Tyrnyauz formed from very concentrated pneumatotytic-hydrothermal solutions at Th 700-230°C (quartz) and 625-225°C (scheelite) and P 600-700 atm. Type 2) and 3) formed from moderately concentrated solutions at Th 420-210°C (type 2) and 320-260°C (type 3) and P about 400-500 atm. (From the authors' abstract, transl. by A.K.)

ROEDDER, Edwin, 1979a, Fluid inclusions as samples of ore fluids, in Geochemistry of Hydrothermal Ore Deposits, 2nd Ed., H.L. Barnes, ed.: New York, John Wiley, p. 684-737.

A review, considerably shortened and somewhat modified from a similar chapter in the first edition (1967). In spite of several reviewer's criticisms of "no change" from the earlier version, half of the 118 references are new. (ER)

ROEDDER, EDWIN, 1979b, Fluid-rock interaction in igneous and metamorphic processes as evidenced by fluid inclusions (abst): Fortschritte der Mineral., v. 58, part 1, p. 109.

Fluid inclusions trapped within minerals during their growth ("primary"), or at some later time during the healing of fractures ("secondary"), provide samples of fluids that were present at the time and place of trapping. However, 1) the recognition of primary inclusions is frequently difficult, except for silicate melt inclusions; 2) some igneous and most metamorphic rocks provide few if any verifiably primary inclusions; 3) a variety of changes can occur after trapping; and 4) the fluid inclusions in most igneous and metamorphic rocks are generally difficult to work with experimentally. In spite of these problems, the recent inclusion studies summarized here have provided important data on the temperatures, pressures, and chemistry of many igneous and metamorphic processes.

All data from fluid inclusions in igneous rocks must be evaluated in terms of two questions: 1) is the inclusion fluid a representative sample?; 2) has the composition of the fluid in the inclusion mainly controlled, or been controlled by, the solid phases in the rock before trapping? If two immiscible fluids were present, the fluids that are trapped will generally be grossly nonrepresentative of the bulk fluid, and may consist of only one of the two fluids. Examples include silicate melt and dense CO_2 fluid, as in the formation of most olivine nodules, or silicate melt and hydrosaline melt, as in some granites and pegmatites. However, even the qualitative recognition of the previous existence of an immiscible assemblage from study of the inclusions can be useful. The compositions of such fluids were probably close to equilibrium with each other and with the solid phases present at the time of trapping. Because a volatile-rich phase, in particular, probably has a very small mass fraction, its composition is effectively controlled by that of the bulk of the magma.

Late-stage processes, such as formation of greisen or skarn, albitization, and the hydrothermal alteration around metal deposits, solfataras, and geothermal systems generally form by fluid-solid interactions in which the mass ratio of fluid to affected rock is large. In such environments, the largest changes occur in the solids as they approach compositions in equilibrium in the fluid. Effectively infinite ratios may prevail along an armored passageway, but intermediate apparent ratios may prevail during infiltration of a porous zone. This wide range in mass ratio can result in a wide range of fluid-inclusion compositions. "Immiscibility" (i.e., boiling) in aqueous fluids may be easily recognized in fluid inclusions and also may cause significant changes in fluid composition and hence in solid-phase assemblage.

Studies of inclusions in metamorphic rocks show that fluids squeezed out of the metamorphic pile in the early, low-temperature stages have a wide range in salinity and may contain major N_2 and CH_4 and higher hydrocarbons. Later fluids may be from dehydration reactions and tend to be richer in CO_2 from decarbonation reactions; cation ratios are presumably controlled by the silicate phases with which they equilibrated. Salinity may also vary widely, for several possible reasons, and a continuum may exist between the fluids in high-temperature metamorphism and those in late-stage igneous processes.

Not all fluid-inclusion data can be interpreted unambiguously at present. For example, the apparently primary, very high-methane gas inclusions in nepheline in several alkalic intrusions are difficult to interpret in terms of known gas reactions. Similarly, evidence from fluid inclusions clearly indicates immiscibility between granitic (or pegmatitic) silicate and hydrosaline fluids in some occurrences, and a continuum in evolution of others, but unfortunately most examples are ambiguous. Thus, the study of fluid inclusions has not always been successful, but it has provided an important source of data, some of which is otherwise unobtainable, on many geologic problems. (Author's abstract)

ROEDDER, Edwin, 1979c, Fluid inclusion evidence on the environments of sedimentary diagenesis, a review: SEPM Special Publication No. 26, p. 89-107. Author at 959 U.S. Geological Survey, Reston, Virginia 22092.

Most sedimentary diagenesis involves recrystallization or overgrowths on original minerals, or the growth of new phases. This new growth may trap fluid as inclusions that provide data not only on the nature, composition, pressure, and density of the fluids present during diagenesis, but particularly on the temperature at which the host crystals grew. As most optical methods of study require inclusions >1-2μm in diameter, fine-grained products of diagenesis, in the 10-20 μm range, seldom provide useful material. The possibilities of finding inclusions of useful size increase as the size of the host crystal increases. In spite of this limitation, reasonably valid quantitative or qualitative physical and chemical data, both new and from the literature, have been obtained on inclusions from the following specific diagenetic environments: (1) crystal-lined geodes, vugs, and veins in sediments; (2) Mississippi Valley-type ore deposits; (3) carbonate and quartz cements in detrital rocks; (4) saline and sulfur deposits; (5) petroleum reservoir rocks; (6) sphalerite in bituminous coal beds.

Most inclusion temperatures in these and other similar environments range from 25-150°C, and most of the fluids are moderately to strongly saline brines which commonly contain petroleum and as much as tens of atmospheres of methane-rich gas. Homogenization temperatures of inclusions in some Mississippi Valley-type ore deposits are higher than 150°C but seldom more than 200°C. It is concluded that hot, strongly saline fluids have moved through many, if not most, sediments at some time in their history, and that at least part of the diagenetic changes seen have been caused by such fluids. (Author's abstract)

ROEDDER, Edwin, 1979d, Origin and significance of magmatic inclusions, Bull. Minéral., v. 102, p. 487-510 (in English). Author at 959 U.S. Geol. Sur., Reston, VA 22092 U.S.A.

This paper reviews work on magmatic (particularly silicate-melt) inclusions in terrestrial and extraterrestrial samples and evaluates its significance. For ordinary inclusions, formed during normal magmatic differentiation by crystal fractionation, this review details the trapping mechanisms, the three main changes that may occur within inclusions after they have been trapped (separation of an immiscible fluid phase, crystallization, and leakage), and the five main types of useful data available from such inclusions (temperature of trapping, temperatures and sequence of phase changes during cooling, constraints on maximum and minimum cooling rates, bulk composition and the liquid line of descent, and the volatile content). Other inclusions in magmatic rocks are trapped and have their compositions determined by a variety of types of fluid immiscibility. Although several types of inclusions, particularly in the lunar samples, are still inexplicable, magmatic inclusions have yielded much useful data and show great promise for the future. Some of these data are unavailable from any other source. (Author's abstract) (A more detailed abstract was published in COFFI, v. 11, p. 179-80, 1978)

ROEDDER, Edwin, 1979e, Silicate liquid immiscibility in magmas, _in_ The Evolution of the Igneous Rock, Fiftieth Anniversary Perspectives, H.S. Yoder, Jr., Ed.: Princeton, Princeton Univ. Press, p. 15-57.

A review of the nature of immiscibility and the evidence for its occurrence in nature, in part from silicate melt inclusions (ER)

ROEDDER, Edwin, 1979f, Melt inclusions in 75075 and 78505 - The problem of anomalous low - K inclusions in ilmenite revisited: Proc. Lunar Planet. Sci. Conf. 10th (1979), p. 249-257. Author at 959 National Center, U.S. Geol. Surv., Reston, Virginia 22092.

A number of mare basalts surveyed by Roedder and Weiblen (1975) showed that melt inclusions in the ilmenite crystals were clearly bimodal in composition. The composition of one type ("high-K"; $\sim$6 wt. % K_2O) was the same as that of the interstitial glass considered to be a late-stage, immiscible liquid of potassic granite composition. The other type ("low-K"), which made up 70% of the inclusions found, was extremely and inexplicably low in K_2O averaging 0.04 wt. %. No satisfactory explanation was found for the origin of the anomalous "low-K" inclusions.

The present, more detailed study of 110 inclusions in two samples reveals the same bimodal distribution but unfortunately sheds no new light on the origin of the enigmatic "low-K" inclusions. (Author's abstract)

ROEDDER, Edwin, 1979g, Melt inclusions in 75075 - The problem of anomalous low-K inclusions in ilmenite revisited (extended abstract): Lunar Science X, p. 1033-1035, (The Lunar and Planetary Inst., Houston).

This is a longer abstract of the previous item. ER)

ROEDDER, Edwin, 1979h, Fluid-inclusion studies and their application to exploration for hydrothermal deposits (abst.): Mining Geology (Japan), v. 29, no. 5, p. 332-333 (in Japanese).

A review (ER)

ROEDDER, Edwin, and BELKIN, H.E., 1979a, Application of studies of fluid inclusions in Permian Salado salt, New Mexico, to problems of siting the Waste Isolation Pilot Plant, in Scientific Basis for Nuclear Waste Management, vol. 1, J. McCarthy, ed.: New York, Plenum, p. 313-321. Authors at 959 U.S. Geol. Surv., Reston, VA 22092.

This paper presents a summary of the data obtained when inclusions in cores from the proposed WIPP site were examined petrographically, and with microscope freezing, heating, and crushing stages. Fluid now present in the samples studied ranges widely from <0.1 to 1.7 wt.%; the total in situ fluid content of the rock is certainly greater. The inclusion fluid is not just saturated NaCl solution but a variable and extremely saline bittern containing some noncondensable gases under pressure. The inclusions move in thermal gradients and react quickly to uniaxial stress, but decrepitation is estimated to be a more important mechanism of fluid release under thermal loading. Subsequent movement of the released fluids is not considered. (Authors' abstract)

ROEDDER, Edwin, and BELKIN, H.E., 1979b, Fluid inclusions in salt from the Rayburn and Vacherie domes, Louisiana: U.S. Geological Survey Open File Report 79-1675, 25 pp.

Core samples from the Rayburn and Vacherie salt domes in Louisiana were examined for fluid inclusions, in connection with the possible use of such domes for nuclear waste storage sites. Three types of fluid inclusions were found, brine, compressed gas, and oil (in decreasing volume percent abundance). The total amount of such fluids is small, certainly <0.1 vol. % and probably in the range 0.01 to 0.001 volume %, but the inclusions are highly erratic in distribution. Unlike many bedded salt deposits, the brine inclusions in this salt contain fluids that are not far from simple NaCl-H_2O solutions, with very little of other ions. One of three possible explanations for such fluids is that fresh water penetrated the salt at some unknown time in the past and was trapped; if such entry of fresh water has occurred in the past, it might also occur again in the future. (Authors' abstract)

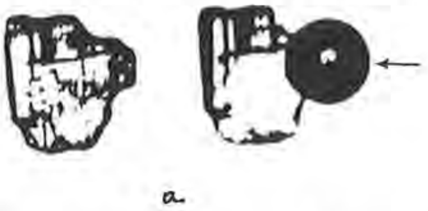

Figure a. Anhydrite crystal embedded in salt, with almost invisible high-pressure gas inclusions at interface between the two phases. The salt is being dissolved in water, and when the solution front reaches the high pressure gas inclusions, they expand to form the large bubble (100 um diameter).

Figure b. Inclusion (200 µm diameter) of liquified hydrocarbons with small bubble, in salt. When solution front reaches inclusion, entire contents flashes into vapor and leaves inclusion full of gas.

ROEDDER, Edwin and BELKIN, H.E., 1979c, Migration of fluid inclusions in salt from Waste Isolation Pilot Plant site (WIPP) in thermal gradients, Materials Research Society Symposium G, Scientific Basis for Nuclear Waste Management, Cambridge, Mass, Nov. 26-30, 1979, Abstracts volume, p. J1-K, 2 pp. (unpaginated).

Most salt beds contain at least some water in the form of liquid inclusions within single salt crystals or in the larger intergranular cavities (i.e., pores). The storage of any heat-generating waste will establish thermal gradients in the salt. A liquid inclusion in a crystal of a soluble salt, when placed in a thermal gradient, will continuously dissolve on the hot side and crystallize on the cold side of the cavity, thus causing the cavity, with its included liquid, to move up the thermal gradient, toward the heat source. Inclusion movement is of consequence in the design of a waste repository as the included brines are probably more corrosive to possible canister materials than even a saturated NaCl solution.

Wilcox (1968) summarizes the extensive work (111 references) on the nature and rate of inclusion movement in various substances. Most liquid inclusions move up the thermal gradients, but if the vapor bubble in the liquid is large relative to the liquid, and particularly if boiling occurs in the inclusion in the gradient, the movement may be in the reverse direction, down the thermal gradient (Wilcox, 1969; Anthony and Cline, 1972; Chen and Wilcox, 1972). The rate of movement is independent of inclusion size in many systems, but strongly (and directly) dependent on inclusion size in others (Wilcox, 1968); there may be a threshold size below which no movement occurs ($\sim$10 µm in KCl, Anthony and Cline, 1971). Large inclusions in several hosts break up during movement (Wilcox, 1968; Anthony and Cline, 1973). Many factors may affect the rate of migration, even in a given host: gravity, composition and surface tension of the liquid, inclusion size and shape, host crystal anisotropy, strain, and imperfections, external stress, volume percent of vapor bubble and presence of a foreign gas in it, etc. In salt, rate of movement in a given gradient can be expected to increase as ambient temperature increases, because the thermal coefficient of solubility, although small at room temperature, increases greatly as temperature increases. Higher ambient temperature also increases the rate by increasing the solubility, the diffusion coefficients, and the interface kinetics in any host; the increase in rate was found to be particularly striking in NaCl (Wilcox, 1968; p. 20). That the inclusions in the WIPP site salt have not moved measurably during geological time in the geothermal gradient (Roedder and Belkin, 1979) is perhaps an indication of an exceedingly slow rate under the natural gradient. It may also be a result of other weak factors, such as gravity, counteracting the thermal gradient effect.

The rates of migration of natural liquid-filled inclusions in salt from the ERDA no. 9 borehole at the WIPP site, Carlsbad, N.M., have been determined experimentally. The range of values of the two most important parameters investigated, ambient temperature and initial inclusion volume, are 108°-260°C, and 10^9-10^9 $(\mu m)^3$, respectively. Most runs were made at a gradient of 1.5°C cm^{-1}, maintained perpendicular to (100), for 3-10 days. The runs were made at 1 atm pressure, with a heat-up rate at the start of the run of $\leq$30°C-hr^{-1}, so most of the inclusions studied have not decrepitated, but have expanded beyond their original volume by deformation of the host salt. In each run, $\sim$50 inclusions were selected, measured, and photographed against fiducial marks before and after the run. At 160° ambient and gradient of 1.5°C cm^{-1}, 10^9 μm^3 inclusions (i.e., 1mm cubes) moved toward the heat source at a rate of 1.6 cm yr^{-1}. Smaller inclusions moved more slowly, e.g., 10^6 μm^3 inclusions (i.e., 0.1 mm cubes) moved only 0.5 cm yr^{-1}. The movement rates at 260°C for a given size are larger by a factor of $\sim$3.2, but at 108°C the rates are only $\sim$10-20% lower than those at 160°C. Higher gradients yielded higher rates, in approximately direct proportion, but as a different sample was used for these runs, and samples from different WIPP strata have since been found to differ systematically in movement rate by factors of $\gtrsim$3 (for reasons still unknown), exact comparisons are not possible. Such variation, but within a given sample, probably explains the anomalously low rates shown for the run at 201°C. Inclusions $\leq\sim 10^6$ μm^3 maintain their original cubic shape during migration; larger inclusions change shape, tapering down in the forward direction and forming a peripheral fringe toward the rear. Inclusions forced to migrate perpendicular to (110) formed similar fringes, and moved at similar rates. In contrast, natural inclusions that have a large vapor/liquid ratio in these same samples (Roedder and Belkin, 1979) moved at $\sim$1-5 times these rates, but down the gradient, away from the heat source. Some observed phenomena remain unexplained.

In using rate data to calculate the amount of fluid that could be delivered to the canister area in an actual repository, it is important to remember that the great bulk of the liquid water in the WIPP salt is present in the form of a relatively small number of inclusions $\geq$1mm. size. (Modified from authors' abstract).

ROMANCHEV, B.P. and SOKOLOV, S.V., 1979, Liquation in the production and geochemistry of the rocks in carbonatite complexes: Geokhimiya, 1979, no. 2, p. 229-240 (in Russian; translated in Geochem. Internat., v. 16, no. 1, p. 125-135, 1979).

Detailed studies have been performed on inclusions in minerals in rocks from carbonatite complexes; this has defined the temperatures during the evolution of alkali-ultrabasic magmas, which indicate that liquid immiscibility or liquation is involved in the production of carbonatites. It has been found that the crystallization temperature fell from 1260° for alkaline picrite to 550° for alkaline carbonatite in East Africa, and similar temperature ranges apply for the corresponding instrusives in the Kovdor intrusion (Kola peninsula). Liquation is the decisive factor in the distributions of niobium, rare earths, and phosphorus in the final stages of these complexes. (Authors' abstract)

ROSASCO, G.J., and ROEDDER, Edwin, 1979, Application of a new Raman microprobe spectrometer to nondestructive analysis of sulfate and other ions in individual phases in fluid inclusions in minerals: Geochim. Cosmo. Acta, v. 43, p. 1907-1915. First author at U.S. National Bureau of Standards, Washington, DC 20234.

Rosasco et al. (1975), reported the first successful application of laser-excited Raman spectroscopy for the identification and nondestructive partial analysis of individual solid, liquid, and gaseous phases in selected fluid inclusions. We report here the results of the application of a new instrument, based on back-scattering, that eliminates many of the previous stringent sample limitations and hence greatly expands the range of applicability of Raman spectroscopy to fluid inclusions.

Fluid inclusions in many porphyry copper deposits contain 5-10 μm 'daughter' crystals thought to be anhydrite but too small for identification by the previous Raman technique. Using the new instrument, we have verified that such daughter crystals in quartz from Bingham, Utah, are anhydrite. They may form by leakage of hydrogen causing internal autooxidation of sulfide ion. Daughter crystals were also examined in apatite (Durango, Mexico) and emerald (Muzo, Colombia).

Valid analyses of sulfur species in solution in small fluid inclusions from ore deposits would be valuable, but are generally impossible by conventional methods. We present a calibration procedure for analyses for SO_4^{2-} in such inclusions from Bingham, Utah (12,000±4000 ppm) and Creede, Colo. (probably $<$500 ppm). A fetid Brazilian quartz, originally thought to contain liquid H_2S, is shown to contain only HS^- in major amounts. (Authors' abstract)

ROSIKHINA, A.I. and YATSENKO, G.M., 1978, On temperatures and sequence of the ultrametamorphic processes, (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 1, Thermobarogeochemistry in geology: Vladivostok, Acad. Sci. USSR, p. 124-125, (in Russian). Authors at the L'vov State Univ., L'vov, USSR.

Metamorphosed oligomictic sandstones of the Lower Precambrian in the Central Ukrainian shield, Ingul river region are biotite and biotite-gneissed with boudins of diopside-plagioclase-quartz schists (granulite and amphibolite facies). Ultrametamorphism yielded migmites, biotite-garnet granitoids and pegmatites. P G/L inclusions - at 450-350°C; S ones - at 227-217°C, all in L, except of few which homogenized in G. Probably all inclusions are connected with retrograde metamorphism of the ultrametamorphic assemblages. (From the authors' abst.)

RÖSLER, H.-J. and SHUGUROVA, N.A., 1978, Fluid inclusions from the tin deposit of Ehrenfriedersdorf: Z. angew. Geol., v. 24, no. 6, p. 258-259.

Dolomanova et al. have given information about the composition of fluid inclusions in minerals from the tin-deposit of Ehrenfriedersdorf and determined Th and Td. They determined "that most of the fluid-inclusions formed at temperatures near the critical temperature of water." Depending on the method, they measured values between 250° and 600°C. They also give information about the chemical composition of the liquid and the precipitation of minerals in the inclusions.

Our analyses are meant to be a completion of these extensive examinations. We determined Th and the composition of the gaseous part of the inclusions from 6 mineral samples. The sampling was made in 1968 and was intended to follow the substantial temperature change from granite to the hydrothermal products. The methods of gas-analysis were described by Shugurova (1967). The 6 analyzed samples are described and figured schematically in their geological positions. The results are summarized in graphical form in fig. 1 and 3, and are interpreted as follows:

(a) The gaseous-part of the fluid inclusions varies very much, as Dolomanova et al. mentioned. No H_2S, SO_2, SO_3, HCl, HF, NH_3, CO, H_2 was found in any sample. O_2 was found in 1 sample. The main components were CO_2 and N_2 (including noble gases); their distribution in the 6 samples is shown in fig. 2. It can be recognized that the chemical composition within one sample doesn't vary much; there is a tendency of decrease of CO_2 in the gaseous phase from granite to the hydrothermal products, corresponding with a relative increase of nitrogen and noble gases in the hydrothermal phase.

(b) In fig. 3 the results of Th (in the same order of samples) are shown. The values are within the range that Dolomanova determined, but somewhat lower. There is a decrease of temperature from sample 1 to sample 6, but unfortunately there are not many values.

Though sample 1 corresponds to an overprinted granite, the Th of 300°C in quartz is probably due to an earlier secondary transformation.

It can be concluded that the determined values show a genetic and substantial similarity between granite, pegmatite, pneumatolyte and hydrothermalite. (Translated by H.A. Stalder)

Tab.: Origin and type of samples from Ehrenfriedersdorf

Nr.	Type of sample	Origin
1	granite	Leimgrüber east 2. "Gezeugstrecke"
2	"Stockscheider"	Prinzler east 2. "Gezeugstrecke"
3	Pneumatolitic lode with cassiterite and wolframite	Theobald-lode 1. "Gezeugstrecke"
4	Greisen with cassiterite	sw-Greisen-cupola 2. "Gezeugstrecke"
5	Schlieren containing cassiterite in granite	Prinzler-west
6	Hydrothermal quartz in sphalerite	unknown locality

ROSSOVSKIY, L.N., 1977, First find of pollucite and its crystals in Afghanistan: Dokl. Akad. Nauk SSSR, v. 236, p. 216-219 (in Russian;

translated in Dokl. Acad. Sci. USSR, v. 236, p. 157-160, 1979).
Abstract in Fluid Inclusion Research--Proceedings of COFFI, v. 10, p. 239 (1977). (E.R.)

ROSSOVSKIY, L.N. and KONOVALENKO, S.I., 1977, Corundum plagioclasite of the southwestern Pamirs: Dokl. Akad. Nauk SSSR, v. 235, p. 663-666 (in Russian; translated in Dokl. Acad. Sci. USSR, v. 235, p. 145-147, 1979).
Abstract in Fluid Inclusion Research--Proceedings of COFFI, v. 10, p. 239-240 (1977). (E.R.)

ROUCAN, J.P., 1978, Gems their inclusions, imitations and synthetic products: Monde Miner. (Paris), v. 21, p. 630 (in French).

ROWE, E.C. and SCHILLING, J.-G., 1979, Fluorine in Iceland and Reykjanes Ridge basalts: Nature, v. 279, p. 33-37.
Unlike chlorine and bromine, fluorine is not appreciably outgassed from basalts erupted above 500 m depth along the Reykjanes Ridge and subaerially over Iceland. The mantle beneath Iceland seems to be twice as rich in fluorine as the asthenosphere source of normal ridge basalts south of 61°N. (Authors' abstract)

ROYZENMAN, F.M., FORTUNATOV, S.P., DOROGOVIN, B.A., YEKHOV, S.V., KARSKIY, B.Ye. and PETROVA, M.G., 1978, The two principal stages of postmagmatic ore formation, in Thermobarogeochemistry of the Earth's Crust and Ore Formation, N.P. Ermakov, ed., Izd. Nauka, p. 55-61 (in Russian).

ROYZENMAN et al., 1978 (See p. 212)

ROZKOWSKI, Andrzej, RUDSINSKA, Teresa, and BUKOWY, Stanislaw, 1979, Thermal brines as a potential source of the ore mineralization of the Silesia-Cracow area: Prace Instytutu Geologicznego, Research on the Genesis of Zinc-Lead Deposits of Upper Silesia Poland, v. 45, p. 59-85 (in English).

RUBIN, Hillel and ROTH, Cornel, 1979, On the growth of instabilities in groundwater due to temperature and salinity gradients: Advances in Water Resources, v. 2, p. 69-76. Authors at Dept. Civil Eng., Israel Inst. Tech., Haifa, Israel.
Geothermal activity creates destabilizing temperature gradients which are significant in some aquifers. Usually, in such aquifers stabilizing salinity gradients also exist. The combination of temperature and salinity distribution in the aquifer may induce various types of hydrodynamic instabilities. Calculations of heat transfer through various types of aquifer by applying numerical simulations are presented. (From the authors' abstract)

RUMBLE D., III, and HOERING, T.C., 1979, Rock permeability during metamorphism: Carnegie Inst. Wash. Yearbook 78 (1978-1979), p. 608-611.

RYTSK, Y.O. and KOZLOV, A.V., 1978, Reasons for the influence of inclusion size on the decrepitation temperature (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 1, Thermobarogeochemistry in geology: Vladivostok, Acad. Sc. USSR, p. 201-202 (in Russian). First author at VSEGEI, Leningrad, USSR.

Decrepigraphs of quartz bearing G/L inclusions of the same Th, F (i.e., degree of fill. ER.) and composition, have a polymodal character. Influence of inclusion size on Td was evaluated experimentally. Theoretical analysis of tension in a crystal caused by the heated inclusion, on the basis of the elasticity theory, proves that tension Gψψ does not depend on the inclusion size but only on the internal pressure in inclusion, under condition that distance from the inclusion center to the grain surface R_2 significantly exceeds the inclusion radius R_1. The latter condition was realized in an experiment with quartz plates 2-4 mm thick bearing inclusions not larger than 0.1 mm, usually 0.025-0.05 mm.

$$G\psi\psi = \frac{PR_1{}^3}{R_2{}^3 - R_1{}^3} \left(1 - \frac{R_2{}^3}{r} \right)$$

when $r = R_1$ and $R_2 \gg R_1$, then $G\psi\psi = P$.

Deviation of experimental data from theoretical calculations are caused by local anomalies of quartz mechanical resistivity. This is the reason of variations of Td of inclusions with the same Th. (From the authors' abstract, transl. by A.K.)

RYTUBA, J.J. and CONRAD, W.K., 1979, Structural and petrologic associations of uranium deposits within the McDermitt caldera, Nevada-Oregon (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 508-509.

The uranium deposits in the youngest rhyolite are associated with pyrite, fluorite, and quartz. Fluid inclusions in quartz-fluorite veins indicate temperatures of 310°C and salinity of 4.5 percent equivalent NaCl in quartz, and 210°C and salinity of 1.8 percent in fluorite associated with uraninite. Geochemical analyses indicate that these moderately saline solutions that formed the uranium deposits were not only fluorine-rich but also were transporting As, Hg, Mo, Tl, W, and Zr. (From the authors' abstract)

RYTUBA, J.J. and GLANZMAN, R.K., 1979, Relation of mercury, uranium, and lithium deposits to the McDermitt caldera complex, Nevada-Oregon, in Papers on mineral deposits of western North America, IAGOD Fifth Quadrennial Symposium Proc., v. 2, J.D. Ridge, ed; Nevada Bur. Mines and Geology Report 33, p. 109-117.

The McDermitt caldera complex, located along the Nevada-Oregon border, is a Miocene collapse structure 45 km in diameter. The complex is the site of large deposits of mercury, an ore deposit and several occurrences of uranium, and widespread occurrences of lithium. Mercury deposits at Cordero, McDermitt, Bretz, Ruja, and Opalite occur along ring fractures in sedimentary rocks that fill the calderas. Near the deposits the rocks are altered to zeolites and within the ore zones to potassium feldspar and silicate minerals. Although the mercury deposits contain anomalous concentrations of uranium, the most important uranium occurrences are restricted to rhyolitic ring domes emplaced along the western margin of the calderas.

A decrease of crystallinity of cristobalite around the McDermitt deposit has resulted from a decreasing temperature away from deposit; a thermal gradient extends laterally from the deposit into the country rocks for a distance of 4 km. Homogenization of fluid inclusions in quartz indicates a maximum temperature of 200°C at the core of the deposit, where the cristobalite is most crystalline. Because of the thermal gradient, zeolite alteration zones formed around the deposit, and the size of the alteration aureole defines the maximum extent to which reactive hydrothermal fluids penetrated into the country rocks.

In the Moonlight uranium mine, ore occurs along the brecciated contact of the intrusion with the caldera wall rocks and includes both granodiorite and andesite. The ore mineral is pitchblende, and gangue minerals are pyrite, quartz, and fluorite; in the oxidized portion of the deposit autunite and hematite are present. Anomalous concentrations of molybdenum, beryllium, and mercury are present in and outside the ore zone. Fluid inclusions in quartz associated with the pitchblende indicate a deposition temperature of 330°C, and stratigraphic evidence indicates that the deposit formed at a shallow depth of about 800m.(ER)

SABOURAUD, C. and HUMBERT, L., 1978, Endoscopy of calcite crystals filling fractures in limestone and reconstruction of the tectonic and diagenetic evolution; preliminary study: Acad. Sci. (Paris), C.R., Ser. D, v. 287, no. 7, p. 667-670 (in French).

SABOURAUD, C. and TRICHET, J., 1978, Confirmation, through study of intracrystalline inclusions, of the superficial origin of pyramidal quartz: Geoderma, v. 20, no. 3-4, p. 191-199 (in French).

SACKETT, W.M., BROOKS, J.M., BERNARD, B.B., SCHWAB, C.R., CHUNG, H. and PARKER, R.A., 1979, A carbon inventory for Orca Basin brines and sediments: Earth and Planet. Sci. Lett., v. 44, p. 73-81. Authors at Dept. Oceanog., Texas A&M Univ., College Station, TX U.S.A.

Orca Basin, an intraslope depression at a depth of about 2400 m on the continental slope of the north-central Gulf of Mexico, contains an anoxic, hypersaline brine similar in composition to those reported in the Red Sea. Concentrations and stable carbon isotope compositions of various inorganic and organic carbon species have been determined on the brine and sediments in order to gain an understanding of the origin and cycling of carbon in this unique environment.

ΣCO_2 in the brine (55 mg C/1) is about twice seawater with $\delta^{13}C_{PDB}$ = -16.4% and $\Delta^{14}C = -501\%$. CH_4 has a concentration of 12 mg C/1 and $\delta^{13}C$ values several permil different than the overlying seawater. ΣCO_2 and CH_4 in the interstitial waters are considerably higher in concentrations and isotopically lighter than the overlying brine.

Solution of near-surface salt deposits by seawater with subsequent microbial production and consumption of methane can be used to explain most of the data. (Authors' abstract)

SACKETT, W.M., And CHUNG, H.M., 1979, Experimental confirmation of the lack of carbon isotope exchange between methane and carbon oxides at high temperatures: Geoch. Cosmo. Acta, v. 43, p. 272-276. Authors at Dept. Oceanog., Texas A&M Univ., College Station, TX 77843, U.S.A.

No exchange was observed between (1) CH_4 and CO_2 at 500°C for times as long as 136 hr; (2) CH_4 and CO_2 in the presence of a water-containing calcium montmorillonite at 200°C up to 32 days and at 500°C up to 10.5 days; and (3) CH_4, CO_2 and CO generated during the pyrolysis at 500°C of a natural lignite for times up to 180 hr. These experiments also indicate that the isotopic compositions of CH_4, CO_2 and CO found in natural environments at temperatures less than 200°C are not regulated by isotopic exchange with one another. (Authors' abstract)

SAFAROV, Yu.A. and VEKILOV, V.S., 1978, Thermobaric conditions of formation of hydrothermal ore mineralization in the Northern Caucasus (abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 83-84 (in Russian). Authors at the Rostov State Univ., USSR.

Quartz-ore veins connected with Middle and Upper Paleozoic granitoids occur in schists. The vein quartz contains mainly P and PS inclusions. The inclusions are filled by LH_2O+G, LH_2O+LCO_2+G, LH_2O+ colloids, LH_2O, LH_2O+G+dms, G>>L, glass (sic.). Td and Th are in ranges 260-320°C, P was about 400-500 atm. (From the authors' abstract, transl. by A.K.)

SAGONOV, V.N., TALANTSEV, A.S., ILYASOVA, L.K., BAKHTINA, A.P. and DEMINA, N.Ye., 1979, PTX-conditions for the formation of gold-sulfide quartz formation of the Urals, <u>in</u> Major parameters of natural processes of endogenetic ore formation, V.A. Kuznetsov, ed.: Novosibirsk, Izdat. Nauka, v. 2, p. 145-154 (in Russian). [Dokl. Vses. Soveshch., 1977]

Some values of Th, and 13 analyses of leachates for Na, K, Ca, Mg, HCO_3, Cl, and SO_4. (E.R.)

SAKHIBGAREYEV, R.S. and LASHKOVA, L.N., 1977, Mineral corrosion by petroleum and bitumens: Dokl. Akad. Nauk SSSR, v. 234, p. 1452-1455 (in Russian; translated in Doklady Acad. Sci. USSR, v. 234, p. 268-271, 1979).

See <u>Fluid Inclusion Research--Proceedings of COFFI</u>, v. 10, p. 243, 1977. (E.R.)

SAKUYAMA, M and KUSHIRO, I., 1979, Vesiculation of hydrous andesitic melt and transport of alkalies by separated vapor phase: Contributions to Mineralogy and Petrology, v. 71, p. 61-66.

SALIOT, P., GRAPPIN, C., GUILHAUMOU, N. and TOURAY, J.C., 1978, Conditions of formation of hypersaline fluid inclusions in quartz from the "gypsum zone," Vanoise, Savoy Alps: Acad. Sci. (Paris), C.R., Ser. D, v. 286, no. 5, p. 379-381 (in French).

SAL'NIKOV, V.N. and GAN'KINA, L.N., 1978, Observations of electromagnetic impulses in heated rock samples following the separation of mineral-forming fluids: Vyssh. Uchebn. Zaved., Izv., Geol. Razved., v. 5, p. 61-68 (in Russian).

SAL'NIKOV, V.N. and KOROBEYNIKOV, A.F., 1978, Determination of temperature of mineral formation by the electroconductivity method, (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 1, Thermobarogeochemistry in geology: Vladivostok, Acad. Sci. USSR, p. 183-184 (in Russian). Authors at the Tomsk Polytechnical Inst., Tomsk, USSR.

Electromagnetic impulses may originate during decrepitation and other phenomena such as oxidation, polymorphic alterations etc. Also, the electric conductivity changes in those alterations. Decrepitation of four rock and mineral specimens was registered by use of various accompanying phenomena yielding relatively good coincidence of Td. (A.K.)

SAL'NIKOV, V.N., KOROBEYNIKOV, A.F. and ZAVERTKIN, S.D., 1978, Studies of electrophysical properties of minerals for solution of some problems of thermobarogeochemistry, (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 1, Thermobarogeochemistry in geology: Vladivostok, Acad. Sci. USSR, p. 185-186 (in Russian). Authors at Tomsk Polytechnical Inst., Tomsk, USSR.

Many phenomena in minerals (including decrepitation) are accompanied by anomalies in electric conductivity and emission of radiowave impulses. Studies were made for quartz and for solid solutions NaCl-KCl of various ratio. On the basis of measurements of radiowave impulses and decrepitation, the curves of solubility and exsolution in solid state for NaCl-KCl were made, and the curves were compared with published data obtained by the X-ray determinations. Pressed polycrystalline KCl-NaCl mixtures have large specific surface (model of a rock). On heating, between grains of NaCl and KCl, at T of solid solubility, the bridges of solid solution form, decreasing free energy of the system. The electrodiffusion fields generate radiowave electromagnetic impulses and acoustic impulses. By the same way the ranges of isomorphic replacement in more complicated systems like minerals and rocks may be investigated. The complex application of decrepitation in vacuum, radiowave impulses registration and acoustic method may be used for determination of mineral formation temperature. (Authors' abstract, transl. by A.K.)

SAMORUKOVA, L.M. and KOZAKOV, I.K., 1979, Estimation of formation conditions of the West Sangilen Precambrian granite rocks: Geol. i Geofiz., Akad. Nauk SSSR, Sib. Otdel., 1979, no. 9, p. 34-42 (in Russian).

The formational conditions of the West Sangilen Precambrian granitoid complexes are discussed on the basis of geological, petrological and experimental data on the homogenization temperatures of melt inclusions. It is concluded that the depth of magma generation varies with different stages of endogeneous cycles. Peculiarities of crystallization of granite rocks concerned are considered from temperatures of phase transformations in melt inclusions. (Authors' abstract)

SANGSTER, D.F., 1979, Carbonate-hosted lead-zinc occurrences in northeastern British Columbia with emphasis on the Robb Lake deposit: Discussion: Can. J. Earth Sci., v. 16, p. 2063-2066.

Discussion of Macqueen and Thompson, 1978 (see abstract this volume). (E.R.)

SASAKI, Akira, and ISHIHARA, Shunso, 1979, Sulfur isotopic composition of the magnetite-series and ilmenite-series granitoids in Japan: Contrib. Mineral. Petrol. v. 68, p. 107-115. Authors at Geol. Survey of Japan, 1-1-3, Higashi, Yatabe, Ibaraki, 305 Japan.

The isotopic data of gabbroids, mostly between -1 and +3^0/00, are close to the commonly assumed value for mantle sulfur. Nevertheless, the gabbroids from the magnetite-series granitic terranes tend to have higher $\delta^{34}S$ value than those from the ilmenite-series belts. It is inferred that the factors controlling the isotope characteristics of the granitoid sulfur have also been operative in these grabbroids at least to some extent. (From the authors' abstract).

SATO, Motoaki, 1979, The role of gas-forming elements in intraplate basaltic volcanism,(abst.): Hawaii Symposium on Intraplate Volcanism and Submarine Volcanism, Hilo, Hawaii, July 16-22, 1979, Internat. Assoc. Volc. and Chem. of Earth's Interior, P. 98.

How gas-forming elements are stored in the upper mantle and how these degas are important questions regarding the nature of the driving force for intraplate volcanism. In oceanic tholeiitic magmas, H_2O is undersaturated and P_{H_2O} is probably less than 100 bars (J.G. Moore). The rupture of the roof of a magma chamber at a depth greater than 1 km requires a considerably greater pressure. Calculations show that such a pressure could be provided by the generation of CO_2 due to the reaction of graphite with H_2O and Fe^{3+} in the magma. Evidence indicates that elemental carbon exists in the mantle and in basaltic magmas at depth, and that CO_2 is saturated in basaltic magmas even at the source region. Oxygen fugacity studies of minerals formed in the mantle suggest that the redox state of the upper mantle is controlled by the C-CO_2 or C-carbonate equilibrium. (From the author's abstract)

SAVEL'YEVA, N.I. and NAUMOV, G.B., 1979, Methods of analyzing salt composition for fluid inclusions in minerals: Geokhimiya, 1979, no. 5, p. 730-736 (in Russian with English abstract).

Natural quartz specimens have been used in examining the results of water extraction of gas-liquid inclusions. It is shown that fine grinding causes additional effects that distort the results substantially. A method is given for minimizing the error. (Authors' abstract)

Editor's note - The method is decrepitation for opening the inclusions. (E.R.)

SAWKINS, F.J., 1979, Fluid inclusion studies of the Inguaran copper-bearing breccia pipes, Michaocan, Mexico: Econ. Geol., v. 74, p. 924-927. Author at Dept. Geol. and Geophys., Univ. Minn., Minneapolis, MN.

Th and % NaCl in quartz (224-364°C; 11.9-36.0%) and scheelite (150-319°C; 14.9-23.5%) are reported, with the lowest Th values given for secondaries. Some evidence found for boiling. Dm halite and an acicular mineral, with high birefringence and parallel extinction may be dawsonite. (E.R.)

SAWKINS, F.J., O'NEIL, J.R. and THOMPSON, J.M., 1979, Fluid inclusion and geochemical studies of vein gold deposits, Baguio district, Philippines: Econ. Geol., v. 74, p. 1420-1434.

Fluid inclusion studies on quartz indicate deposition throughout the vein systems in the range 250° to 300°C, by low salinity fluids (0-6 equiv. wt. % NaCl). Gas analyses of fluid inclusions demonstrate that CO_2, CO, H_2, NO, H_2S, SO_2, and CH_4 were present in the fluids but that the combined total of these gases was always less than 1 mole percent relative to H_2O.

Chemical and isotopic analyses of the modern geothermal waters and isotopic analyses of vein and host-rock material suggest considerable similarities between the ore fluids and present thermal waters. The δD values of fluid inclusion waters range from -72* to -82 versus -58 to -75 for the modern waters. The $\delta^{18}O$ values of vein quartz (3.2-6.1) are light, given the temperature of quartz deposition. Complex partial mixing patterns of the modern geothermal waters are suggested by the isotopic data, and similar conditions probably prevailed during the earlier gold mineralization.

The source of the gold in the vein systems could be either the country rocks, older low-grade gold-copper mineralization within them, or contributions from magmas at depth. The gold/silver ratios in the ores, however, are much higher (~ 1:1) than they are in the host rocks (~ 1:130). (From the authors' abstract.) (*In the text, "per mil" units are mentioned.)

SAWKINS, F.J. and RYE, R.O., 1979, Additional geochemical data on the Messina copper deposits, Transvaal, South Africa: Econ. Geol., v. 74, p. 684-689.

Stable isotope and geochemical data were obtained on samples remaining from a previously published inclusion study (Sawkins, 1977, Fluid Inclusion Research--Proceedings of COFFI, v. 10, p. 244-245). Quartz and other minerals (23) were analyzed for $\delta^{18}O$ and inclusion fluids (15) for δD. Presents two analyses of inclusion gases (given in mole % to 4 significant numbers) and three pairs of water and acid leach analyses for Na, K, Ca, Mg, Zn, Cu, Cl, and SO_4 (also given to 4 significant numbers). (E.R.)

SAWKINS, F.J. and SCHERKENBACH, D., 1979, High copper contents of fluid inclusions in quartz from a mineralized breccia pipe, Sonora: Implications for ore genesis theory (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 510.

The San Judas molybdenum deposit near Cumpas Sonora occurs in a pipe-like body of angular collapse breccia within granodiorite. Coarse grained biotite, K-feldspar and quartz accompany the mineralization, and apatite is present locally in significant amounts.

Studies of fluid inclusions in quartz crystals from the deposits indicate mineralization occurred from 302-409°C, and that three distinct inclusion types are present: (I) A high salinity type with NaCl from 34-40 wt. %, KCl up to 30 wt. % and a spectrum of birefringent and opaque daughter minerals. (II) A lower salinity type without daughter minerals, and equivalent NaCl contents from 5-20 wt. %. (III) Vapor dominated inclusions with salinities ranging from 3-18 equiv. wt. % NaCl, many of which contain an opaque daughter mineral. Mixing of these fluid types is apparent in some inclusions, and probably accounts for the high salinities in many type III inclusions.

The opaque tetrahedra in most type I and many type III inclusions give S.E.M. emission spectra indicating a copper iron sulfide (chalcopyrite). Volumetric calculations based on careful measurement of inclusion dimensions and chalcopyrite size indicate the copper (and iron) p.p.m. These data, on fluids of presumed magmatic origin, hold important implications for ore genesis theory. For example, a tenfold dilution of such metal rich fluids by non-magmatic waters would not necessarily render them ineffective as ore fluids. Thus, stable isotope data indicative of predominance of non-magmatic fluids during ore deposition is no proof of a non-magmatic source of the metals involved. (Authors' abstract)

SAZONOV, V.N., TALANTSEV, A.S., ILYASOVA, L.K., BAKHTINA, A.P. and DEMINA, N.E., 1979, Pressure-temperature-composition conditions for the formation of gold-sulfide-quartz formation deposits in the Urals, in Major parameters of natural processes of endogenetic ore formation, V.A. Kuznetsov, ed.: Novosibirsk, Izdat. Nauka, v. 2, p. 145-154 (in Russian). [Dokl. Vses. Soveshch., 1977]

Formation conditions of the ore-bearing quartz veins and the beresite-listwanite metasomatites enclosing them are estd. on the basis of fluid-inclusion studies and the compns. of coexisting calcite and dolomite. The metasomatites formed at 360-500° and varying pressures (0.6-1.5 kilobars) which increased with depth, and must have exceeded the lithostatic pressure. The quartz veins formed at 250-450°, from alkali metal-Cl-HCO_3 solns. Listwanitization of serpentinites and resulting development of successive fuchsite-quartz-carbonate (inner), quartz-carbonate (intermediate), and talc-quartz (outer) metasomatic zones occurred under the effect of convectively diffusing alkali metal-HCO_3 solns. (C.A. 92:79635s)

SCHAEFER, Bernward and STRUBEL, Günter, 1979, Hydrothermal solubility of fluorite in the system CaF_2-$MgCl_2$-H_2O: N. Jb. Miner. Mh., 1979, no. 5, p. 233-240 (in English).

The conditions of dissolution, transport and precipitation during the formation processes of hydrothermal fluorite deposits are still problematic. Therefore, in addition to existing data, we carried out quantitative analyses of hydrothermal reactions and dissolution behaviors in the system CaF_2-$MgCl_2$-H_2O at temperatures of 150°C and 300°C and pressures of about 4.5 and 85 bar.

The concentrations of the initial solutions were between 0.001 and 2.00 mole $MgCl_2$/kg H_2O. The maximum values obtained for the hydrothermal solubility were $5.16 \cdot 10^{-1}$ g CaF_2/kg H_2O at 150°C/4.5 bar and 8.6 g CaF_2/kg H_2O at 300°C/85 bar. Sellaite appears in the system already at concentrations of 0.01 m $MgCl_2$ at 300°C. This mineral has also been found in considerable amounts in fluorite deposits. Economic geological aspects of the results are discussed. (Authors' abstract)

SCHUILING, R.D. and KREULEN, R., 1979, Are thermal domes heated by CO_2-rich fluids from the mantle?: Earth and Planet. Sci. Lett., v. 43, p. 298-302. Authors at Vening Meinesz Lab., Dept. Geochem., Univ. Utrecht, The Netherlands.

A large part of the fluid present in the thermal dome at Naxos, Greece, during the main stage of metamorphism was CO_2-rich and of deep-seated origin. Samples of this pervasive fluid were trapped in fluid inclusions, which are particularly abundant in syn-metamorphic quartz segregations. These quartz segregations are considered to represent the main passageways of the escaping fluids. Mass-balance calculations based on $\delta^{13}C$ values of fluids and rocks indicate that most fluid/rock mass ratios are between 0.06 and 0.8. The heat added to the metamorphic system by the cooling of these fluids may have been the prime cause of metamorphism and updoming. (Authors' abstract)

SELLSCHOP, J.P.F., 1979, Nuclear properties in physical and geochemical studies of natural diamond, in The properties of diamond, Field, J.E.

(Editor): England, Academic Press, p. 107-163.

Includes discussion of the trace element geochemistry of diamond. (E.R.)

SELLSCHOP, J.P.F., MADIBA, C.C.P., ANNEGARN, H.J. and SHONGWE, S., 1979, Volatile light elements in diamond: Diamond Res., 1979, p. 24-30.

SERAFIMOVA, Ye.K., 1979, Mineralogy of the exhalation products of the Kamchatka volcanos: Moscow, "Nauka" Pub. House, 168 pp (in Russian). Author at the Volcanology Inst. of the Far East Sci. Center of the Acad. Sci. of the USSR, Petropavlovsk-Kamchatskiy, USSR.

The book includes a detailed discussion of the physico-chemical parameters of exhalations, composition and mode of occurrence of the exhalation products and their sources and transport capacity. Few photos present fluid inclusions in exhalation minerals: p. 154 - G inclusions in halite, p. 161 - G/L inclusions in sylvite, p. 162 - G/L inclusions in sal ammoniac. (Abst. by A.K.)

SEWARD, T.M., 1979a, Hydrothermal transport and deposition of gold: Gold Mineralization, a Seminar, J.E. Glover and D.I. Groves, eds.: Geology Dept., Univ. Western Australia, p. 45-55.

In two examples, thio gold complexing provides the most plausible mechanism of transport, but this does not eliminate the possibility of chlorogold (I) complexes playing an important role in the formation of other deposits. There is apparently no problem in transporting gold in ore-forming fluids and many hydrothermal solutions may be unsaturated with respect to gold. As discussed by Seward (1973), there are a number of ways of precipitating gold when it is present as a thio complex and in particular, changes in reduced sulphur activity by oxidation and boiling (H_2S loss) may be very important. More detailed studies of gold ore deposits are required, and experimental data on the stability of $AuCl_2^-$, $AuClOH^-$ and $AuHS^\circ$ up to at least 400° are needed. (Author's abstract.)

SEWARD, T.M., 1979b, Modern hydrothermal systems in New Zealand and their relation to gold mineralization processes: Gold Mineralization, a Seminar, J.E. Glover and D.I. Groves, eds.: Geology Dept., Univ. Western Australia, p. 56-64.

Discusses temperatures, fluid compositions, origin of the waters, hydrothermal alteration, metal-rich precipitates, equilibrium criteria, and ore elements in the waters. Includes a table of water compositions and heavy metals in fluids from Broadlands, Steamboat Springs, and other areas. (E.R.)

SEYFUL'-MULYUKOV, R.B., SERENGIN, A.M., SOKOLOV, B.A., MAZOR, Yu.R. and MEL'NIKOV, F.P., 1978, Use of thermobarogeochemical studies in oil geology (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 37-38 (in Russian). First author at All-Union Inst. of Sci. and Techn. Inf., Moscow, USSR.

Valuable data on oil migration conditions may be obtained by fluid inclusion studies of minerals from fissures syngenetic with oil migration. (A.K)

SHAN, Lin and ZHANG, Wenzhi, 1979, A study of double-decked vacuum glass isolating set of fire cracking instrument: Geochimica, 1979, p. 340-341.

Described in this paper is a double-decked vacuum glass isolating set built in the fire cracking instrument. It is characterized by high sensitivity and as being free from sound, electro-magnetic and vibrating interferences from outside, thus enjoying the advantages of sound-isolation, shock-proof and no electro-magnetic interference, as well as simple construction, portability, lower cost and easy popularization. (Authors' abstract)

(Editor's note - The device that is described, with a drawing, is apparently for decrepitation.)

SHAPENKO, V.V. and VITVITSKIY, V.V., 1978, Character of inclusions in gypsum forming during salt precipitation in oil-producing boreholes (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 49 (in Russian). First author at GEOKHI, Moscow, USSR.

In the late stage of oil deposit exploitation under conditions of abundant brines, gypsum and other salts precipitate in boreholes and collectors. The studies were performed in samples from Povolzh'ye (i.e., Volga territory) and Bashkiria. Gypsum bears numerous inclusions filled in various proportions by oil, gas (hydrocarbons?-A.K.), LH_2O, paraffins and air bubbles. The inclusions characterize the heterogeneous fluid surrounding the rapidly growing gypsum crystals. Epigenetic minerals of the oil-bearing Paleozoic beds (anhydrite, dolomite, calcite) bear inclusions with Th 180-270°C and filled only by G and L. (From the authors' abstract, transl. by A.K.)

SHCHEKA, S.A., MALAKHOV, V.V. and ROMANENKO, I.M., 1979, The composition of gas-liquid inclusions in minerals of basic-ultrabasic nodules from volcanic rocks: Geol. Geofiz. (Novosibirsk), v. 7, p. 70-74 (in Russian; translated in Sov. Geol. Geophys., v. 20, p. 59-63, 1979).

Salt-forming and gas components of gas-liquid inclusions in minerals of basic-ultrabasic nodules from alkaline and calc-alkaline basalts of the Primorye and Kamchatka have been investigated by electron microprobe and gas chromatography. The composition of the gaseous phase is shown to be due to basaltic melt. (Authors' abstract)

SHCHEPETKIN, Yu.V. and SHAPENKO, V.V., 1978a, Paleotemperatures of formation of the fissure carbonates of Paleozoic beds in the West-Siberian Plate in connection with the possibility of gas and oil occurrence (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 41-42 (in Russian). First author at the W. Siberian Sci.-Research Geol. Oil Inst., Tyumen', USSR.

Th was determined in over 100 samples of calcite (accuracy ± 2°C). About 70% of samples bear P and PS G/L inclusions (G 5-20 vol. %). S inclusions bear only 1-3% of G phase. Inclusion size 0.001-0.01 mm. Samples came from boreholes, depth 1994-3514 m. Rocks are Precambrian and Devonian limestones, Middle Paleozoic, Upper Devonian and Lower Carboniferous shales, Paleozoic effusives Upper Jurassic argillites, aleurolites and sandstones. Calcite occurs in veinlets 3-20 mm thick and bears P and PS inclusions with Th 115-240°C, and S inclusions with Th 40-105°C; no relationship was found between Th and depth. Th is much higher than present rock temperatures, but some microinclusions have lower Th than present rock temperatures (Th 55°C vs rock T 88°C). Maximum Th 240°C cannot be the feature indicating the destruction of hydrocarbon deposits. (From the authors' abstract, transl. by A.K.)

SHCHEPETKIN, Yu.V. and SHAPENKO, V.V., 1978b, Paleotemperatures of Paleozoic formations of the Western Siberian Platform according to microinclusion homogenization of interstitial carbonates: Tr. Zap.-sib. N.-i. Geol.-razved. Neft. In-t, 1978, (v. 133), p. 65-69 (in Russian).

See previous item. (E.R.)

SHCHERBAN, I.P. and SHIROKIKH, I.N., 1977, New type of metasomatic rocks in pyrite-polymetal deposits: Dokl. Akad. Nauk SSSR, v. 235, no. 2, p. 458-461 (in Russian; translated in Dokl. Acad. Sci. USSR, v. 235, p. 141-144, 1979).

Abstract in Fluid Inclusion Research--Proceedings of COFFI, v. 10, p. 254 (1977). (E.R.)

SHELNUTT, J.P., 1979, Intrusive breccias of the Julcani silver district, Peru: M.S. thesis, Michigan Technol. Univ., Houghton, MI, 56 pp.

Indexed under fluid inclusions. (E.R.)

SHELTON, K.L. and ORVILLE, P.M., 1979, Synthetic fluid inclusions in natural quartz, (abst): EOS, v. 89, p. 422.

Bubble planes consisting of water-rich fluid inclusions were created by annealing laboratory-induced fractures in natural quartz in a hydrothermal apparatus at 600°C and 2 Kb pressure in the presence of water. The size, distribution, and morphology of the synthetic fluid inclusions show a remarkable similarity of natural fluid inclusions from metamorphic terranes. Fluid inclusion trains along former fracture-surface step lineations are evident as well as a pattern of fluid inclusions population size varying directly with the spacing of step lineations on the original fracture surface: where step lineations were closely spaced, a large number of small (1-2 microns) inclusions develop; areas where the step lineations were more widely spaced develop a smaller number of larger (5-10 microns) inclusions. The fluid inclusions are three-dimensional ellipsoids varying from equant to elongate (maximum dimension up to 3 times the minimum dimension). The minimum dimension of the fluid inclusions is considerably greater than the original crack width. The fluid inclusions appear to have grown at the expense of the original crack walls while the surface of the unhealed crack appears unchanged, suggesting a solution phenomenon at the advancing edge of the bubble plane. This study suggests a likely mechanism for formation of bubble planes in quartz. Further applications of this experimental technique include: 1) a method of testing filling temperatures and pressures of fluid inclusions using microthermometric techniques, 2) a means of demonstrating isotopic equilibrium between the fluid inclusions and the coexisting quartz, and 3) a study of possible compositional and isotopic fractionation within the fluid phase during fluid inclusion genesis. (Authors' abstract)

SHEPHERD, T.J., 1979, Mineral exploration at Carrock Fell: a fluid inclusion approach (abst.): Program of Fourth Meeting of the Geological Societies of the British Isles, Univ. Sheffield, Sept., 1979 (unpaginated). Author at Inst. Geol. Sciences.

As part of a research program to evaluate the significance of fluid inclusion studies in mineral exploration, a detailed examination is currently being made of the Carrock Fell tungsten deposits. Initial results show a systematic chemical variation in the gases released from inclusions in quartz gangue from the mineralized and non-mineralized sections of the tungstaniferous veins. Temporal and spatially related changes in the chemistry of the ore fluids are interpreted in terms of conditions favorable for the deposition of wolframite. A similar study of inclusion gases (H_2O, CO_2 and CH_4) in quartz grains from the hydrothermally altered Skiddaw granite wallrocks reveals a symmetrical pattern of chemical change about the veins which provides a means of estimating the relative fluid flux involved. Both geochemical patterns are considered relevent to the future exploration and development of other veins in the area. (Author's abstract)

SHIREY, S.B., SIMMONS, Gene and PADOVANI, E.R., 1979, Angular, oriented microtubes in metamorphic oligoclase (abst.): Eos, v. 60, p. 424.

SHLYAPNIKOV, D.S. and SHTERN, E.K., 1979, Solubility of cadmium and mercury oxides in NaCl solutions at relatively high carbon dioxide partial pressures: Dokl. Akad. Nauk SSSR, v. 249, p. 457-461 (in Russian; translated in Dokl. Acad. Sci. USSR, v. 249, p. 173-176, 1982).

SHNAY, G.K. and LEVITSKIY, Yu.F., 1978, The relationship of gold mineralization to metasomatic processes in alkalic rocks, Termobarogeokhimiya Zemnoy Kory I Rudoobrazovaniye, N.P. Ermakov, ed.: Moscow Izd. Nauka, p. 196-200 (in Russian).

Indexed under fluid inclusions, geothermometry, geobarometry. (E.R.)

SHNAYDER, A.A., SHNAYDER, M.S. and IL'INYKH, V.V., 1978, Formation temperature of Industryal'noe tin ore deposit (in the NE part of the USSR) (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 67-68 (in Russian). Authors at Far-East Inst. of Mineral Raw Materials, Khabarovsk, USSR.

The vein deposit Industryal'noe in the Omsukchan ore region, Magadan area, is connected with the dome of Upper Jurassic granite. Hydrothermal ore formation is characterized by decreasing Th and Td of the following mineralization stages: 1) chlorite, Td 435-395°C, 2) early hematite-cassiterite, Td 405-385°C, 3) quartz-chlorite-cassiterite, Th 380-360°C, Td 395-355°C, 4) quartz-tourmaline, Th 350-300, Td 355-305, 5) quartz-tourmaline-cassiterite, Th 290-250°C, Td 305-265°C, 6) late hematite-cassiterite, Td 315-245°C, 7) fluorite, Th 260-80, Td 275-205. T increase in stage 6 should be connected with injections of dikes of diabase porphyrite . Hydrothermal mineral formation developed after origin of pegmatoid veins of quartz with Th 540-440°C. (Authors' abstract, transl. by A.K.)

SHNAYDER, M.S. and SHNAYDER, A.A., 1978, Selection of thermobarogeochemical cross-sections taking into account vein morphology during evaluation of ore content (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 54-56 (in Russian). Authors at Far-East Inst. of Mineral Raw Materials, Khabarovsk, USSR.

Studies of vein tin deposits in N. Sikhote-Alin' Mts and in Omsukcha region proved that asymmetric veins have to be studied with special care to reveal this asymmetry and the ore distribution. T measurements are especially useful. (A.K.)

SHOJI, T., 1978, Skarn formation, in Geological studies of the mineral deposits in Japan and East Asia, H. Imai, ed., Univ. of Tokyo Press, p. 201-212 (in English).

Indexed under fluid inclusions. (E.R.)

SHOJI, T. and IMAI, H., 1978, Chichibu mine, Saitama Prefecture, in Geological studies of the mineral deposits in Japan and East Asia, H. Imai, ed., Univ. of Tokyo Press, p. 190-196 (in English).

Indexed under fluid inclusions. (E.R.)

SHUGUROVA, N.A., SHOKHONOVA, L.A. and GRISHINA, S.N., 1978, Methods for determination of the composition of the gaseous phases of individual inclusions, in Theory and Practice of Thermobarogeochemistry, N.P. Ermakov, ed., Izd. Nauka, p. 237-240 (in Russian).

SHUKAYLO, L.G., 1979, The composition of microinclusions in apatites of Neogene hypabyssal intrusions in Transcarpathia: Mineral. Sb. (L'vov. Gos. Univ.), v. 33, no. 2, p. 53-60 (in Russian).

This article deals with the possibility of correlation of the rocks of Miocene and Pliocene andesite magmatic Carpathian formations according to accessory minerals and fusion inclusions in them and besides the possibility of establishing the connection of products of postmagmatic activity with concrete magmatic formations. (Author's abstract)

SHVADUS, M.I., 1978, Inclusions in fluorites from granitoid rocks of the Transbaikalia region, in Thermobarogeochemistry of the Earth's Crust and Ore Formation, N.P. Ermakov, ed., Izd. Nauka, p. 86-89 (in Russian).

SHVEDOV, V.N. MARCHENKO, A.V. and KHOLODKOV, Yu.I., 1979, Some peculiarities of formation of celestite deposits on the northern Caucasus according the data of investigation of microinclusions in minerals: Geokhimiya, 1979, no. 11, p. 1723-1727.

Celestite from Cretaceous limestones have gas-liq. inclusions with low Th. (E.R.)

SIANISYAN, E.S. and TARASOV, M.G., 1978, Complex studies of isotopic and chemical composition of subsurface waters and fluids of gas-liquid inclusions in minerals and rocks in relation to the problem of the genesis of deep-seated brines: Mater. Geol, Izuch. Zemnoi Kory Beloruss., 1978, p. 56-59: Izd. Nauka Teknika, Minsk, USSR (in Russian).

SILBERMAN, M.L., POTTER, R.W., II, NISSENBAUM, A. and COBB, E.H., 1976, Stable isotope, sulfide mineralogy, fluid inclusion, and K-Ar age study of the massive sulfide deposits at Kennecott (abst.): U.S. Geol. Survey Circular 733, p. 51-52.

Indexed under fluid inclusions and geothermometry. (E.R.)

SILVA, L.C., 1979, Geological consideration and preliminary studies of primary solid and liquid inclusions in apatite of carbonatites and ijolites from the island of Santiago (Cape Verde Republic): Comunic. Serv. Geol. Portugal, v. 64, p. 261-268; (in Portuguese with English abstract).

Some geological and petrographic aspects concerning ijolitic and carbonatitic associations of Santiago island (Republic of Cape Verde) are described and particular references are made to the existence of teralitic and ijolitic fenites supposed to have originated from saturated gabbroic rocks by fenitization.

The results of preliminary studies on primary fluid and solid inclusions found within the apatite crystals of ijolitic and carbonitic formations of Santiago island are presented. (Author's abstract)

Inclusions of H_2O and of CO_2 reported, and some dms (alkaline carbonates?) (ER)

SIMKIN, Tom, 1979, Volcanology: U.S. National Report, 17th General Assembly, IUGG, Canberra, Australia, Dec. 1979, Papers in volcanology, geochemistry, and petrology: Reviews of Geophysics and Space Physics, v. 17, no. 4, p. 872-886.

SIMKIV, Zh.A., 1978, Ion ratios in water leachates as indices of the depth of ore formation (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 57-58 (in Russian). Author at L'vov Univ., Ukrainian SSR.

Ores in the deposits of the Sadon group (N. Caucasus) formed in three stages (quartz-pyrite, quartz-sulfide and quartz-carbonate) over a large vertical interval. Samples from depth 800 to 1600 m a.s.l. were investigated by water leachate method. The solution composition (from upper to lower levels) changed from HCO_3 + $HSiO_3$(?) + Cl + Na + Ca to $HSiO_3$(?) + Cl + Na + Ca for quartz associated with pyrite or from $HSiO_3$(?) + HCO_3 + Ca + Na to HCO_3 + Cl + Ca + Na for quartz associated with galena and sphalerite. The method helps to evaluate the depth of formation of ore bodies. (A.K.)

SIMONOV, V.A., SHUGUROVA, N.A. and DOLGOV, Yu.A., 1978, Determination of the cationic composition of individual inclusions: Genet. Mineralogiya. po Vklyucheniyam v Mineralakh, Novosibirsk, 1978, p. 19-23 (in Russian).

SIVORONOV, A.A. and ROSIKHINA, A.I., 1978, Physicochemical conditions of metamorphism from mineral thermobarometry data (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 1, Thermobarogeochemistry in geology: Vladivostok, Acad. Sci. USSR, p. 122-124 (in Russian. Authors at the L'vov State Univ., L'vov, USSR.

Studies were performed on rocks of isochemically metamorphosed siliceous iron formation (Lower Cambrian) of Kola Peninsula, Ukrainian shield and

Kursk Magnetic anomaly, metamorphosed conglomerates of the Zvenigorod complex, and gneiss-amphibolite formation of the Tikichskiy complex in the Ukrainian shield. Th 340-290°C and P >2000 atm characterize greenschist facies (jaspilites and schists of the Krivoy Rog and Kurst Anomaly); 460-440°C, >2000 atm for the epidote-amphibolite facies (almandine-cummingtonite-chlorite schists and ferruginous quartzites of Krivoy Rog and Kremenchug, inclusions in quartz and garnet). Zvenigorod complex of epidote-amphibolite and amphibolite facies yielded Th (in quartz) 440-380°C in G and 420-375°C in L, upper T range was estimated for 510°C, solution concentration 42%.

Gneiss-amphibolite rocks of amphibolite facies in the Bazavluk basin (Ukrainian shield) bear inclusions in quartz with Th 525°C and P >2200 atm. At the Olenegorsk deposit inclusions in garnet and diopside have Th 730-675°C; retrograde metamorphism formed inclusions with Th 525-370°C and P 1400 atm.

Granulite facies is characterized by Th 750-1100 C (upper range was not established, from inclusions in "blue" quartz and garnet from the Chudnovo-Berdychov area and in hypersthene of the iron-ore-gneiss formation of the Ukrainian shield. (Authors' abst.)

SIVORONOV, A.A., and ZHIKHAREV, A.P., 1978, Inclusions of mineral-forming medium in hypersthenes of granulite facies, (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 1, Thermobarogeochemistry in geology: Vladivostok, Acad..Sci. USSR, p. 121-122 (in Russian). Authors at the L'vov State Univ., L'vov, USSR.

Fluid inclusions were studied in hypersthenes of the former supracrustal rocks metamorphosed under granulite facies conditions and occurring in the Pobuzhye rock complex of the Ukrainian shield. Three morphological types of inclusions were distinguished: 1) prismatic, similar to the host mineral habit, 2) tubular, 3) irregular. Their filling is of two types: 1) polyphase, formed by highly concentrated solutions, 2) two-phase G/L formed by concentrated solutions. The first type includes dms that dissolve partly or completely on heating (probably Ca and Mg carbonates, of rhombic, prismatic or round habit), and prismatic or acicular silicate (?) crystals which do not dissolve on heating. G occupies 20-30 vol. %. Fluid consists of CO, CO_2, hydrocarbons and nitrogen-hydrogen compounds plus very little water. The lowest Th (in L or in G) were for G/L inclusions, 860-970°C, (sic); polyphase inclusions yielded Th 950-1100°C. P calculated from polyphase + LCO_2 and polyphase salt inclusions was 4.5-5 kbar. (From the authors' abstract.)

SKRIPNICHENKO, V.A., 1979, Phosphorus as factor of liquation of silicate melts: Akad. Nauk SSSR Doklady, v. 245, no. 4, p. 930-933 (in Russian). Author at Arkhangel'sk Territorial Geol. Office, USSR.

In the Northern Timan a gabbro-syenite complex occurs, with a formation that is explained as liquation of a "primary" essexite melt to form melanocratic gabbroic and leucocratic syenitic parts. The evidence is as follows: alternating gabbro-syenite layers and spherical syenite bodies in dikes of alkaline gabbroids. Experimental melting of a mixture of gabbro + syenite at 1200°C gave homogeneous brown glass. When 3% (by weight) or more of $Na_4P_2O_7$, NaH_2PO_4 or KH_2PO_4 were added, the melt split into two melts: brown similar to basaltic melt and colorless one similar to trachytic melt. Addition of 15% of $(K,Na)H_2PO_4$ caused splitting to black magnetic glass rich in titanomagnetite and light one. (Abst. by A.K.)

SKRIPOV, V.P., KOVERDA, V.P. and BUTORIN, G.T., 1979, Crystal nucleation kinetics in small volumes: Growth of Crystals, v. 11, p. 22-25.
Pertinent to nucleation in inclusions. (E.R.)

SLOBODSKOI, R.M., KUZEBNYI, V.S. and FILIPPENKO, I.I., 1979, Composition of ore-bearing fluids and the problem of the genesis of pyrite-polymetal deposits of Rudnyi Altai: Geologiya i Geofizika, v. 20, no. 8, p. 3-9 (in Russian; translated in Geology and Geophysics, v. 20, no. 8, p. 1-6, 1979).
A review including inclusion data from the literature. (E.R.)

SMIRNOV, G.I., MOFOLO, M.M., LEROTHOLI, P.M., KAMINSKY, F.V., GALIMOV, E.M. and IVANOVSKAYA, I.N., 1979, Isotopically light carbon in diamonds from some kimberlite pipes in Lesotho: Nature, v. 278, p. 630.
Values for $\delta^{13}C$ (re. PDB, in ‰) ranged from -4.6 to -20.5. (E.R.)

SMITH, B.M. and GILETTI, B.J., 1979, The nature of fluids circulating near a granite-limestone contact, Isle of Skye, NW Scotland, (abst): EOS, v. 89, p. 417.
The Beinn an Dubhaich Granite (BDG) is singular among the "epigranites" at the Skye intrusive center in that it is less depleted in ^{18}O than the other Skye granites studied by Forester and Taylor (1977). These authors note that (a) the BDG may have been emplaced after much of the Skye hydrothermal interaction was completed, and (b) the relatively impermeable, ^{18}O-rich intruded carbonate rocks (Durness Limestone, DL) may have reduced the fluid flux, or increased the $\delta^{18}O$ of these fluids. To understand the ^{18}O-distribution in these rocks, O-isotopic compositions were determined in a traverse across the BDG-DL contact. For this traverse, whole-rock $\delta^{18}O$ values of BDG (6 samples) range from -0.6 to +3.6‰ (SMOW); DL varies from -1.7 to +12.2‰. The most ^{18}O-depleted BDG sample analyzed to date gives $\delta^{18}O = -0.8$‰. The occurrence of brucite ($Mg(OH)_2$) in recrystallized dolomitic DL near the contact indicates $X_{H_2O} \gg X_{CO_2}$ in the fluid (Greenwood, 1975). The profound ^{18}O-depletion in these samples requires high local fluxes of low-$\delta^{18}O$ hot water which had not become significantly ^{18}O-enriched through exchange with carbonate host rocks. ^{18}O-depletion in BDG and DL samples is strongly correlated with amount of fracturing. This structural control is the subject of research, currently in progress. (Authors' abstract)

SOBOLEV, V.S. and BAKUMENKO, I.T., 1979, Limits of magmatic crystallization during the formation of granitic pegmatites, *in* Problems of physicochemical petrology, v. 1: Moscow, "Nauka" Press (Acad. Sci. USSR, Inst. Exper. Mineralogy).
A review (41 references) of Th from various pegmatites. (E.R.)

SODOVA, I.S., 1978, Thermodynamic formation regime of ultrametamorphogenic granitoids in zones of metamorphism of moderately-high pressure, *in* Theory and Practice of Thermobarogeochemistry, N.P. Ermakov, ed., Izd. Nauka, p. 66-74 (in Russian).
Indexed under fluid inclusions. (E.R.)

SOKOLOV, S.V., 1979a, On the differences of phase composition of inclusions in minerals: Zapiski Vses. Mineral. Obshch., 1979, pt. 2, p. 202-206 (in Russian).

SOKOLOV, S.V., 1979b, Shortite-first occurrence in carbonatites: Dokl. Akad. Nauk SSSR, v. 247, no. 5, p. 1253-1256 (in Russian; translated in Dokl. Acad. Sci. USSR, v. 247, p. 174-177, 1981).

Inclusions in shortite from carbonatite of the Vorijarvi alkaline massif have Th 170-190°. (E.R.)

SOKOLOVA, N.T., KARYAKIN, A.V., EFIMOVA, N.F. and KREMNEVA, M.A., 1979, Disseminated organic matter in the hydrothermal mineral-formation: Geokhimiya, 1979, no. 11, p. 1679-1686 (in Russian; translated in Geochem. Internat., v. 16, no. 6, p. 57-64, 1979).

IR spectroscopy has been applied to the changes occurring in dispersed organic matter during thermal rock metamorphism and hydrothermal mineral formation. High-temperature processes produce organic compounds in various states of oxidation, but reduced ones predominate (aliphatic hydrocarbons). Low-temperature processes are accompanied by the formation of more highly oxidized compounds (alcohols, acids, esters, etc.). (Authors' abstract)

SOLOMON, M. and WALSHE, J.L., 1979, The formation of massive sulfide deposits on the sea floor: Economic Geology, v. 74, p. 797-813. First author at Dept. Geol., Univ. Tasmania, Hobart, Tasmania.

The physical processes of mixing and precipitation are compared with the forms of the ores. (E.R.)

SONDERGELD, C.H. and TURCOTTE, D.L., 1979, A laboratory study of mineral deposition in a boiling environment: Econ. Geol., v. 74, p. 109-115.

SPECZIK, Stanislaw, 1979, Ore mineralization in the basement Carboniferous rocks of the Fore-Sudetic monocline (SW Poland): Polska Akad. Nauk, v. 14, no. 1, p. 103-122; (in Polish with English abstract and 4-page English summary.)

Carboniferous rocks occurring in the basement of the Fore-Sudetic Monocline were investigated mineralogically and petrographically by means of optic, thermobarogeochemical, X-ray, and other methods. Ore minerals are ubiquitous in these rocks. They usually appear in form of fine inclusions, "pseudo-veins", proper veinlets, impregnations, and concretions. The studied ore minerals represent several genetic types of which postmagmatic-hydrothermal mineralization is the most significant. The hydrothermal veins contain 26 ore minerals crystallizing directly from hydrothermal fluid or resulting from their reconstitution owing to changes in the environment chemistry, 10 hypergenic minerals, and 12 non-ore ones. The conditions of mineralization were reconstructed on a basis of detailed analysis of hydrothermal deposits, interrelationships of ore and non-ore minerals, recognized index minerals, and thermobarogeochemical investigations. Two mineral paragenesis were found in the postmagmatic-hydrothermal deposits: the first representing high and medium temperatures and characterized by three (A,B,C) coexisting associations of ore minerals, and the second representing low temperatures and characterized by two (D, E) ore mineral associations. The hydrothermal mineralization is related to Hercynian microtectonics and is absent from Rotliegendes deposits, therefore it is assigned to the Hercynian epoch. Hydrothermal fluids are thought to have been connected with Hercynian granite and porphyry intrusion. Based on the results obtained and depth of occurrence of Carboniferous rocks, the author rather excludes presence of industrial ore deposits of this age in western and middle part of the Fore-Sudetic Monocline, excepting its eastern part where hydrothermal mineralization seems to have a greater practical significance. Various genetic types of the studied ore minerals as well as knowledge of primary thickness and extent of Carboniferous rocks point to the role of post-Carboniferous erosion possibly providing metals for Zechstein copper deposits. (Author's abstract)

SPRUNT, E. and NUR, A., 1979a, Microcracking and healing in granites: New evidence from cathodoluminescence (abst.): Eos, v. 60, p. 417.

In a study of the cathodoluminescence (Cl) of quartz in granites and pegmatites we discovered previously undetected features. In most of the granites examined the quartz luminesces blue. However, many of the blue luminescing quartz grains have red luminescing structures within them. These red structures are often in linear, elongated domains, which are indistinguishable under the microscope with either ordinary or polarized light. Some linear red luminescing domains are associated with fluid inclusion planes but others are not.

We interpret the domains of red CL quartz as lower temperature filling of microfractures and open subgrain boundaries in deformed higher temperature blue CL grains. The combination of secondary fluid inclusions, formed at depth 8-10 km, and red luminescing quartz domains suggests a continuous process of cracking and healing, beginning when the rock cools just enough for the quartz to become brittle, down to lower temperatures until solubility, diffusion, and mobility of silica becomes too small for healing in a reasonable period of time. Thus cracking and healing in quartz may be much more abundant and common in crustal rocks than previously thought. This conclusion has important bearing on the evolution of quartz, and feldspars, in the crust particularly for problems related to pore pressure and transport such as metamorphism, the origin of granites, long period crustal deformation, earthquakes mechanics, rock physical properties, deep seated geothermal energy, and the flow of meteoric water needed for oxygen exchange to great crustal depth. (Authors' abstract)

SPRUNT, E. and NUR, A., 1979a, Microcracking and healing in granites: New evidence from cathodoluminescence: Science, v. 205, p. 495-497.

See previous item. (E.R.)

STALDER, H.A., 1979, Mineral finds at the construction sites of the Oberhasli power plants: Lapis, v. 4, no. 9, p. 26-28 (in German).

Two-phase (V + L) and 3-phase ($CO_2G + CO_2L + H_2O$) in quartz are illustrated. (E.R.)

STANLEY, D.J., SHENG, Harrison, and KHOLIEF, M.M., 1979, Sand on the southern Mediterranean Ridge: proximal basement and distal African-Nile provenance: Nature, v. 279, p. 554-598.

Includes some discussion of fluid inclusions as criteria. (ER)

STAROSTIN, V.I., DOROGOVIN, B.A. and LYCHAKOV, V.A., 1979, Role of sulfide melts in formation of the pyrite-polymetallic deposits of the Rudnyi Altai:

Akad. Nauk SSSR Doklady, v. 245, no. 4, p. 933-937 (in Russian; translated in Dokl. Acad. Sci. USSR, v. 245, p. 157-160, 1981). Authors

Sulfide ores bear spherical or oval quartz grains from tenths of mm to 5 cm in size. Quartz consists of two varieties: white with small G/L inclusions with Th 110-205°C, and transparent grains bearing inclusions of solutions-melts plus CO_2 with Th 890°C. The presence of CO_2 causes too high Th due to its low solubility in melts and hence T of complete melting of solid phases (560-620°C) was accepted as the minimum T of melt (sic.). Transparent quartz bears also CO_2 inclusions of specific volume 1.1-1.5 cm^3/g and G inclusions of Th 460-560°C. P_{CO_2} at 560-620°C was 3-4 kbar and at 800-920°C -5-6 kbar. The data prove that ores formed from a kind of sulfide melt. (Abst. by A.K.)

STETTLER, A., and BOCHSLER, P., 1979, He, Ne and Ar composition in a neutron activated sea-floor basalt glass: Geochi. Cosmo. Acta, v. 43, p. 157-169. Authors at Physik. Inst. Univ. Bern, Sidlerstrasse 5, 3012 Bern, Switzerland.

We have measured the composition of He, Ne and Ar in the glassy rim of a fresh oceanic basalt from the East Pacific Rise. Three splits of the sample were subjected to neutron irradiation prior to analysis to investigate the noble gas release as a function of different neutron doses. The shapes of the observed ^{39}Ar-^{40}Ar degassing profiles depend critically on the irradiation dose due to a severe redistribution of excess ^{40}Ar. This shows that the application of the ^{39}Ar-^{40}Ar method for dating of glassy samples requires the utmost care.

Including the He and Ne results from the irradiated specimens, it was possible to determine the concentrations of Li and Mg and to estimate upper limits for Na and F in addition to the concentrations of K, Ca and Cl which are measured routinely as a byproduct of the ^{39}Ar-^{40}Ar dating method. This provides a useful extension of the ^{39}Ar-^{40}Ar technique since it may help to identify the outgassing sites during stepwise heating experiments. Furthermore, it allows one to study the diffusion behavior of He and Ne isotopes artificially produced during irradiation. In our samples the activation energies of ^3He and ^{21}Ne tend to increase with growing neutron doses. (Authors' abstract)

STEWART, D.B. and POTTER, R.W., II, 1979, Application of physical chemistry of fluids in rock salt at elevated temperature and pressure to repositories for radioactive waste. Scientific basis for nuclear waste management; Volume I, McCarthy, G.J., ed.: New York, Plenum Press, p. 297-311.

Briefly covers the composition of brines in rock salt, sets some limits on the compositional variables (particularly with increase in temperature), shows that the vapor pressures at elevated temperature are remarkably low, and shows that the physical properties of polycomponent brines can be estimated from those of a NaCl solution with the same depression of the freezing point (i.e., Tm ice), using a corresponding state argument. (E.R.)

STOLPER, Edward, 1979, Theoretical petrology: U.S. National Report, 17th General Assembly, IUGG, Canberra, Australia, Dec. 1979, Papers in volcanology, geochemistry, and petrology: Reviews of Geophysics and Space Physics, v. 17, no. 4, p. 761-775.

STOLYAROV, Yu.M., 1977, Hypogene sulfide-sulfate zoning of ore deposits: Dokl. Akad. Nauk SSSR, v. 235, p. 939-942 (in Russian; translated in Dokl. Acad. Sci. USSR, v. 235, p. 213-215, 1979).

Indicates that certain empirical data from fluid inclusion studies suggest the presence of both sulfate and sulfide sulfur in the ore fluids. (E.R.)

SURLES, T.L., 1978, Temperature variations accompanying formation of skarns near Patagonia, Arizona (abst.): Geol. Soc. Am., Abstr. Programs, v. 10, no. 3, p. 149.

Intrusion of granodiorite into Permian limestones, dolomites and quartzites has resulted in the formation of sulfide-bearing exoskarns near Washington Camp south of Patagonia, Arizona. Pervasive development of garnet, pyroxene and quartz required addition of large amounts of Fe, Al and Si to relatively clean limestones and dolomites. The earliest calc-silicates to form were garnets followed by pyroxenes; quartz occurs with pyroxene and garnet, and as massive late-stage replacement and open space filling. Fluid inclusion and microprobe analyses indicate two types of garnet; unzoned crystals consisting of nearly pure andradite with inclusions which homogenize to liquid in the range 440-480°C, and zoned crystals ranging from An_{100} outward to rims as low as An_{30} with sparse liquid-rich inclusions which homogenize near 380°C. Pyroxenes consist of diopside and manganiferous salite-ferrosalite; fluid inclusions homogenize to liquid at approximately 380°C. Late quartz crystals in open vugs show homogenization temperatures as low as 210°C and scattered quartz with garnet and pyroxene provide temperatures between 240°C and 390°C. Inclusions in garnet which homogenize to vapor at about 450°C indicate intermittent boiling and a minimum salinity of about 10 wt% NaCl equivalent (~2 molal) at a maximum pressure of 400 atm. Such pressure exerted by a hydrostatic column would require slightly less than 5 km of burial which is in general agreement with estimates of overburden using reconstructed stratigraphy. This adds a 30°C pressure correction to homogenization temperatures of quartz and pyroxene. The temperature variation accompanying the paragenetic sequence garnet→pyroxene→quartz shows progressive cooling with time from a maximum of slightly less than 500°C. (Author's abstract)

SUSHCHEVSKAYA, T.M., RYZHENKO, B.N., KNYAZEVA, S.N., MALAKHOV, V.V. and BARSUKOV, V.L., 1978, Redox potential of tin-bearing hydrothermal solutions: Geochem. Inst., v. 15, no. 4, p. 89-99 (in English).

See Fluid Inclusion Research--Proceedings of COFFI, v. 11, p. 209, 1978. (E.R.)

SUSHCHEVSKAYA, T.M., VOLOSSOV, A.G., KNJAZEVA, S.N., BORISOV, M.V., and BARSUKOV, V.L., 1979, General features of ore-forming process in the mineralized zones of cassiterite-silicate type (abst.): Pacific Science Congress, 14th, Khabarovsk, 1979, Abstracts of Papers, Section BVI, p. 55-56 (in English).

It was found from fluid inclusion studies, that ore deposits of cassiterite-silicate type were formed from high-temperature water solutions. In their chemical composition two types of the solutions may be distinguished: 1) $Na\text{-}K\text{-}Cl\text{-}HCO_3$ solutions are typical of the zones with wide manifestation of tourmaline-quartz metasomatites and with predominance of Sn and Sn-W mineralization, 2) Na-Cl solutions are typical of zones with intense propylitization of wall rocks and various sulfides in ore fillings.

The pH values of tin-bearing hydrotherms (for temperatures close to 300°C) were computed from the data on fluid inclusion composition, assuming the complex formation for the major solution components. The pH values correspond to a neutral or slightly alkaline character of the solutions. Redox potential, calculated from CO_2-CH_4 equilibrium data of fluid inclusion solutions varies within 0.6-0.9 V, and so tin and other ore elements transport proceeded under reduction conditions in these solutions.

Two affinities in chemical evolution of solutions with temperature decrease were found: 1) the grade of complex formation increased for all elements, 2) pH values decreased. Cassiterite deposition was accompanied by acidity decrease of ore-forming solutions.

The characteristic feature of solutions forming tin ores is a constant presence of remarkable amounts of fluorine. All the above data on solutions composition suggest that the general forms of tin transport in hydrothermal solutions were: $Sn(OH)_4$ sol., $Sn(OH)_2F_2$ sol., with small amount of Sn(II) compounds. In alkaline suite the Sn(II) forms may predominate. (Authors' abstract)

SVOREN', I.M., 1978, Forms of hydrogen occurrence in mineral-formation processes, (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 1, Thermobarogeochemistry in geology: Vladivostok, Acad. Sci. USSR, p. 195-196 (in Russian) Author at Inst. Geol. Geochem. of Mineral Fuels of Acad. Sci. of the Ukrainian SSR, L'vov.

Experiments proved that hydrogen may join minerals in atomic form (H°) and under changing thermodynamic conditions it may change into molecular form (H_2). By mass spectrometry it was found that the atomic (or proton) form is the main one that occurs in mineral-forming processes in nature. The ratios H-H_2 released from ground crystal at 333, 575, and 780°C were respectively: pegmatite from Volyn', gray quartz - 0.7686, 0.0985, no data; reticulate quartz - 3.62, 0.1170, 0.0598; white quartz - 3.84, 0.0455, 0.0196; smoky quartz - 1.1136, 0.4190, 0.0049; morion - 0.8670, 0.0130, 0.0101; reticulate quartz - 2.310, 0.1085, no data; morion 2.570, 0.1265, 0.0928; quartz (sic.,A.K.) - 1.1375, 0.1069, 0.0038; magmatic quartz - 0.5250, 0.0898, 0.0280; synthetic NaCl grown from H_2SO_4 solution - no data, 0.2978, 0.0917. (From the authors' abst., transl. by A.K.)

SWANENBERG, H.E.C., 1979, Phase equilibria in carbonic systems, and their application to freezing studies of fluid inclusions: Contrib. Mineral. Petrol., v. 68, p. 303-306. Author at Geol. Inst., Rijksuniv. Utrecht, Oude Gracht 320, 3511 PL Utrecht, The Netherlands.

Addition of CH_4 to CO_2 lowers the temperatures at which phase changes occur with respect to those in the unary system CO_2. At high density and high XCH_4 a melting interval of solid CO_2 can be expected.

Rearrangement of currently available theoretical and experimental data permits bulk compositions of carbonic fluid inclusions to be determined from the final melting temperature of CO_2 and the degree of filling at that temperature.

Homogenization temperatures of CO_2-CH_4 inclusions can be expressed in terms of equivalent CO_2-densities, permitting estimates of P-T relations using isochores in the unary system CO_2. (Author's abstract)

SWANSON, S.E., 1979, The effect of CO_2 on phase equilibria and crystal growth in the system $KAlSi_3O_8$-$NaAlSi_3O_8$-$CaAl_2Si_2O_8$-SiO_2-H_2O-CO_2 to 8000 bars: Am. Jour. Sci., v. 279, p. 703-720. Author at Geol. Dept., Appalachian State Univ., Boone, North Carolina 28608.

A bulk composition in the system $KAlSi_3O_8$-$NaAlSi_3O_8$-$CaAl_2Si_2O_8$-SiO_2-H_2O-CO_2 was studied at pressures of 2000 and 8000 bars to determine the effect of CO_2 on phase equilibria and crystallization kinetics in granitic systems. An aqueous solution saturated with oxalic acid was used as the fluid in the experiments and yields a vapor that is 96 percent H_2O and 4 percent CO_2 by weight at subsolidus run conditions. However, differential solubility of H_2O and CO_2 in the melt results in a H_2O-rich silicate liquid and a CO_2-rich vapor phase at hypersolidus temperatures. The presence of CO_2 produced an increase in the liquidus temperatures at 8000 bars. No significant change was found in the solidus temperatures or in the liquidus temperatures at 2000 bars. Phase assemblage fields were shifted to higher temperatures at 8000 bars by the addition of CO_2. Shifts of phase assemblage fields and the liquidus to higher temperatues at 8000 bars are related to the reduced activity of soluble component (H_2O) by the addition of a less soluble component (CO_2). However, the magnitude of the dilution effect is dependent on the presence or absence of a vapor phase. In vapor undersaturated regions addition of small amounts of CO_2 to the melt does little to change $a^{melt}_{H_2O}$ while in the presence of a vapor CO_2 is strongly partitioned into the vapor reducing $a^{vapor}_{H_2O}$ and hence $a^{melt}_{H_2O}$. Thus the greatest changes due to the addition of CO_2 are expected in the vapor-saturated portion of the system, and this is confirmed by the 50°C increase in the vapor saturated liquidus at 8000 bars. Addition of CO_2 to the hydrous system produces a decrease in the fluid solubility at 8000 bars, but at 2000 bars the presence of CO_2 apparently slightly increases the fluid solubility. Calcite is found in subsolidus experiments at 2000 bars and in equilibrium with the silicate melt at 8000 bars. Reconnaissance experiments indicate that calcite is stable in the hypersolidus region for these bulk compositions above approx 3000 bars. Stability of calcite is controlled by the CO_2-rich vapor in the system. Crystallization kinetics are not affected by the presence of CO_2 in the experiments.

Based on these results, calcite is expected as a primary phase in granitic rocks that crystallized at pressures greater than 3000 bars in the presence of CO_2-rich fluid. However, calcite is not found as a magmatic phase in granitic rocks. The absence of primary calcite in granitic rocks together with these results on calcite stability suggest that if a CO_2-rich fluid was present in the magmatic source region, it was left in the source region or escaped before the magma was emplaced. Fluids accompanying crystallization of granitic magma are thus probably H_2O-rich. (Author's abstract)

TAGUCHI, S., FUJINO, T. and HAYASHI, M., 1979, Homogenization temperature measurements of fluid inclusions in quartz and anhydrite from the Hatchobaro geothermal field, Japan, and its applications for geothermal development: Trans. Geothermal Resour. Counc. (Davis), v. 3, p. 705-708.

TAKENOUCHI, S., 1978a, Fluid inclusion studies, in Geological studies of the mineral deposits in Japan and East Asia, H. Imai, ed., Univ. of Tokyo Press, p. 312-334 (in English).

TAKENOUCHI, S., 1978b, Fluid inclusion and ore-forming fluids of porphyry copper deposits: Min. Geol. (Soc. Min. Geol. Jap.), v. 28, no. 148, p. 117-130.

TAKUBO, Hiroshi, 1979, Characteristics of synthetic hydrothermal emerald from USA and USSR: Journal of the Gemmological Society of Japan, v. 6, no. 4, p. 113-120 (in Japanese; English abstract).

Some mention of inclusion types. (E.R.)

TAKUBO, H., KITAMURA, Y., NAKAZUMI, Y and KOIZUMI, M., 1979, Internal textures and growth conditions of flux-grown emeralds from USSR: Journal of the Gemmological Society of Japan, v. 6, no. 1, 2, p. 22-27 (in Japanese; English abstract).

Some description of inclusions. (E.R.)

TALANTSEV, A.S., 1978, New method for determination of both temperature and pressure of mineral-formation on the basis of gas liquid inclusions and calcite composition, (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 1, Thermobarogeochemistry in geology: Vladivostok, Acad. Sci. USSR, p. 173-176 (in Russian). Author at Inst. Geol. Geochem. of Ural Sci. Center of Acad. Sci. of the USSR, Sverdlovsk.

Th is connected with T of formation, or trapping, Tt, by the relation $Tt = Th + \Delta T$, where $\Delta T = f(P)$; if P = 1 kbar, $\Delta T \sim 100^\circ C$. Tt, Th and Tm are connected by the empirical relation:

$$Tt = Th + \frac{P - 4.3 \times 10^{-9} Th^{4.16} (1 + 0.001\ Tm)}{19.3 - 9 \times 10^{-5} Th - \frac{265 - Th}{465} Tm}$$

where temperatures are in °C; P, in bars. This equation was derived from a series of data on water-salt systems of total salt concentration up to 25 wt.%, T interval 120-500 C, P up to 2 kbar.

Composition of calcite crystallizing in equilibrium with dolomite or replacing dolomite is characterized by equation:

$\log[M/(1-M)] = 4.21 \log T + 0.10 \log P - 13.53$ (2)

where T in kelvins, P in kbars, M - magnesium index calculated from formula:

$M = Mg \times (1 + 11.5Fe + 5Fe^2 + 550Fe^3 + 8Mn - 50Mn^2 - 4Sr + 50Sr^2)$ (3)

where Mg, Fe, Mn and Sr are in mole fractions of the respective components in mineral. The equation system (1-3) permits determining T and P of calcite formation. It is necessary to determine for this reason a) Th and Tm of P G/L inclusions, b) the composition of calcite in the immediate neighborhood of the P inclusion, c) to make on the basis of equations (1-3) a plot similar to that presented in the figure; numbers on the lines refer to the equation numbers, dashed lines reflect the error in the determination, the shadowed area shows the final result and its error. Immediate calculation T=f(P) from the equation (1) is relatively difficult due to its size. A graphical solution is simpler, with use of a series of nomograms. The results agree well when compared with results obtained by other methods. Preliminary theoretical calculation of the accuracy of the method yielded the relative error value ±5% of T and ±10% of P. The method is applicable for calcite formed at $T \leq 500^\circ C$ and $P \leq 2$ kbar. (Author's abst.)

TALANTSEV, A.S., 1979, Combined method of geologic thermobarometry with use of results of studies of gas-liquid inclusions and limiting isomorphism in calcite: Akad. Nauk SSSR Doklady, v. 244, no. 4, p. 978-982 (in Russian). Author at Inst. Geol. and Geochem. of the Ural Sci. Center of Acad. Sci. of the USSR, Sverdlovsk.

Same as previous entry, with three nomograms added. (A.K.)

TALANTSEV, A.S., 1979b, Determination of erosion cut off depth according to the data of geothermobarometry: Dokl. Akad. Nauk SSSR, v. 249, p. 164-167 (in Russian).

TALANTSEV, A.S., 1979a, Construction of isochores of the gas-liquid inclusions by their cryometry and homogenizaton: Geokhimiya, 1979, no. 9, p. 1357-1366 (in Russian; translated in Geochem. Internat., v. 16, p. 58-65. 1979). Author at Geol. Geochem., Ural Sci. Center, USSR Acad. Sci., Sverdlovsk.

A new method of construction of isochores for two-phase gas-liquid inclusions in minerals according to the freezing temperatures and their liquid phase homogenization is substantiated in the paper. Principles of detecting the point on the resulting isochore, characterizing temperature and pressure of mineral formation at the moment of inclusion trapping, are given. The possibilities of construction of combined geothermobarometers, based on the results of investigation of the initial gas-liquid inclusions and distinctive features of the chemistry of the equilibrium minerals in the binary paragenesis, are shown by particular examples. (Author's abstract)

TANNER, J.E. and LAMB, F.W., 1978, Specific heat of aqueous solutions of NaCl, NaBr, and KCl: Comparisons with related thermal properties: Jour. Sol. Chem., v. 7, no. 4, p. 303-316.

TAUSON, L.V., 1979, Exploration geochemistry; analytical methods: Irkutsk, Akad. Nauk SSSR, 173 pp (in Russian, with English summary).
Indexed under fluid inclusions. (E.R.)

TAYLOR, B.E., FOORD, E.E. and FRIEDRICHSEN, Hans, 1979, Stable isotope and fluid inclusion studies of gem-bearing granitic pegmatite-aplite dikes, San Diego Co., California: Contrib. Min. and Pet., v. 68, p. 197-205. First author at Dept. Geol., Univ. of California, Davis, CA 95616, USA.

Late Cretaceous, granitic pegmatite-aplite dikes in southern California have been known for gem-quality minerals and as a commercial source of lithium. Minerals, whole-rock samples, and inclusion fluids from nine of these dikes and from associated wall rocks have been analyzed for their oxygen, hydrogen, and carbon isotope compositions to ascertain the origins and thermal histories of the dikes. Oxygen isotope geothermometry used in combination with thermometric data from primary fluid inclusions enabled the determination of the pressure regime during crystallization.

Two groups of dikes are evident from their oxygen isotope compositions ($\delta^{18}O_{qtz}\simeq+10.5$ in Group A, and $\simeq+8.5$ in Group B). Prior to the end of crystallization, Group A pegmatites had already extensively exchanged oxygen with their wall rocks, while Group B dikes may represent a closer approximation to the original isotopic composition of the pegmatite melts. Oxygen isotope fractionations between minerals are similar in all dikes and indicate that the pegmatites were emplaced at temperatures of about 730° to 700°C. Supersolidus crystallization began with the basal aplite zone and ended with formation of "quench-aplite" in the pocket zone, nearly to 565°C. Subsolidus formation of gem-bearing pockets took place over a relatively narrow temperature range of about 40°C (approximately 565-525°C). Nearly closed-system crystallization is indicated.

Hornblende in gabbroic and noritic wall rocks ($\delta D_{w.r.}$=-90 to -130) in the Mesa Grande district crystallized in the presence of, or exchanged hydrogen with, meteoric water ($\delta D \simeq -90$) prior to the emplacement of the pegmatite dikes. Magmatic water was subsequently added to the wall rocks adjacent to the pegmatites.

Groups A and B pegmatites cannot be distinguished on the basis of their hydrogen isotope compositions. A decrease in δD of muscovite inward from the walls of the dikes reflects a decrease in temperature. δD values of H_2O from fluid inclusions are: -50 to -73 (aplite and pegmatite zones); -62 to -75 (pocket quartz: Tourmaline Queen and Stewart dikes); and -50±4 (pocket quartz from many dikes). The average $\delta^{13}C$ of juvenile CO_2 in fluid inclusions in Group B pegmatites is -7.9. In Group A pegmatites, $\delta^{13}C$ of CO_2 is more negative (-10 to -15.6), due to exchange of C with wall rocks and/or loss of ^{13}C-enriched CO_2 to an exsolving vapor phase.

Pressures during crystallization of the pockets were on the order of 2100 bars, and may have increased slightly during pocket growth. A depth of formation of at least 6.8 km (sp. gr. of over burden = 3.0, and $P_{fluid} = P_{load}$) is indicated, and a rate of uplift of 0.07 cm/yr. follows from available geochronologic data. (Authors' abstract)

TAYLOR, H.P., Jr., 1979, Oxygen and hydrogen isotope evidence for meteoric-hydrothermal alteration and ore deposition in the epithermal gold-silver deposits associated with volcanic centers in western Nevada: A case study of the Tonopah deposit (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 526.

The discovery of low-^{18}O and low-D vein minerals and hydrothermal alteration zones in Tertiary epithermal Au-Ag deposits of Nevada (O'Neil et al., 1973, 1974; Taylor, 1973) proves that heated ground waters were the major component of the ore-forming fluid. Commonly, the exchange histories, water/rock ratios and circulation paths were such that the fluids were not ^{18}O-shifted very far from the meteoric water line. $\delta^{18}O$ quartz = -5.1 to +5.2, $\delta^{18}O$ adularia = -8.2 to +9.0, and $\delta^{18}O$ of the altered rock is -6.0 to +5.8. The δD of fluid inclusions = -90 to -139, and δD of altered volcanic rocks (Tonopah) = -135 to -152. Temperatures were 250°-300°C and salinities were low (commonly < 1% NaCl eq.). Extremely large amounts of meteoric ground H_2O were heated by epizonal igneous intrusions, producing a general propylitic alteration and locally an intense sericitic, kaolinitic, or alunitic alteration around the veins. The low-pH fluids were developed in part by near-surface oxidation (and boiling?). At Tonopah, Nolan (1935) showed that the productive ore zones in the veins extend downward only about 125 meters and that they are sharply truncated both above and below. The topography of this productive horizon defines the center of the Tonopah district as also does $\delta^{18}O$ contouring of the altered wall rocks; the lowest $\delta^{18}O$ (-6.0) occurs in the center of the district. This is the locus of the highest water/rock ratios and/or the highest temperatures. Overall water/rock ratios (mass units) in the hydrothermal systems were at least 1 to 2, and were locally much higher. The Au and Ag were probably leached at high T from fractured intrusive stocks at depth, but a small component of magmatic H_2O cannot be precluded, evidenced by a deep vein quartz sample from the Comstock Lode ($\delta^{18}O$ = 8.9, δD fluid = -69). (Author's abstract)

TAYLOR, R.G., 1979, Geology of tin deposits: Amsterdam, Elsevier Pub. Co., 543 pp.

Includes a table (11.3) and brief discussion of fluid inclusion studies (p. 483) with 13 references. (ER)

TAYLOR, R.P., and FRYER, B.J., 1979, Rare earth geochemistry as an aid to interpreting hydrothermal ore deposits (abst.): Geological Society Newsletter (G.B.), v. 8, no. 6, p. 17.

The rare earth elements (REE) are widely accepted as powerful tools in the study of rock petrogenesis but their use has been neglected in the study of ore deposits. As a monitor of the processes involved in hydrothermal alteration their coherent group behavior actively reflects changing fluid characteristics and behavior. For example in the porphyry environment magmatic hydrothermal fluids produce potassic alteration with strong enrichment in the light rare earths(LREE) reflecting their high pH and the low water/rock ratios. With increasing water/rock ratios and decreasing pH accompanying the progressive involvement of meteoric fluids (i.e. propylitic and phyllic alteration) all REE are leached but with the LREE more severely than the HREE. (Authors' abstract)

TAYLOR, T.R., VOGEL, T.A. and WILBAND, J.T., 1979, The origin of coexisting granitic and basaltic liquids at Mt. Desert Island, Maine, (abst.): Eos, v. 59, p. 411-412.

The REE data and petrographic evidence cause the authors to reject immiscibility as the explanation. (ER)

TERESHCHENKO, S.I., 1979, Thermobaric characteristics of the metamorphism of ferruginous rocks of granulitic facies of the Bug area (according to gas-liquid inclusins in minerals): Vopr. Geokhimii, Mineral., Petrol. i Rudoobraz., Kiev, 1979, p. 118-119 (in Russian). (C.A. 92:201213v)

THOMAS, D.M., 1979, Gases from Hawaiian volcanoes,(abst.): Hawaii Symposium on Intraplate Volcanism and Submarine Volcanism, Hilo, Hawaii, July 16-22, 1979, Internat. Assoc. Volc. and Chem. of Earth's Interior, p. 175.

Samples of helium from several Kilauea summit fumaroles have yielded exceptionally high $^{3}He/^{4}He$ isotope ratios ($^{3}He/^{4}He \simeq 1.92 \times 10^{-5}$) as compared to atmospheric and most abyssal sources (e.g., sea floor basalts $^{3}He/^{4}He \simeq 1.3 \times 10^{-5}$, Iceland thermal gases $^{3}He/^{4}He \simeq 1.75 \times 10^{-5}$). Although it is presently felt that this helium may be more similar to juvenile helium than any other heretofore observed, several factors, arising both from contamination and from fractionations inherent in the probable release and migration mechanisms, need to be considered in any evaluation of these very high ratios.

Samples of carbon from two rather divergent sources have been obtained and isotopically analyzed. Carbon extracted from glass-vapor inclusions in olivine from Hualalai dunnite have yielded considerably higher carbon isotope ratios ($\delta^{13}C \simeq -12\%$ to -14% versus PDB) than carbon dioxide obtained from Kilauea summit fumaroles ($\delta^{13}C \simeq -3.12\%$ to -3.34% versus PDB).

If, as has been proposed by other workers, Hualalai olivine contains uncontaminated samples of mantle volatiles, it must be concluded that substantial fractionation effects are inherent either in the release of the carbon dioxide from the summit magma reservoir or in the mechanism of its migration to the surface fumaroles. (Author's abstract)

THOMAS, Rainer, 1979, Investigations of inclusions for the thermodynamic and physico-chemical characterization of ore-forming solutions and processes in the magmatic and postmagmatic range: Ph.D. dissertation, Bergakademie Freiberg (text 245 pp with 469 references and 93 figures; Appendix 83 pp; in German; English abstract courtesy Dr. Thomas). Author at 9200 Freiberg/Sa., Lomonossowstrasse 14, DDR.

Presents the fundamentals of the methods of mineralogic thermobarogeochemistry, with special attention to application to the title environments. It is shown that correlation of Th temperature and $\delta^{18}O$-data on quartz, and Th with Δ_{021} X-ray measurements of topaz allow significant genetic conclusions.

Data on the pressure and temperature of formation, as well as on the composition, concentration and order of magnitude of the pH values are presented for the mineral-forming solutions in the Sn-W mineralization of the Erzgebirge as well as of minerals of the Variscan and post-Variscan fluorite mineralization in the southern part of the DDR. The combination of thermobarogeochemistry with thermodynamic analysis of mineral paragenesis in specific deposits, helps in the development of better genetic models.

Most of the work involved heating and freezing studies of inclusions in cassiterite and other minerals of the Erzgebirge. Four stages of cassiterite formation - pegmatitic, high-hydrothermal, pneumatolytic, hydrothermal - are recognized, based on temperature, pressure and salinity data. Table 1* summarizes the results, including Th of silicate-melt inclusions from the magmatic stage. The formation of cassiterite and other minerals (quartz, topaz, beryl, fluorite, zinnwaldite, etc.) in the postmagmatic deposits of the Erzgebirge occurred mainly from solutions rich in Na, (K), Cl and F. Most ore minerals formed during stages III and IV, under rather limited temperature and pressure ranges. In both of these stages, all primary inclusions homogenize to either liquid (type I - $T_{Hfl.}$) or vapor (type III - T_{HG}) at the same temperature range, and some inclusions homogenize with critical phenomena (type II - $T_{HG/fl.}$). In the simplest possible case, the binary system H_2O - NaCl from Sourirajan and Kennedy (1962) illustrates these features, under the assumption that Th is the actual temperature of boiling ($T_{Hfl.} < T_{HG/fl.} < T_{HG}$). The total pressure on the fluid can be easily determined from the data of Sourirajan and Kennedy, as mentioned above, because the total pressure at any given temperature equals the vapor pressure for the boiling fluid at that temperature (critical curve), and lithostatic pressure changed to hydrostatic conditions.

The simultaneous occurrence of inclusions with different G/L ratios, and of high-salinity fluids with several dms. (including halite, sylvite, hematite, ulexite, borax, anhydrite, and carbonate) strongly supports simultaneous precipitation from boiling solutions.

Repeated tectonically induced pressure drops were of major importance. Retrograde boiling and the related cavitation phenomena resulted in hydraulic fracturing and granulation of rock. The greisenization so common in these tin deposits can be partly traced back to these processes. Repeated transitions from a high temperature supercritical mineral-forming solution, along with intensive changes in the pH, fugacity of oxygen and sulfur, composition, ionic strength, and solubility products of metal complexes are characteristic of the Sn-W ore stage of the Erzgebirge. It is shown that at least boiling and adiabatic expansion is of fundamental importance for the formation of Sn-W-mineralization. (Author's abstract, modified by E.R.)

*See p. 213

THOMASSIN, J.-H. and TOURAY, J.-C., 1979, The early stages of water-basaltic glass interaction: X-ray photoelectrons spectroscopy (XPS) and scanning electron microscopy (SEM) investigations: Bull. Minéral., v. 102, p. 594-599 (in French).

THOMPSON, T.B., LYTTLE, Thomas, PIERSON, J.R. and OSBORNE, L.W., 1979, Genesis of the Bokan Mountain U-Th deposits southeastern Alaska (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 527.

Bokan Mountain is a peralkaline granite-syenite complex with vein and pipe-shaped zones of uranium-thorium mineralization in microveinlets with calcite, fluorite, and quartz. The mineralization is closely related to but post-dates magma crystallization. The margin of the peralkaline igneous complex is composed of a riebeckite-bearing granite pegmatite/aplite zone up to 13 m thick. Inward the complex consists of an aegirine granite porphyry shell approximately 180 m thick that passes inward into a transition interval about 15 m thick in which riebeckite becomes the dominant alkali ferromagnesian at the expense of aegirine. The interior portions of the Bokan Mountain intrusive complex consist of banded or massive zones of riebeckite granite porphyry. Finer-grained equigranular syenite masses are localized near the transition zone between aegirine- and riebeckite-bearing granite porphyry. The granite-syenite complex has been dated as mid-Devonian (K-Ar on albite; 372 m.y.).

The U/Th mineralization is localized in shear zones or in irregular cylindrical bodies formed by concentrations of microfractures. The ore zones are localized within or adjacent to the syenitic masses and have intense albitization and chloritization with subordinate amounts of calcite, fluorite, quartz, tourmaline, and sulfides. Hematite occurs peripheral to the higher-grade ore zones. Uranothorite is the main ore mineral. Th/U ratios range from 10 to >100 within the ore zone but are <10 outside ore zones. Rb_2O/SrO is <5 within ore and 20 to 40 outside ore. Preliminary fluid inclusion analyses on fluorite and quartz yield homogenization temperatures of 320°C. Sulfur and carbon isotope analyses on contemporaneous pyrite and calcite indicate the ore fluids had a pH of 4.5 and were moderately reducing. (Authors' abstract)

TILLMAN, J.E., BARNES, H.L., WOODFORK, L.D. and OVERBEY, W.K., Jr. (Chairpersons), 1979, Hydrothermal and uplift histories of the northern Appalachian Basin (abst.), *in* Energy for the eighties; a joint DOE/EGSP-ES/AAPG symposium; U.S. Dept. Energy, Washington, DC, Am. Assoc. Pet. Geol., p. 22.

Indexed under fluid inclusions. (E.R.)

TIMOFEYEV, A.V., SHTEYNSHNEYDER, T.L. and KHOTEYEV, A.D., 1978, Temperatures of mineral formation and temperature zonation of uranium-molybdenum deposits; Termobarogeokhimiya Zemnoy Kory I Rudoobrazovaniye, N.P. Ermakov, ed.: Moscow, Izd. Nauka, p. 205-213 (in Russian).

Indexed under fluid inclusions, geothermometry, geobarometry. (E.R.)

TOMILENKO, A.A., BERDNIKOV, N.V. and KARASAKOV, L.P., 1977, Cryometric study on inclusions in rocks of the deep-seated Chogar metamorphic complex, eastern Siberia: Akad. Nauk SSSR Doklady, v. 234, no. 5, p. 1189-1192 (in Russian; translated in Dokl. Acad. Sci. USSR Earth Sci. Sect., v. 234, p. 163-166, 1979).

See *Fluid Inclusion Research--Proceedings of COFFI*, v. 10, p. 280, 1977. (E.R.)

TOMILENKO, A.A. and DOLGOV, Yu.A., 1978, Conditions of formation of the "granulated" quartz from the Borus chain (Western Sayan): Akad. Nauk SSSR Doklady, v. 242, no 5, p. 1173-1176 (in Russian). Authors at the Inst. Geol. Geoph. of Siberian Branch of Acad. Sci. USSR, Novosibirsk.

In the Borus hyperbasite massif (Altae-Sayan folded area) there occur jadeite and albitite bodies. The latter bear lenticular intercalations of colorless "granulated" quartz. The rock complex bears also cross cutting coarsely crystalline quartz veins. Heterogenization T of inclusions in "granulated" quartz is -165 C, T of complete freezing >-185°C, Tm -182.5°C, hence inclusions filling should be methane (triple point -182.5°C). This conclusion was confirmed by analysis of G in individual inclusions (P and PS inclusions bear in vol. %. [H_2S+HF+CO_2+HCl+SO_2+NH_3] 0.0-49.0, hydrocarbons 15.0-43.0, CO 0.0-23.0; H_2 0.0-24.0; N_2 + rare gases 6.0-61.0, O_2, LH_2O and CO_2 itself were not found in P inclusions). Th was in interval -126 to -149°C. PS inclusions occur in the marginal parts of the quartz crystals, they bear CH_4 + CO_2 or L water-salt solutions. Th of the CH_4 + CO_2 inclusions are at -84°C to -126°C, Tm ~-182.5°C. Te of water-salt inclusions ~-33°C, i.e. probably ~10% solution of $MgCl_2$. PS inclusions were trapped during splitting of fluid into 2 immiscible phases: CH_4(+CO_2) and H_2O(+ salts) seemingly at ~400°C. S inclusions are usually coeval H_2O and CO_2 inclusions, aqueous ones have Th 260-240°C. T of formation of the "granulated" quartz was ~450-500 C. Since CH_4 specific vol. was, in P inclusions, 2.73-2.46 cm³/g, P at 400-500°C was 4.5-8.0 kbar. Conditions of jadeite formation were evaluated to be T 600°C and P>10 kbar. (Abst. by A.K.).

TOMSHIN, M.D. and PANKOV, V.Yu., 1979, Melt inclusions in plagioclase protocrystals of traps in the Siberian platform and their petrogenetic significance: Mineral. i Geokhimiya Kimberlitov. i Trappov. Porod, Yakutsk, 1979, p. 100-106 (in Russian).

TOURAY, J.C., 1978, Fluid inclusions; unraveling a few mysteries: Recherche, v. 93, p. 900-901 (in French).

TOURAY, J.C., 1979, Fluid inclusions: evidences for the metamorphism of evaporitic series: Sciences de la Terre, v. 23, no. 2, p. 99-103 (in French). Author at Inst. Rech. Res. Mat. Min., Univ. Orléans, 45046 Orléans Cedax, France.

Synthesis of published data about microthermometry and chemical analysis (Na/Br, K/Br, Cl/Br ratios) of brines trapped in minerals (quartz, dolomite, albite) from various outcrops of tectonometamorphosed evaporites (diapirs and nappes). Criteria indicating former salt deposits presently dissolved; simplified use of halite-bearing fluid inclusions as geothermobarometers; discussion of the possible trapping of CO_2, hydrocarbons and N_2. (Author's abstract)

TOURET, Jacques and BOTTINGA, Yan, 1979, Equation of state of CO_2; application to carbonic inclusions: Bull. Minéral., v. 102, p. 577-583 (in French). First author at Lab. Pétrog., Univ. Paris VII, L.A.C.N.R.S. no. 286, 61 rue de Buffon, 75005 Paris, France.

CO_2 inclusions are abundant in rocks from the lower crust and upper mantle. Estimations of the P and T of formation of these inclusions is presently only possible when they are filled with pure CO_2. For this purpose detailed knowledge of the PVT relations for CO_2 are needed up to at least 1,200°C and 20 kbar. After a critical examination, the available PVT data are used to derive a modified Redlich-Kwong equation of state for CO_2. Molar volumes, down to 27 cm^3/mole are calculated for P and T conditions of interest to earth scientists. The densities of the saturated liquid and gas phase along the two-phase curve are given. (Authors' abstract)

TROSHIN, Yu.P., BOYKO, S.M. and GREBENSHCHIKOVA, V.I., 1978, Comparison of contents of volatile components in gas-liquid inclusions in ore quartz and in biotite from parent intrusives (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 69-70 (in Russian). Authors at Ins. Geochem. of Siberian Branch of Acad. Sci. USSR, Irkutsk.

In the E. Transbaikalia, the wall rock biotites and ore-forming fluids are similar in terms of reported high F contents for Sn and W deposits, and in Cl plus eventually CO_2 for Au, Mo, Zn and Pb deposits. (From the authors' abstract, transl. by A.K.)

TROSHIN, Yu.P., PLYUSNIN, G.S. and SANDIMIROVA, G.P., 1979, The joint evolution of the volatile regime, magmatism and ore formation during tectonic-magmatic activation: Geol. Rudnikh Mestor. v. 21, no. 4, p. 43-57 (in Russian).

Pertinent to melt inclusions (A.K.)

TRUESDELL, A.H., MANON, M.A., JIMENEZ, S.M.E., SANCHEZ, A.A. and FAUSTO, L.J.J., 1979, Geochemical evidence of drawdown in the Cerro Prieto geothermal field: Geothermics, v. 8, p. 257-265. First author at U.S. Geol. Survey, Menlo Park, CA.

Some wells of the Cerro Prieto geothermal field have undergone changes in the chemistry of fluids produced which reflect reservoir processes. Pressure decreases due to production in the southeastern part of the field have produced both drawdown of lower chloride fluids from an overlying aquifer and boiling in the aquifer with excess steam reaching the wells. These reservoir changes are indicated by changes in fluid chloride concentrations, Na/K ratios and measured enthalpies and by comparisons of aquifer fluid temperatures and chloride concentrations calculated from enthalpy and chemical measurements. Fluid temperatures have not been greatly affected by this drawdown because heat contained in the rock was transferred to the fluid. When this heat is exhausted, fluid temperatures may drop rapidly. (Authors' abstract)

TRUESDELL, A.H., RYE, R.O., PEARSON, F.J., OLSON, E.R., NEHRING, N.L., WHELAN, J.F., HUEBNER, M.A. and COPLEN, T.B., 1979, Preliminary isotopic studies of fluids from the Cerro Prieto geothermal field: Geothermics, v. 8, p. 223-229. First author at U.S. Geol. Survey, Menlo Park, CA.

Preliminary isotopic studies of Cerro Prieto geothermal fluids and earlier studies of Mexicali Valley ground waters suggest local recharge of the geothermal system from the area immediately to the west. Oxygen isotope exchange of water with reservoir rock minerals at temperatures increasing with depth has produced fluids with oxygen-18 contents increasing with depth, and pressure drawdown in the southeastern part of the field has allowed lower oxygen-18 fluids to invade the production aquifer from above. The contents of tritium and carbon-14 in the fluid suggest only that the age of the fluid is between 50 and 10,000 years. The isotopic compositions of carbon and sulfur are consistent with a magmatic origin of these elements but a mixed sedimentary-organic origin appears more likely for carbon and is also possible for sulfur. Investigations of the isotopic compositions of geothermal and cold ground waters continue and are being expanded as fluids become availale and as separation and analysis methods are improved. (Authors' abstract)

TRUFANOV, V.N., 1978, Thermodynamic thresholds of ore formation (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 61 (in Russian). Author at Rostov State Univ., USSR.

Thermobarogeochemical studies of over 500 ore deposits revealed ten optimum combinations of P and T for major precipitation of minerals from mineral-forming solutions. T intervals of these specific thresholds of ore formation differ somewhat for rare-metal, polymetallic and sulfide deposits, whereas P changes in individual ore formations. Distinct regularity was found: P/T ratios of those thresholds are small figures, e.g., for mercury deposits:

$$\frac{P}{T} = \frac{60\text{-}70}{70\text{-}80} : \frac{100\text{-}120}{90\text{-}120} : \frac{180\text{-}240}{180\text{-}220} = 1:1:1$$

for polymetal deposits:

$$\frac{P}{T} = \frac{100\text{-}120}{100\text{-}120} : \frac{325\text{-}350}{200\text{-}220} : \frac{550\text{-}650}{265\text{-}325} = 1:1.5:2 = 2:3:4$$

for rare-metal deposits:

$$\frac{P}{T} = \frac{400\text{-}450}{200\text{-}220} : \frac{1100\text{-}1200}{375\text{-}425} : \frac{2800\text{-}3000}{575\text{-}625} = 2:3:5 \text{ etc.}$$

where P in atm, T in °C. The nature of thresholds may be explained by rapid structural changes in metastable ore-forming fluids. (From the author's abstract, transl. by A.K.) (Editors' note: sic.)

TSERTSVADZE, Z.Ya. and ASTAKHOV, G.N., 1978, Use of steam and diffusion aureoles in exploration for deposits of mercury, antimony and arsenic, Termobarogeokhimiya Zemnoy Kory I Rudoobrazovaniye, N.P. Ermakov, ed.: Moscow, Izd. Nauka p. 214-217 (in Russian).

Indexed under fluid inclusions, geothermometry, geobarometry. (E.R.)

TSO, J.L., GILBERT, M.C., and CRAIG, J.R., 1979, Sulfidation of synthetic biotites: Amer. Min., v. 64, p. 304-316.

TSUI, T.-F. and HOLLAND, H.D., 1979, The analysis of fluid inclusions by laser microprobe: Econ. Geol., v. 74, p. 1647-1653. First author at Mobil Res. and Dev. Corp., Dallas, TX 75221.

Partial chemical analyses of large (d>100 µm), single fluid inclusions have been obtained with a laser microprobe. Weight concentration ratios of Na, Mg, Mn, and Cu relative to Ca in inclusion fluids within quartz from the Finlandia vein, Colqui, Peru, from Casapalca, Peru, and from the OH vein, Creede, Colorado, were determined within a factor of 2 to 5. Individual cation concentrations were determined with an uncertainty of a factor of 3 to 7 by combining the calculated weight ratios with the measured fluid inclusion salinities. The concentration of Ca ranged from a few hundred ppm to a few thousand ppm, the concentration of Mg from a few tens to a few hundred ppm, and the concentration of Mn from a few ppm to about 100 ppm.

Cu was detected in very few of the spectra of natural fluid inclusions. In spectra in which Cu was observed, its presence was probably due to contamination. The upper limit of the concentration of Cu in the analyzed inclusion fluids is estimated to have been in the range of 1 to 40 ppm at Colqui, 1 to 50 ppm at Casapalca, and 1 to 25 ppm at Creede. These results are consistent with Crerar and Barnes' (1976) solubility measurements of chalcopyrite in the presence of pyrite, which indicate that in the hydrothermal solutions of stage II Au-Ag mineralization in the Finlandia vein at Colqui and in the OH vein at Creede the concentration of Cu was probably between 1 to 10 ppm. (Authors' abstract)

TVALCHRELIDZE, A.G., YAROSHEVICH, V.Z. and NAROZAULI, I.G., 1979, Genetic model of the Urup copper-sulfide deposit: Geol. Rudnikh Mestor. v. 21, no. 6, p. 44-58 (in Russian). Authors at Caucasian Inst. of Mineral Raw Materials, Tbilisi, Georgian SSR.

Chlorite-sericite wallrock metasomatites bear quartz with Th 305-215°C. Also Td of ore-bearing quartz, pyrite and chalcopyrite are discussed. (A.K.)

TYLER, R.D., 1979, Chloride metasomatism in the southern part of the Pierrepont Quadrangle, Adirondack Mountains, New York: Doctoral dissertation, State Univ. of New York, Binghamton, N.Y., USA, 548 pp.

Indexed under fluid inclusions. (E.R.)

VACHER, A., 1978, Study of the process of constriction of intracrystalline cavities: Rev. Gemmol. A.F.G., v. 56, p. 3-4 (in French).

VAKHRUSHEV, V.A. and VLADYKIN, N.V., 1979, Apatite-titanomagnetite ores of the carbonatite complex of the Southern Mongolia: Geol. Rudnikh Mestor. v. 21, no. 1, p. 93-96 (in Russian). Authors at Inst. Geochem. of Siberian Branch of Acad. Sci. USSR, Irkutsk.

The Upper Jurassic Carbonatite complex Mushugay-Khuduka bears magnetite-apatite ores with fluorite and celestite. Apatite bears P sulfide melt inclusions, now pyrrhotite, about 0.0n mm in size and other melt inclusions of unspecified filling (quoted as personal communication of V.B. Naumov). (A.K.)

van GIJZEL, P., 1979, Manual of the techniques and some geological applications of fluorescence microscopy, a workshop sponsored by the Assoc. of Stratigraphic Palynologists, 12th Annual Meeting Dallas, 1979: Dallas, TX, Core Labs., Inc., 55 pp.

VASILENKO, V.N., VASIL'EV, B.D. and KURSHEV, S.A., 1979, Operational parameters of the formation of native gold in pyrite ores of the Northern Caucasus and in the gold-ore deposits of Southern Siberia and the Far

East, in Major parameters of natural processes of endogenetic ore formation, V.A. Kuznetsov, ed.: Novosibirsk, Izdat. Nauka, v. 2, p. 136-144 (in Russian). [Dokl. Vses. Soveshch., 1977]

Mineral thermometry by thermovacuum decrepitation of ultramicroscopic inclusions in Au bearing quartz and native Au verified the broad temp. range of Au mineralization and distinguished 4 temp. intervals of Au formation. The Au in pyrite deposits formed in several crystn. intervals. Early Au finely dispersed in volcanic-sedimentary country rocks crystd. at 250-400°, whereas later finely dispersed Au, assocd. with the sulfides of pyrite ores, crystd. at 150-280°. The Au formed last, both in the pyrite ores and the Au-quartz formation, crystd. at 160-200 and 60-130°, resp. The bulk of the Au was pptd. in the last stage. The compn. of the hydrothermal solns. and the form in which the Au in them is transported differs for each ore formation. (C.A. 92:79634r)

VASIL'YEV, B.D. and VASILENKO, V.N., 1978, Method of determination of temperature of gold precipitation (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 1, Thermobarogeochemistry in geology: Vladivostok, Acad. Sci. USSR, p. 177-178 (in Russian). First author at Tomsk Polytechnical Inst., USSR.

For native gold the homogenization method is not applicable and decrepitation is of doubtful value due to the plastic properties of gold. The authors used thermovacuum decrepitation of gold and coeval quartz. Grain size of both gold and quartz for decrepitation was <1 mm; the gold grains were obtained by dissolution of gold quartz intergrowths in hydrofluoric acid. In the studied gold samples the gas release was at 60-100°C, with maximum intensity at 75-95°C; the gold-bearing quartz has two gas release peaks: 60-100° and 180-340°C. The lower T may be connected with gold precipitation. A second heating of the pre-heated quartz sample gives a similar decrepitation curve with a more distinct peak at 60-80°C. The higher Td in gold than in quartz is connected with the plasticity of gold. (From the authors' abst.)

VAZIROV, K.V., 1979, Thermodynamic conditions for the formation of a gold-ore deposit in central Tadzhikistan: Dokl. Akad. Nauk Tadz. SSR 1979, v. 22(8), p. 490-493 (in Russian).

The Zervashan-Gissar Au rare metal ore deposit is localized in the propylitized and deformed sandstones, mudstones, and siltstones, intruded by plagiogranite, porphyries, plagiogranodiorites, and lamprophyres. Au-quartz-As (early sulfide stage), quartz-Sb, quartz-carbonate-polysulfide, and quartz-carbonate-aragonite assocs. are recognized. Based on Th, the P-T conditions of formation of each mineral are calcd. Ore precipitation occurred in 3 stages, 380-250, 270-190, and 200-80°C. (C.A. 92:62028y)

VDOVYKIN, G.P., BODUNOV, Ye.I., IZOSIMOVA, A.N., BOTKUNOV, A.I., UTKINA, N.A., BOCHKOVSKAYA, A.B. and ZUEVA, I.N., 1979, Bitumens in kimberlites of the "Mir" pipe: Akad. Nauk SSSR Doklady, v. 245, no. 4, p. 941-945 (in Russian). Authors' addresses not given.

Dispersed organic substance in kimberlite came from the sedimentary wall-rocks, being in part the source of the carbon in diamonds. (A.K.)

VDOVYKIN, G.P. and IVANOV, A.G., 1979, Thermal action of trap magma on carbonate wall rock in the northern part of the Aldan anticline: Akad.

Nauk SSSR Doklady, v. 245, no. 6, p. 1436-1439 (in Russian). Authors at All-Union Sci.-Research Inst. of Natural Gases, Moscow.

The authors quoted Th of melt inclusions in silicates of the Talnakh trap intrusion: 1100-1150°C (A.K.)

VIKRE, P.G., 1978, Geology and silver mineralization of the Rochester District, Pershing County, Nevada: Doctoral dissertation, Stanford Univ., Stanford, CA, USA, p. 471.

Indexed under fluid inclusions. (E.R.)

VIL'DENBERG, Ye.V., VYSOTSKIY, I.V., VOYTOV, G.I. and MUROGOVA, R.N., 1978, Gases in salt of the Caspian basin and adjacent districts: Akad. Nauk SSSR Doklady, v. 239, p. 1430-1433 (in Russian).

Analyses were made, from numerous salt deposits, for N_2, CO_2, H_2 and hydrocarbons. Total gas ranged from 40-70 cm^3/kg, with N_2 = 85-95%, and CH_4 was the major hydrocarbon. (E.R.)

VLASOVA, L.S., AGEEV, A.N., ESIKOVA, A.D., NECHAEV, V.V., EROKHIN, V.E., CHERNIKOVA, N.S. and YAKUBOVSKII, A.V., 1979, Origin of hydrothermal solutions according to data of the isotopic composition of oxygen, carbon, and hydrogen: Izot. Isled. Prir. Vod, Ferronskii, V.I. (Ed), 1979, p. 93-110 (in Russian).

Indexed under fluid inclusions.

VOROB'YEV, Ye.I. and LOZHIN, V.I., 1978, Identification of daughter minerals in fluid inclusions by coloring caused by X-radiation (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 1, Thermobarogeochemistry in geology: Vladivostok, Acad. Sci. USSR, p. 178 (in Russian). Authors at Inst. Geochem. of Siberian Branch of Acad. Sci. of the USSR, Irkutsk.

Crystals (dms) of halite after X-radiation became intense yellow, sylvite - deep violet. Other dms also became colored under such conditions. (From the authors' abst.)

WANG, Qingduo, DING, Biying, YANG, Yanzheng and LIAO, Fengxian, 1979, Fluid inclusion studies of A-Mon iron deposits, Sin Kiang Province, China: Jour. Central-South Institute of Mining and Metallurgy, no. 3, p. 51-59 (in Chinese)

The A-Mon iron deposits occur as a marine volcanic-sedimentary belt, later regionally metamorphosed to magnetite. Many fluid inclusion methods were used to study the physical-chemical conditions of deposition. Tt = 337-447°C; pressure 724 atm; salinity 16.89 wt.% NaCl equiv.; pH of ore-forming fluid, 7.15; Eh +86.96 mv.; CO_2 was found

The author used these conditions successfully in the laboratory to synthesize magnetite. (Abstract courtesy Dr. Huan-Zhang Lu)

WATANABE, Makoto, 1979, Fluid inclusions in some Neogene ore deposits in the Green Tuff region, Japan: Mining Geology, v. 29, no. 5, p. 307-321 (in English).

By means of fluid inclusions in minerals, this study examines common features that characterize the ore fluids responsible for the Neogene mineralization in the Green Tuff region of Japan. The main conclusions are summarized as follows:

1) All the inclusions investigated belong to simple two-phase (liquid>gas) type without having daughter minerals such as halite or CO_2-rich liquid at room temperature.

2) All homogenize in the liquid phase.

3) The density of ore fluids was above the critical density 0.8 to 0.9 $g \cdot cm^{-3}$, and mostly was not boiling. Some of the inclusions, especially in some Kuroko deposits, however, might have been trapped in or very close to a boiling condition.

4) Most mineralization probably took place in a temperature range from 200° to 250°C.

5) According to the published freezing data, the salinity of the inclusion fluids (i.e., ore fluids) is as low as 0 to 10 wt. % NaCl equivalent (mostly less than several wt. %), which may suggest the participation of circulating meteoric waters in the Neogene ore formation.

6) From the reported data on fluid inclusions, almost all hydrothermal ore deposits can be generally classified into three groups; (i) a group characterized by high temperature and high salinity ore fluids (e.g., porphyry copper deposits), (ii) a group characterized by low temperature and high salinity ore fluids (e.g., Mississippi Valley-type deposits), and (iii) a group characterized by low to intermediate temperature and low to intermediate salinity ore fluids (e.g., Neogene ore deposits in Japan). Moreover, it is worthwhile to mention that many other hydrothermal ore deposits are located within a region between group (i) and group (ii), whether they are closely associated with or without granitic intrusives (e.g., Taishu Pb-Zn veins; Providencia Pb-Zn-Ag ore deposits, Mexico). (Author's abstract)

WELHAN, J.A., and CRAIG, H., 1979, Methane and hydrogen in East Pacific Rise hydrothermal fluids: Geophysical Research Letters, v. 6, p. 829-831. Authors at Isotope Lab., Scripps Inst. Oceanog., Univ. Cal. San Diego, La Jolla, California 92093.

Recently discovered hydrothermal vents at 21°N on the East Pacific Rise are discharging turbid waters at up to 400°C, mixtures of the plumes with ambient seawater contain significant amounts of dissolved H_2 and CH_4, as well as He. The first grab samples of these waters were diluted 50-100 fold, but they contained as much as 20×10^{-5} cc(STP) of H_2 and 2×10^{-5} cc(STP) of CH_4 per gram of water. H_2/CH_4 ratios in the vents increase with temperature, a result that is tentatively attributed to chemical equilibrium and/or redox state of the individual waters. The phase diagram for the $NaCl-H_2O$ "surrogate-seawater" system shows that liquid-vapor separation may take place prior to discharge, and mixing of a vapor phase with entrained cooler seawater would profoundly alter original concentrations of volatiles as well as dissolved salts. H_2 and CH_4 ratios to basalt-derived helium are respectively about 550 and 70 in these waters. The total fluxes from the world-ocean ridge system, estimated from the He-3 flux, are of the order of 1.3×10^9 m^3/y for H_2 and 1.6×10^8 m^3/y for CH_4. The CH_4 flux so calculated is sufficient to replace the deep-sea methane in ~30 years, implying a very rapid bacterial consumption rate below the thermocline. (Authors' abstract)

WELHAN, J.A., POREDA, R. LUPTON, J.E. and CRAIG, H., 1979, Gas chemistry and helium isotopes at Cerro Prieto: Geothermics, v. 8., p. 241-244. Authors at Scripps Inst. Oceanog., La Jolla, CA.

Seven producing wells and seven hot springs in the Cerro Prieto geothermal field were sampled during April and September 1977, for determination of gas chemistry and helium isotope ratios. Well gases are remarkably uniform in gas chemistry and helium isotope ratio, showing high $^3He/^4He$ ratios characteristic of mantle-derived helium, and higher than expected N_2/Ar ratios. Comparison with the hot spring data suggests that the deep gas component observed in wells is modified during transit to the hot springs by addition of crustal helium, dissolved air and possibly organic methane, alternatively, chemical reequilibration at lower temperatures may be responsible for increasing the CH_4/H_2 ratio. (Authors' abstract)

WERRE, R.W., Jr., BODNAR, R.J., BETHKE, P.M. and BARTON, P.B., Jr., 1979, A novel gas-flow fluid inclusion heating/freezing stage (abst.): Geol. Soc. Am. Abstr. Programs, v. 11, no. 7, p. 539.

A gas-flow heating/freezing stage has been developed which allows rapid, accurate fluid-inclusion measurement from -150° to 700°C. Heating and cooling are accomplished by forcing externally heated or chilled gas over the sample. The INVAR sample chamber has a viewing area of ~2 cm in diameter. A 2 mm-thick sample may be observed using a 32X objective having a 6 mm working distance; a chamber accommodating plates up to 5 mm thick is available for use with a 10X objective having a 14 mm working distance. Triple silica-glass windows are placed above and below the sample with dead air enclosed by the outer pairs. Gas first passes between the innermost pairs above and below the sample chamber, then back through the sample chamber, and finally out around the equatorial exterior. This circulation pattern provides nearly instantaneous thermal response. Calibration from ambient temperature up to 300°C using melting-point standards sealed in evacuated capillaries indicates an accuracy and precision better than 1.0° and 0.1°C, respectively. Freezing measurements have an accuracy and precision of 0.1°C, calibrated to -10°C. Gradients within the chamber are ~1.0°C over 3/4 of the viewing area up to 300°C and ~0.2°C over the same area during freezing runs. The large sample chamber greatly simplifies sample preparation and documentation, and minimizes set-up time. This, and the rapid response time, allows many fluid inclusions to be examined in a relatively short time when compared with other stages in current use, with no loss in precision or accuracy. The external temperature control and simple design minimize "down time" due to equipment failure. Plans and calibration data will be available at the poster session. (Authors' abstract.)

WESTRA, Gerhard, 1979, Porphyry copper genesis at Ely, Nevada; Nevada Bur. Mines and Geology Rept. 33, IAGOD 5th Symp. Proc. Vol. 2, p. 127-140. Author at Exxon Minerals Company, 2425 N. Huachuca Drive, Tucson, AZ.

Porphyry-copper deposits near Ely, Nevada, are parts of a single large sulfide system fragmented by normal faulting. Restoration of the system allows detailed study of a major porphyry-copper deposit over a vertical range of 9000 feet. Five stages of formation are recognized.

1. Emplacement of a quartz-monzonite magma to within 1850 m of the surface. The magma was overheated (900-1000°C), water-undersaturated (1.4 wt.%) and crystallized over a 300°C interval with a 10°-25°C interval of final crystallization. Estimated Cu content was 115 to 145 ppm. At the top of the magma column, a 375 m-thick, water-saturated silicate-melt layer formed, adjacent to which important iron metasomatism produced an anhydrous andradite-pyroxene-magnetite skarn in Ely Limestone.

The deeper parts of the magma chamber were surrounded by an isochemical contact-metamorphic aureole.

2. A sharp decrease in confining pressure resulted in rapid crystallization of the water-saturated melt layer as early quartz-monzonite porphyry with concomitant formation of an extensive zone of potassic alteration. Catastrophic water release produced a zone of stockwork fracturing in early quartz-monzonite porphyry and surrounding sediments that facilitated the inward flow of cool meteoric waters, thus cooling the area directly above the magma chamber. A new water-saturation surface was established in the magma some 300 m below the base of the porphyry.

3. Magma convection caused by steep thermal gradients resulted in the movement of water-undersaturated magma volumes through the saturation surface with attendant release of volatiles, base metals, and sulfur. The magmatic hydrothermal fluid was supercritical and contained 4 to 5 wt. % NaCl equivalent and between 2000 and 4000 ppm Cu. Moving upward, the fluid entered a zone of throttling and was forced to boil This zone of boiling coincides with a high silica-chalcopyrite zone located directly below the region dominated by meteoric water. Boiling produced a highly saline fluid phase and a low density acid vapor phase that, upon rising, reacted with porphyry and sediments to form quartz-sericite-pyrite and silica-pyrite zones. Moving outward, the now neutralized fluids reacted with porphyry to form argillic assemblages and with limestone to form pyritic marble.

4. Argillization and silica deposition in overlying rocks enabled the water-saturated magma layer once again to build up a fluid overpressure. Pressure release was followed by crystallization of late quartz-monzonite porphyry with associated weak alteration, mineralization, and stockwork fracturing. Magma convection stopped but upward diffusion of alkalies and volatiles in the crystal-silicate melt column resulted in a zone of potassium enrichment in the quartz monzonite located directly below the porphyry phases. Subsequently, the meteoric convection system encroached upon the former zone of boiling, resulting in pervasive argillization of early quartz-monzonite porphyry.

5. Following consolidation of the main magma body as quartz monzonite, the meteoric convection system entered the hot stock, resulting in the formation of quartz, zeolite, and calcite veins. (Author's abstract)

WETLAUFER, P.H., BETHKE, P.M., BARTON, P.B.,JR. and RYE, R.O., 1979, The Creede Ag-Pb-Zn-Cu-Au district, Central San Juan Mountains, Colorado: a fossil geothermal system, _in_ Papers on mineral deposits of western North America, IAGOD Fifth Quadrennial Symposium Proc., v. 2, J.D. Ridge, ed; Nevada Bur. Mines and Geology Report 33, p. 159-164.

The similarities between the characteristics of the Creede deposit and those at intermediate depths in active geothermal systems suggest that Creede is a fossil geothermal system. Parallels exist in terms of geologic setting, postulated geometry of the hydrologic system, source of solutions, temperature, salinity, base-metal contents, and lifespan of the system. No known active geothermal system is exactly like the Creede deposit, but most characteristics of the Creede ore system are compatible with those of known active systems.

Studies of appropriate ore deposits and of active geothermal systems are mutually complementary. Ore-deposit studies can document the detailed evolution in time and space of a small part of a fossil geothermal system, whereas studies of active geothermal systems reveal the "instantaneous" near-surface patterns of systems analogous to some that have formed ores. (Authors' abstract). (Includes a summary of fluid inclusion data - ER)

WHITE, R.S., 1979, Gas hydrate layers trapping free gas in the Gulf of Oman: Earth and Planet. Sci. Lett., v. 42, p. 114-120. Author at Dept. Geod. and Geophys., Univ. Cambridge, Cambridge, CB3 OEZ, U.K.

It has been postulated that the sediments of the Gulf of Oman, in the northwest Indian Ocean contain a number of localized accumulations of free gas which are apparent on continuous seismic reflection profiles as horizons with anomalously high amplitude reflections. We suggest that the gas is trapped beneath a relatively impermeable gas hydrate layer which is stable within the uppermost 350-700 m of sediment. The depth beneath the sea floor of all the observed highly reflective horizons varies with water depth in a manner similar to that predicted from theoretical estimates of the depth at which the phase change occurs from gas hydrate to free gas. Further evidence that the gas is trapped by a hydrate layer is provided by the detailed shape of gas layers within the cores of gentle anticlines. The curvature of the gas reflector mirrors that of the sea floor above it, but transgresses the local bedding, suggesting that the gas is trapped by a hydrate phase change governed by the pressure and temperature conditions rather than by a stratigraphic trap. (Author's abstract)

(Editor's note - Such layers may yield later CH_4-H_2O fluids?)

WHITNEY, J.A., SIMON, F.O., HEMLEY, J.J. and DAVIS, N.F., 1979, Iron concentrations in chloride solutions equilibrated with synthetic quartz monzonite assemblages, Part 1: Sulfur free systems (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 540.

The concentrations of iron in 1N chloride solutions have been determined at tempertures of 400° to 700°C and a pressure of 1 kb for fluids in equilibrium with synthetic magnetite- or biotite-bearing quartz-monzonite. K/H and Na/K ratios were controlled by reactions similar to those observed in natural alteration assemblages involving alkali feldspar and plagioclase with aluminosilicate, muscovite, or montmorillonite. Oxygen fugacity was controlled by internal or external methods using Hem.-Mag., Ni-NiO, and Qtz.-Fay.-Mag. assemblages. Starting compositions of fluids were solutions of HCl; $2HCl:FeCl_2$; HCl:NaCl; and $NaCl:KCl:FeCl_2$. Equal masses of solid and solution were used to expedite equilibration. Iron was added as synthetic magnetite, synthetic biotite, or in solution. Run times ranged from 4 days to several weeks.

At 400°C, the dominant cations in solution are Na, K, and Ca, and iron concentrations are 0.01 to 0.05 molal. By 500°C, Na, K, and Fe are dominant, and Fe concentrations are 0.10 to 0.17 molal. By 600-°C, the Fe concentration reaches a maximum of 0.20 to 0.25 molal and then appears to drop to between 0.10 to 0.15 molal at 700°C. The effect of f_{O_2} on concentration is consistent with changes in the iron-bearing assemblage from magnetite to biotite and, along with charge balance calculations, suggests that ferrous chloride is the dominant species at low temperatures. Ferric chloride concentrations <u>may</u> increase at the highest temperatures. These data indicate that, in natural magmatic systems, the concentration of iron in chloride solutions coexisting with magnetite or biotite is extremely high. This high transportability may explain large quantities of iron deposited in skarns and related deposits around some mineralized granitic stocks. (Authors' abstract)

WILSON, J.W., 1978, Fluid inclusion geochemistry of the Granisle and Bell copper porphyry: Master's thesis, Univ. of Toronto, Toronto, Ont., Can .

Indexed under fluid inclusions. (E.R.)

WODZICKI, Antoni, and BOWEN, F.E., 1979, The petrology of Poor Knights Islands: a fossil geothermal field Note: N.Z. Jour. Geo. and Geophy., v. 22, p. 751-754.

Intense hydrothermal alteration has resulted in almost complete replacement of primary rhyolitic tuff minerals by quartz, adularia and albite, minor sericite, cristobalite, pyrite, leucoxene and sphene, and retrograde smectite and kaolinite. The alteration took place at temperatures up to about 240°C and resulted in addition of silica and potash and the leaching of lime. Except for the near absence of calcium bearing minerals and the presence of retrograde minerals, the alteration is very similar to that occurring in the active thermal areas of Taupo Volcanic Zone today. (Authors' abstract)

Includes Th determinations of 231, 236, and 243°C. (ER)

WOLERY, T.J., 1979, Sea water-ocean crust hydrothermal chemistry: Some theoretical considerations (abst.): Eos, v. 60, p. 863.

WOLFFING, C.L., 1978, Fluid inclusion studies in Precambrian rocks, Isua, West Greenland: Master's thesis, Northern Illinois Univ., De Kalb, Ill, USA.

WOLFGRAM, Diane, 1979, Wall-rock alteration in the Homestake Gold Mine, Lead, South Dakota (abst.): Geol. Assoc. Can.-Min. Assoc. Canada Program with Abstracts, v. 4, p. 86.

The Homestake Mine at Lead, South Dakota is the largest gold mine in North America. By the end of its centennial year of operation (1976), 31.8 million troy ounces of gold had been recovered from ore bodies confined to the Homestake iron-formation. The Homestake iron-formation is part of an Early Proterozoic supracrustal sequence which was complexly deformed and regionally metamorphosed during the Hudsonian orogeny, and is now exposed in the core of the Black Hills uplift.

The "pipe like" ore bodies are confined to the carbonate-rich hinges of synclines, whereas cummingtonite is preferentially developed in the ore-poor hinges of anticlines. These relationships suggest that density stratification of H_2O and CO_2 played an important role during remobilization of syngenetic gold. Wall-rock alteration associated with the well known "cross-folding" consists of chloritic alteration halos about quartz "reefs" whose long axes are subperpendicular to the axes of the "cross-folds". A quartz deficient ore zone dominated by secondary carbonate, arsenopyrite, and pyrrhotite forms a transition zone between chloritic alteration and zones of quartz veinlets in the "cross-folding" shear planes.

At an assumed pressure of 5 kb and temperature of 350°C, thermodynamic calculations based on electron microprobe analyses of coexisting minerals indicate that f_{S_2}, and f_{C_2}, decrease veinward across the ore zones, and that the partial pressure of H_2O increases. CO_2 is the dominant gas phase in the ore zones, but methane is the dominant gas phase in the zones of quartz veinlets. $a_{Al^{+++}}/a^3_{H^+}$ decreases, but $a_{Mg^{++}}/a^2_{H^+}$ and $a_{Fe^{++}}/a^2_{H^+}$ increase veinward across the ore zones. Assayed gold values increase in a veinward direction across the ore zones, but the quartz veinlets are barren. Diffusion of components, including gold, from chloritized dilatent zones toward the zones of quartz veinlets is believed to by the critical stage in ore formation.

WOOD, J.A., and MOTYLEWSKI, Karen, 1979, Meteorite research: U.S. National Report, 17th General Assembly, IUGG, Canberra, Australia, Dec. 1979, Papers in volcanology, geochemistry, and petrology: Reviews of Geophysics and Space Physics, v. 17, no. 4, p. 912-

WOTRUBA, N.J., 1978 , Fluid inclusion geothermometry of the ores of the Metaline mining district, Washington: Master's thesis, Washington State Univ., Pullman, WA, USA (50 pp).

Indexed under fluid inclusions. (E.R.)

WOTRUBA, N.J., 1979 , Fluid inclusion geothermometry of the ores of the Metaline mining district, Washington (abst.): in Proceedings of the 1979 Pacific Northwest Metals and Minerals Conference; Am. Inst. Min. Metall. Pet. Eng.

WYLLIE, P.J., 1979, Kimberlite magmas from the system peridotite-CO_2-H_2O, in Kimberlites, diatremes, and diamonds: their geology, petrology, and geochemistry, Proceedings of the Second International Kimberlite Conference, edited by Boyd, F.R., and Meyer, H.O.A.: Washington, Amer. Geophys. Union, v. 1, p. 319-329. Author at Dept. Geophys. Sci., Univ. Chic., Chicago, Il 60637.

Phlogopite-dolomite-peridotite is the most promising source rock for kimberlites and related magmas. At pressure above about 30 kb, very little CO_2 (low CO_2/H_2O in vapor) is required to produce dolomite in mantle peridotite. If oxygen fugacity is too low, however, CO_2 and carbonate are reduced to carbon, and dolomite is unable to exert its distinctive influence on magma compositions. The oxygen fugacity at various depths in the mantle is a critical factor. Rare diamonds and even rarer carbonatites occur in peridotite nodules from kimberlite, and CO_2 is brought to the surface in mantle-derived minerals and lavas. Phase relationships in peridotite-CO_2-H_2O provide a first step for evaluation of the behavior of components C-H-O at depth. Experimental and theoretical data from various sources have been combined for analysis of the near-solidus phase relationships in peridotite-CO_2-H_2O. The divariant solidus surface is traversed by a series of univariant lines where the vapor phase is buffered by amphibole, dolomite (magnesite at higher pressures), phlogopite, or combinations of these. The lines limit the range of vapor-phase compositions that can coexist with peridotite at various pressures. The buffering capacity of dolomite is far greater than that of the hydrous minerals. The buffered curves for partly carbonated peridotite, with and without phlogopite, extend to lower temperatures and higher pressures from an invariant point near 26 kb and 1200°C. Near this line there is a temperature-maximum (a ridge) on the solidus surface, separating the low-pressure surface, where CO_2/H_2O in vapor is lower than in liquid. Enrichment of the high-pressure liquids in CO_2 is associated with the generation of dolomite and low-SiO_2 liquids. Because of this maximum on the solidus, near-solidus magmas rising along an adiabat would evolve volatile components in the depth interval 100-80 km, which could contribute to the explosive eruption of kimberlites. The subcontinental upper mantle is probably heterogeneous with respect to imcompatible elements, because local melting due to sparsely distributed CO_2 and H_2O (dolomite and phlogopite) is followed by magmatic flushes, as the melt migrates upwards. (Author's abstract)

XENOPHONTOS, C., NORMAN, M. and RYDER, G., 1979, Possibly immiscible globules in a tholeiite sill, (abst): EOS, v. 89, p. 412.

A tholeiitic sill in the prebatholitic rocks of the northern Sierra Nevadas contains abundant ovoid pale colored globules which are 2-3 cm in diameter, sharply bounded, and concentrated towards the upper part of the sill.

Effects of immiscibility will depend on the bulk composition of the system, but several chemical characteristics of the globule-matrix pair conform with our present understanding of immiscibility. (From the authors' abstract)

YAJIMA, Junkichi, 1979, Neogene mineralization of the Teine--Chitose district, West Hokkaido, Japan: Bull. Geol. Surv. Japan, v. 30, p. 645-679.

A zonal distribution of metallic ore deposits around Jozankei quartz porphyry is recognized in the Teine--Chitose district. Toyoha mine is one of the representative lead-zinc deposits in the inner Pb-Zn zone, while Chitose mine is the typical gold-silver deposits in the outer Au-Ag zone.

The temperature and salinity of fluid inclusions from Chitose deposits are 200°-300°C and 0.0-3.6 percent, respectively, and vapor pressure and density of the fluid at the lowest level of deposition are estimated as 84.9 atm and 0.734 g/cc which correspond to the depth of 1050 meters.

At Toyoha deposits, decreasing temperature and salinity of fluid inclusions as well as mineral zoning are observed from east to west among earlier veins and from southeast to northwest among later ones. Taking account of heat source at southeastern deeper zone, the sequence of mineralization in space and time was deduced for Toyoha deposits. (Author's abstract)

YAKOVLEV, B.G., MATYASH, I.V., LITOVCHENKO, A.S., PROSHKO, V.Ya., BAGMUT, N.N. and KARPENKO, A.A., 1978, Water inclusions in alkali feldspar solid solutions and characteristics of their crystallization in charnockites and pegmatites of the Ukrainian shield: Dopov. Akad. Nauk Ukr. RSR, Ser. B: Geol, Khim. Biol. Nauki, 1978, (8), p. 706-709 (in Russian).

YARDLEY, B.W.D., 1979, Fluid inclusion studies in metamorphic rocks (abst.): Program of Fourth Meeting of the Geological Societies of the British Isles, Univ. Sheffield, Sept., 1979 (unpaginated). Author at School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ.

Fluid inclusion studies are important for metamorphic petrology both because they allow us a glimpse of the actual fluids present during metamorphism, and because they can be used to define isochores indicating the P-T conditions of metamorphism. The two roles are not entirely independent; in many cases we are now able to calculate the conditions of equilibration of impure minerals in natural rocks from experiments performed in pure end-member systems by using appropriate solution models for the solid phases. Often however, variations in composition can have a far larger effect on the conditions of equilibration than likely variations in mineral compositions. Nevertheless mineral compositions are merely assumed.

Work on fluid inclusions has been carried out in several metamorphic terrains, notably by the Nancy group, but in most classical metamorphic areas no such studies have been done. Large primary inclusions are present in some Alpine veins, but generally only small ($<$30 micron), probably secondary inclusions are available. These are most commonly present in quartz veins, or where the rocks are fairly coarse grained, in groundmass quartz, however a number of other minerals may also act as hosts.

The amphibolite facies Dalradian metasediments of Connemara include a wide variety of rock types, all of which are cut by quartz veins containing abundant fluid inclusions. From their structural relationships it is seen that most veins formed near the peak of metamorphism, but sequences of veining can sometimes be recognized. A major problem with fluid inclusion studies in these rocks is the diversity seen in a single sample. Different generations of inclusions containing similar fluids may have formed under very different conditions, and it is not unusual for nearby inclusions to have very different fillings. Initial studies show that most inclusions contain fairly pure water only, with freezing temperatures (T_f) from -1 to -7°C. At these grades, water liberated by dehydration reactions may have diluted any more saline original fluid. A wide range of homogenization temperatures (T_h) is observed within samples, for example one vein from a pelite gave T_h values from 180-280°C for H_2O inclusions, with the lower density inclusions consistent with independent estimates of the metamorphic maximum. H_2O-CO_2 and CO_2-CH_4 fluids have also been found with H_2O veins from pelite, and CO_2 and CH_4 may be derived from graphite in the pelite or from nearby marble horizons. Small pods of vein quartz in the marble also contain H_2O inclusions, but in one sample from the upper sillimanite zone ($T_{max} \approx 640$°C) the dominant fluid is CH_4 with T_h near - 110°C. Horizons of quartzite are also cut by veins up to 1m in width and these usually only have H_2O inclusions with low equivalent salinity; possibly they represent the passage of water derived from dehydration reactions in interbedded pelite layers. (Author's abstract)

YERMAKOV, V.A., CHERNYKH, Ye.N. and MILYUTIN, S.A., 1979, Immiscibility in ultramafic magma with generation of ultramafic and pyroxenite melts: Dokl. Akad. Nauk SSSR, v. 249, p. 175-178 (in Russian; translated in Dokl. Acad. Sci. USSR, v. 249, p. 112-114, 1982).

YIN, Hanhui, 1978, Ore genesis of a polymetallic mine in Hunan Province: Geochimica, v. 4, p. 270-280 (in Chinese with English abstract).
Indexed under fluid inclusions. (E.R.)

YODER, H.S., Jr., ed., 1979, The Evolution of the Igneous Rocks: Fiftieth Anniversary Perspectives: Princeton, N.J., Princeton Univ. Press, 588 pp.

A 50-year update of Bowen's book on igneous petrology. Includes a chapter on silicate immiscibility by Roedder and one on volatiles by Burnham. (ER)

YOSHIDA, Tetsuo, 1979, Fluid inclusion study and ore forming process of the Iwami deposit, Shimane prefecture, Japan: Mining Geology (Japan), v. 29, p. 21-31 (in Japanese with English abstract). Author at Dept. Mining, Fac. Eng., Kyushu Univ., Hakozaki, Fukuoka, Japan.

The Iwami deposit of the Kuroko-type is situated in the Green Tuff region of the Inner Zone of Southwest Japan. The ore deposit is composed of stratiform Kuroko, gypsum and stockwork ore bodies in descending order. The stockwork ore body is economically more important than the stratiform ore body which consists of clayey ores and fragments of stockwork ores. The clayey ores are composed of fine grained sulfide minerals showing colloform texture and aggregates of sphalerite crystals up to 20 mm in diameter. Sphalerite suitable for inclusion studies in the stratiform ores is found in the fragments of the stockwork ores and the aggregates of sphalerite crystals. Sulfide minerals in the stratiform and stockwork ores are sphalerite, galena, pyrite and chalcopyrite, with minor luzonite and tetrahedirte. The wall rocks of the stockwork ores are composed of dacitic pyroclastics and small rhyolitic intrusives of Miocene age.

Samples were collected from five levels (-30 m to -105 m). The filling temperatures of 395 fluid inclusions in sphalerite and quartz from 89 localities were determined with the microscope heating stage. All the inclusions were two-phase and most ranged from 20 to 50µ in maximum dimension. Salinities of inclusion fluids in sphalerite were studied with the freezing stage. Many small inclusions were observed in gypsum from the gypsum ore body, calcite from the veins of the stockwork ore body and barite from the stratiform ore body. Most of them were monophase (liquid) inclusions and some were extremely liquid-dominant two-phase inclusions.

Filling temperatures range generally from 200°C to 310°C for sphalerite and from 230°C to 295°C for quartz. The temperature values for quartz fall in approximately the same range as that for sphalerite. Salinities of inclusions in sphalerite indicate approximately 1 to 5 wt.% NaCl equivalent. It is clearly seen that the temperatures for sphalerite increase downward in the stockwork ore body. In the stratiform ore body the temperatures for sphalerite from the fragments of stockwork ores range from 230°C to 265°C and correspond to the values for the stockwork ores of -30m and -55m levels. The temperatures for sphalerite from the aggregates of sphalerite crystals range from 250° to 270°C.

The ore forming succession in the Iwami deposit is considered as follows. At first, gypsum precipitated on the bottom of a small basin from sea water at the beginning of mineralization at low temperature. The stockwork ore body was formed, probably at a range of about 200° to 300°C, in the "breccia pipe". At the same time the stratiform fine grained clayey ores were formed on the bottom of the basin of at least 540 m depth. The fragments of the stockwork ores were mixed with clayey stratiform ores due to collapse of the upper part of the stockwork ore body. After this collapse mineralization continued and coarse sphalerite aggregates were formed from fine grained sphalerite in the clayey sediments. Calcite veins were formed below 100°C in the waning stage of the mineralization. (Author's abstract)

YOUNG, J.S., 1979, Paragenesis of gold veins in the Granite district, Grant County, Oregon (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 306.

Vein gold deposits of the Granite district of northeastern Oregon occur in northeast-trending faults and represent mesothermal systems. The veins cut units of the Carboniferous Elkhorn Ridge Argillite and the adjacent Cretaceous Bald Mountain Granodiorite pluton. Mineralized veins contain early quartz, pyrite, arsenopyrite, and electrum, and late quartz, carbonates, sphalerite, galena, chalcopyrite, and Ag-bearing tetrahedrite. Ore deposition was preceded by a stage of hydrothermal alteration.

All vein metals decrease in abundance away from the intrusive, suggesting depletion of metals in solution at progressively greater distances from the proposed magmatic source. Decreasing gold grain-size in veins further from the pluton is attributed to the same depletion mechanism. Restriction of significant Pb, Cu, and Sb to veins close to the pluton apparently reflects more complete filling of the more distant veins by earlier mineral phases.

The presence of carbonates formed during alteration, and Cr in fuchsite indicates that ore fluids were probably neutral to alkaline in pH. Under these conditions, Au transport is best accomplished by sulfide complexing. Preliminary examination of fluid inclusions suggest filling temperatures of approximately 300°C, and salinities of less than 10 wt. % NaCl. (Author's abstract)

YPMA, J.M., 1979, Mineralogical and geological indications for the petroleum potential of the Etosha Basin, Namibia (S.W. Africa); Proc. Koninklijke Nederlandse Akad. van Wetenschapp]en, Ser. B, v. 82 (1), p. 91-112. Author at Dept. Econ. Geol., Univ. Adelaide, Adelaide, S.A. 5001, Australia.

The study entails an assessment of the geological information pertinent of the petroleum potential of the Etosha Basin in Namibia. The carbonates of the Tsumeb Subgroup of the Otavi Group have the best source and reservoir rock potential among the sediments of the Etosha Basin. The detractive aspect of age of the Otavi (600-500 m.y.) is counterbalanced by near ideal conditions for the generation and preservation of algal kerogen. All indications are that temperature incursions never exceeded 150°C. Hydrocarbon-bearing fluid inclusions (Th = 120-150°C, containing C_2H_6, CH_4, C_3H_8 and C_2H_4) in the Otavi carbonates and oil seepage in an uncompleted well in the Etosha Basin demonstrate the suitability of geological conditions. Good matrix porosity and gentle deformation of the Otavi into large folds have created favorable traps. (Author's abstract)

YUDIN, I.M., ADRIANOVA, S.I. and MEL'NIKOV, F.P., 1978, Experiment in complex thermometric methods for research on gold mineralization, in Theory and Practice of Thermobarogeochemistry, N.P. Ermakov, ed., Izd. Nauka, p. 191-193 (in Russian).

YURGENSON, G.A., TUPYAKOV, V.Ye. and SHIROKIY O.I., 1979, Variations of composition and properties of vein quartz of a gold-sulfide-quartz deposit* as a function of ore zoning and conditions of origin: Geol. Rudnikh Mestor. v. 21, no. 3, p. 56-67 (in Russian). Authors at Transbaiklian Complex Sci.-Research Inst., USSR (city not given).

The deposit formed at moderate depth in a fault zone. Ore bodies are exclusively filling veins, formed in three stages: 1) gold-quartz, 2) tourmaline-sulfide-quartz, 3) carbonate-quartz. Stages 1 and 2 are commercial, with Au-Bi ores. Stage 1 yielded Th 350-295°C (P inclusions) and 260-190°C (S inclusions); the latter are the result of overlapping stage 2. Th of P inclusions increases with the increasing depth of sampling. (Abst. by A.K.)

* deposit name not given (A.K.)

YUSMAN, B.I., POLYKOVSKIY, B.S. and IVANOVA, I.A., 1978, Application of the decrepitation analysis for paleogeographical problems (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 44-45 (in Russian). First author at Territorial Geol. Office, Tashkent, Uzbek SSR.

An outline of correlation of decrepitation logs of Cretaceous quartz sandstones in SE Fergana (Uzun-ayrek, Terek-2 and Akboguz-Kadur) with reportedly positive results. (A.K.)

ZARUBINA, S.A., KRYUCHKOV, P.A., SITNIKOVA, N.V. and TISHCHENKO, P.Ya., 1978, Use of glass electrodes for determination of pH and pNa under elevated pressure, (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 1, Thermobarogeochemistry in geology: Vladivostok, Acad. Sci. USSR, p. 188-189 (in Russian). First author at Far East Sci. Center of Acad. Sci. of the USSR, Vladivostok.

No inclusion data. (A.K.)

ZHANG, Shulin, 1979, Ore-forming solution and genesis of a rock crystal deposit in South Hunan, indicated by fluid inclusion study: Geochimica, 1979, p. 28-43 (in Chinese with English abstract).

Si, Al, Ca, Mg, Fe, Na, K, CO_3, F etc. are detected in fluid inclusion leach solution. Among these constitutents, Si, Na and $CO_3^=$ predominate, amounting to more than 80 percent. This indicates that the ore-forming solution must be alkaline with Si, Na and $CO_3^=$ as its dominant components. Homogenization temperatures of this solution range from 80° to $360^{\circ}C$. Although rock quartz can be crystallized at the above temperature interval, perfect crystals of economic importance are largely formed below $260^{\circ}C$. The temperature of formation increases toward the granite intrusion at a rate of about one degree per meter. It is estimated from the lithostatic load that the pressure of formation was 600-750 bars. Freezing studies show that the salinity of fluids for rock quartz is 17-23 (NaCl wt.%), while that for vein quartz is much higher. There is a tendency for the salinity of the ore-forming solution to increase with the depth of burial. (Author's abstract)

ZHAO, Xi-cheng and LIN, Er-wei, 1979, Analysis method of pneumato-hydratogenetic inclusion in minerals: Changchun Dizhi Zueyuan Zuebao, 1979, no. 2, p. 89-92, (in Chinese; translated in China Rep.: Sci. Technol., v. 10, 38 pp. [in English]), avail. from NTIS, JPRS 74313.

ZHAO, Xi-Zheng, YANG, Xian-Jue and HUNG, Ke-Long, 1979, Pressure correction coefficients for the determination of fluid-inclusion homogenization temperatures (at atmospheric pressure): Ch'ang-ch'un Ti Chih Hsueh Yuan Hsueh Pao, 1979, no. 4, p. 150-156 (in Chinese).

ZIDAROVA, B. and KOSTOV, I., 1979, Characteristics of fluorite from the Palat deposit, Blagoevgrad District (Bulgaria): Geokhim. Mineral. Petrol, v. 11, p. 51-65 (in Bulgarian).

The quartz-fluorite veins, veinlets, and vugs contain 3 generations of fluorite : green and 2 lilac varieties. The temp. of crystn. detd. from Th of the gas-liq. inclusions is 150-80° for the octahedral crystals and 150-250° for the cubic crystals. The amt. of rare earths was detd. by neutron activation anal. The processes of crystn. were discussed. Chem. anal. are given. The early-stage fluorites have a higher concn. of rare earths than the late stage fluorites. (C.A. 92:150278k)

ZIMMERMANN, J.-L., ARNOLD, Michel and GUILLOU, J.-J., 1979, Differences between the chemistry of visible inclusions and volatiles extracted from Gour Nègre (Gard): C.R. Acad. Sc. Paris, v. 288, Sec. D, p. 863-866 (in French).

Fluids of low temperature quartz inclusions (Gour Nègre, Gard, France), have been analyzed by mass spectrometry. The high content in organic compounds thus revealed seems to contradict their absence in the visible inclusions. These organic compounds are probably stored in infra-microscopic cavities of the crystals. (Authors' abstract)

ZINCHUK, I.N., 1978, Certain problems of use of properties of crystal hydrates of gases during cryometric studies of fluid inclusions, (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 1, Thermobarogeochemistry in geology: Vladivostok, Acad. Sci. USSR, p. 190-191 (in Russian). Author at Inst. Geol. Geochem. Mineral Fuels of Acad. Sci. of the Ukrainian SSR, L'vov.

Studies were performed on quartz from Central Donbass. CO_2 crystal hydrate forms zones (envelopes) around deformed gas bubble and it remains after melting of ice. Repeated cooling down to -15 or -20°C causes significant increase of crystal hydrate volume. Crystal hydrate decomposition takes place at -1.5 to 0°C. When LCO_2 is present in inclusion, crystal hydrate melts at +8 to +10°C. Inclusions of dense supercritical CH_4 + 1-2% of water solution develop CH_4 crystal hydrate at -35°C as layers on inclusion walls or tiny crystals; this crystal hydrate melts at +19.5 to +20.0°C; such T means P=210 bars from the phase diagram CH_4-H_2O. At T of mineral formation (+160°C, by H_2O solution G/L inclusions), P was 430 bars (P_{H_2O} omitted).

Crystal hydrate observations may be used for: 1. Determination of presence of small amounts of CO_2 and other gases in inclusions, 2. Determination of approximate gas composition by T of melting of crystal hydrates (upper stability limits: CO_2+10°C, CH_4+21.4°C, H_2S+29.5°C), 3. Determination of P from T of crystal hydrate melting in essentially G inclusions when composition is known; mixed crystal hydrates should be studied. Formation of water-rich crystal hydrates changes salt concentration in the remaining solution, which should be considered when the concentration is determined. (Author's abst., translated by A.K.)

ZINCHUK, I.N., KALYUZHNYI, V.A. and MATVIENKO, A.D., 1979, Prospecting-evaluation significance of carbon dioxide of liquid inclusions in quartzes from hydrothermal veins of the Donets Coal Basin: Deposited Doc. VINITI 1169-80, p. 104-110 (in Russian).

ZOLOTAREV, B.P., SARKISYAN, I.S., VOYTOV, G.I. and CHEREVICHNAYA, L.F., 1979, Bituminous substance in young basalts of the mid-Atlantic Ridge: Akad. Nauk SSSR Doklady, v. 244, no. 4, p. 969-973 (in Russian). First author at Geol. Inst. of the Acad. Sci. of the USSR, Moscow.

Samples were taken from drilling cores of the 45th "Glomar Challenger" cruise. They consist mostly of the abyssal oceanic basalts of tholeiitic composition. The studied rocks bear in inclusions and in pores 0.00045 to 0.012 wt.% of bitumen-type substance soluble in chloroform and in alcohol-benzene mixture. Most of the organic substance is secondary since it occurs in microfractures in rocks. (Abst. by A.K.)

Due to an editorial oversight, the following eight items were omitted in preparation of this volume. Cross references have been entered in the correct alphabetical location so the material will not be lost.

BOLOKHONTSEVA, S.V., GANEEV, I.G., POKALOV, V.T. and RUMYANTSEV, V.N., 1978, Thermometric studies of gas-liquid inclusions in crystals of synthetic quartz, (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 1, Thermobarogeochemistry in geology: Vladivostok, Acad. Sci. USSR, p. 192 (in Russian). Authors at All-Union Inst. of Mineral Raw Materials, Moscow, USSR.

The studied inclusions in synthetic quartz are higher in temperature than previously reported in the literature, i.e., 420-480°C. Inclusion size was 0.002 to 0.25 mm; filling ratio was the same as in the autoclave. Also there occur inclusions with variable phase ratio, adjacent to solid particles embedded in mineral; such inclusions are not suitable for thermometry. Results are as follows:

No.	Crystallization temperature, °C	Th, °C	P, atm	Filling, % of L	No. of determinations	ΔT, °C
1	450	375	740	60	9	75
2	480	376	960	60	12	104
3	450	345	1100	67.5	5	105
4	420	304	1400	75	6	116
5	450	305	1730	75	9	147
6	480	302	1920	75	6	178

(From the authors' abst. transl. by A.K.)

CARPENTER, A.B. and GRETHEN, B.L., 1979, The origin of metal-rich brines in sedimentary basins (abst.): Program, 108th AIME Annual Meeting, New Orleans, Feb. 18-22, 1979, p. 18.

Metal concentrations in oilfield brines have been determined at a number of localities:

Locality	Rock Unit	Dissolved Solids, mg/L	Metal Content, mg/L			
			Pb	Zn	Fe	Ba
Mississippi	Cretaceous	320,000	111	357	420	59
Alabama	Jurassic	486,000	215	39	467	504
Texas	Cretaceous	344,000	226	706	1060	1090
Michigan	Silurian	400,000	10	2	10	11
Arkansas	Jurassic	351,000	<.5	0.7	3	34

The available data indicate that oilfield brines may accumulate base metals if the total dissolved sulfur is less than 30 mg/L. Trace amounts of sphalerite and galena occur in the Arkansas reservoir rocks. The metal content of these brines is low because they contain up to 1200 mg/L H_2S. The geologic setting of metal-rich brines in the Gulf Coast area suggest that feldspathic red beds may be a major source of the lead and zinc. (Authors' abstract)

CHOU, I-Ming and WILLIAMS, R.J., 1979, Activity of H_2O in supercritical CO_2-H_2O fluids (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 401.

The activity of H_2O in CO_2-H_2O fluids has been determined at 600°C between 2 and 8 kbars and at 700°C between 2 and 6 kbars along Ni-NiO buffer. The values of a_{H_2O} were calculated from the ratio of the quenched chloride molalities in hydrogen fugacity sensors

(Chou and Eugster, 1976) from paired experiments which were equilibrated in a single run at the same temperature, pressure, and oxygen fugacity.

The a_{H_2O} data listed below extend those given by Chou and Williams (1977).

P(Kbars)	T(°)	X_{H_2O} =	0.2	0.4	0.6	0.8
2	600		0.27	0.42	0.52	0.62
2	700		0.24	0.40	0.49	0.61
4	700		0.27	0.43	0.55	0.66
6	700		0.30	0.46	0.62	0.69

The results of replicate experiments and the precision of our chloride determinations give uncertainties of ± 0.08 (in H_2O-rich mixtures) and +0.04 (in CO_2-rich mixtures).

These data indicate that significant and complex deviations from ideality exist in CO_2-H_2O fluids. Water-rich compositions have a negative deviation from ideality which increases with decreasing pressure or increasing temperature at pressures less than 6 kbars. Carbon dioxide-rich mixtures always have a positive deviation from ideality which increases with increasing pressure and decreasing temperature. The data for CO_2-rich mixture are compatible with predictions from a modified Redlich-Kwong equation, while those for H_2O-rich compositions are not. The occurrence of polyhydrated CO_2-H_2O complexes could explain our observed relations.

The negative deviations from ideality in H_2O-rich mixtures at low pressures can shift the temperatures of dehydration and melting equilibria by up to 25°C more than the shifts predicted on the basis of ideal behavior in the fluid. (Author's abstract)

FEISS, P.G., 1979, The missing sulfur I. Is syngenetic pyrrhotite likely? (abst.): Geol. Soc. Am., Abstr. Programs, v. 11, p. 178.

The massive sulfide deposits of the Blue Ridge province of the southern Appalachians are primarily pyrrhotite (po) with significantly lesser pyrite (py). The deposits are volcanogenic, though modern analogs are py-bearing. Two possible explanations: 1) this is syngenetic po, 2) metamorphic desulfidization (py → po with increasing grade).

Using estimates of boiling temperatures in submarine exhalative systems along with fluid inclusion filling temperatures and the temperatures of geothermal brines, 200°C and 300°C temperatures are assumed. Using a maximum log a_{S_2} of -11.2 (300°C) and -15.1 (200°C) for the limit of po stability, pH's of 4, 6, and 8, ionization constants for H_2S of $10^{-6.96}$ at 200°C and $10^{-8.06}$ at 300°C and for HS^- of $10^{-9.57}$ at 200°C and $10^{-7.72}$ at 300°C, and activity coefficients ($\gamma H_2S \simeq \gamma CO_2$) at solution concentrations of 1.0, 2.0, and 3.0 molar NaCl equivalent, the following maximum H_2S concentrations in a po precipitating brine are predicted:

		log (H_2S) in wt. %	
pH	m_t (NaCl)	200°C	300°C
4	1.0	- 5.14	- 2.08
6	1.0	- 9.14	- 6.08
8	1.0	-13.14	-10.08

Only at high temperatures and low pH's is the concentration of H_2S in equilibrium with po reasonable for an ore-depositional environment. Comparison with the yellow ores of the Kuroko deposits and with the geothermal brines at Wairekei and the Red Sea suggest that po is unlikely to form syngenetically in a volcanic environment that has sufficient S_2

to produce a massive sulfides. Thus, the Blue Ridge type deposits were desulfidized. (Author's abstract)

GEGUZIN, Ya,Ye. and DZYUBA, A.S., 1977, Repulsion of macroscopic particles by gas layer on the front of crystallization: Kristallografiya, v. 22, no. 2, p. 420 (in Russian). Authors at Kharkov State Univ., Kharkov, Ukranian SSR.

Conditions of G eduction on the front of crystallization of water are quite different far from the metallic sphere and close to it, when the front became adjacent to the sphere. Local supersaturation with G in the fissure between solid and sphere is higher than supersaturation close to the front but far from the sphere, since in the fissure G bubbles nucleate more frequently and grow faster.

In experiments distilled water saturated with air was used, hence G bubbles consisted of air. Forming of G bubbles in the fissure causes difficulties with trapping of metallic sphere by crystallizing ice, and often it makes the trapping impossible, since minute air bubbles from layer throwing out the sphere from ice. This is distinctly visible in the figure. (Translated and shortened by A.K.)

Figure. Repulsion of copper sphere by front of crystallization (speed of crystallization $v=1 \cdot 10^{-2} cm \cdot sec^{-1}$) of air-saturated water, mainly due to forming of G bubbles in the fissure between front and sphere, x20.

GROSHENKO, A.R., 1978, Set of microscope heating stages for mineral-thermometric studies (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 1, Thermobarogeochemistry in geology: Vladivostok, Acad. Sci. USSR, p. 210 (in Russian). Author at IGEM, Moscow, USSR.

A set of microscope heating stages with modular spares was made. The heating stages have electric heating wire in stage body, moveable connection of stage body with microscope; short-focus objectives may be used. Differences are listed below.

Variety of the stage	Symbol	Maximum T, °C	Heating wire	Thermo-couple	Preparation size, mm	Rotation in horiz. plane	XY movement of preparation	Use of neutral gas filling
Training	TU	700	Nichrome	chromel-alumel	20	+	+	-
Scientific for stationary laboratories	T-500	500	Nichrome	chromel-constantan	10	+	+	-
	T-800	800	do.	ch.-alumel	6	+	+	+
	T-1300	1300	platinum-rhodium	platinum-PtRh	2	-	-	+
For field use	TP	500	Nichrome	chromel-constantan	4	-	-	-

(From the author's abstract, transl. by A.K.)

ROYZENMAN, F.M., VALYASHKO, L.M. FORTUNATOV, S.P. and ELINSON, M.I., 1978, Regularities of alterations of temperatures and gas composition during the ore formation in rare-metal and muscovite-bearing pegmatites (Abst.): Abstracts of the Sixth All-Union Meeting, Vladivostok, Sept. 15-18, 1978, v. 2, Thermobarogeochemistry in ore genesis: Vladivostok, Acad. Sci. USSR, p. 75-76 (in Russian). First author at Moscow State Univ., USSR.

Ore mineralization formed in two stages: dispersed ores (Th 400-320°C) and concentrated ores (Th <320°C). The rare-metal pegmatites occur in the NW of the USSR as vein bodies with beryl, spodumene, tantalite and pollucite. G composition of inclusion fillings was determined for two pollucite generations and associated quartz. The first (1) generation is finely crystalline, the second one (2) coarse crystalline. Muscovite pegmatites of interest occur in the Kola Peninsula and in Karelia. Gases were determined in quartz from the (3) quartz-muscovite replacement complex and from the (4) coarse-crystalline muscovite-quartz association. In the all studied bodies the later (main ore) stage minerals bear more CO_2 in inclusions than minerals of the earlier stages (see table). Also H_2 and CH_4 were found in inclusions. In the pollucite and muscovite pegmatites the richest commercial parts formed at T <320°C. In this stage the coarse-crystalline raw material was formed. Rare-metal pegmatites bear more CO_2 than muscovite ones.

Type of pegmatite	Stage as in the text	Mineral	Heating T, °C	Average Content CO_2, cm^3/kg	Average Content H_2O, mg/kg	CO_2/H_2O ratio
Rare-metal	1	pollucite	100-340	7.9	1688.5	0.002
			340-530	13.3	866.5	0.015
		quartz	100-340	4.0	33.7	0.120
			340-500	4.6	28.5	0.160
	2	pollucite	100-340	33.9	821.0	0.041
			340-500	19.6	2460.0	0.008
		quartz	100-300	58.9	38.1	1.540
			300-500	47.3	40.1	1.150
Muscovite	3	quartz	100-330	4.5	165.5	0.027
			330-510	20.0	221.0	0.090
	4	quartz	100-320	32.0	76.2	0.420
			320-500	18.5	95.0	0.190

(From the authors' abstract, transl. by A.K.)

THOMAS, Rainer, 1979
(Table omitted from p. 189)

Table 1. Summary of results on cassiterite, quartz, topaz and zinnwaldite of the Sn-W mineralization of the Erzgebirge

Formation stage	Types of Inclusions	Th	Pressure ($x10^5$ Pa)	Salinity (wt.% NaCl)
I. Magmatic stage	Primary incl.: III/IVb/VI/VII	⩾730 - 850°C	⩾2500	70 to 90[1]
	Pseudo secondary inclusions: I/II/III/IVa/Va	⩽ 550°C	1700 ± 400 to 230	about 41
II. Pegmatitic stage	VII/VI/IVa/Va	790 - 550°C	⩾2000 to 600	⩾45 to 40
III. High-hydrothermal stage	IVa/(IVb)	450 ± 20°C	1300 - 800	34.0 ± 4.0
	I/II/III	430 ± 20°C		6.7 ± 2.3
	II	448 ± 13°C	420 ± 60	6.9 ± 1.2
IV. Pneumatolytic stage	I/II/III (Va/Vb)	390 ± 15°C	1000 - 600	3.5 ± 1.7
	II	397 ± 10°C	280 ± 30	2.2 ± 0.9
V. Hydrothermal stage	I	350 to 270°C	600 to 100	0.0 to 20

[1] Simultaneous occurrence of silicate-melt inclusions with high-salinity inclusions containing dms: NaCl, KCl + H_2O ± specularite.

Translation

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.

PETRICHENKO, O.I., 1973, Methods of study of inclusions in minerals of saline deposits: Kiev, "Naukova Dumka" Pub. House. 92pp., (in Ukrainian). (Editor's note - This rather rare* book summarizes the extensive studies of fluid inclusions in saline deposits in the USSR, and in particular, the research of the leading worker, O.I. Petrichenko. A translation has become available, and hence is reproduced here even though the book is some years old. Numerous citations in the text are not to be found in the Bibliography, and some Western names had been transliterated into Cyrillic and back again in this translation; hence, in order to avoid introducing new errors through misunderstanding, I have reproduced the bibliography exactly as provided, and corrected only a few obvious misspellings of Western names. The photographs could not be reproduced here, but to help the reader, translations of the original Ukrainian captions are given here. Where an error seems to exist, I have added "sic.". I cannot distinguish between errors in the original and in the translation.) *Only 350 copies printed.

TABLE OF CONTENTS

Abstract (p.2)

This book presents methods for studying inclusions in the minerals found in saline rock. The properties of specific fluid, gaseous and solid inclusions are described, and an attempt is made to classify inclusions with respect to their state of aggregation, composition, and origin.

Methods are given for ultramicrochemical analysis of small quantities of a solution (less than 0.00X mm^3); determination of the Eh and pH of solutions of specific inclusions; and specifications for the study of temperature and pressure are provided.

This book is intended for geologists and geochemists studying saline formations.

INTRODUCTION

Inclusions in saline rocks have been known for a long time, but the first specific data on their chemical analysis only dates back to the early 19th century (Brewster, 1823, Nicol, 1828). Scientists logically first turned to the study of inclusions in halite, the most prevalent saline mineral, which is the basic raw material for the production of common salt. As gas explosions had often been observed in those mines where rock salt was being extracted, researchers became interested in the composition and natural form of this gas. It was found (Dumas, 1830; Rose, 1839) that gas occurs in salts under great pressure, and is only liberated when specimens are dissolved or heated. Analysis of these gases has revealed a high content of methane and nitrogen (Bunsen, 1851).

In the late 19th century, reports were first published on liquid-gas inclusions in anhydrite and gypsum (Hammerschmidt, 1883); solutions and gas from inclusions in gypsum were chemically analyzed (Sjögren, 1893); liquid, gas-liquid, and solid inclusions of organic matter (ozocerite, petroleum) were morphologically described in halite (Foullon, 1888; Pelikan, 1891). Solid inclusions such as douglasite, chlorcalcite and tachyhydrite were already known to occur in halite at the time ("Mineraly", 1963).

In the early 20th century, as the chemical industry developed, interest intensified in the minerals of potassium-magnesium deposits. Because of the specific properties of these minerals, some attention was given to inclusions in sylvite, carnallite and halite. It was found that their coloration depends to a considerable extent on the kind and quantity of inclusions, e.g. the presence of solid inclusions of hematite, goethite and other forms of iron oxide in sylvite and carnallite gives them a typical red coloration (Razumovskaya, 1927; Burkser, 1935; Morachevsky, 1939); and the eight hues of sylvite result from regularly occurring solid inclusions of halite (Rozen, 1927; D'Ans, Kühn, 1938). In studying inclusions in chlorides, some authors distinguished between primary and secondary inclusions, and solid, liquid and gas inclusions. Gas inclusions were studied very thoroughly at that time: pressure, bulk composition, origin, and other features (Poire, 1930, Temman, Seidel, 1932; Fells, Firth, 1926).

The 1920-1930's were marked by widespread research in the USSR not only of salt-bearing deposits, but salt lakes as well. M.S. Kurnakov and his students described and experimentally demonstrated the natural course of crystallization of salts in a salt basin. Large mineral reserves were found in the salt lakes of Kazakhstan, Siberia and the Crimea. Based on a thorough study of the distributive patterns of primary inclusions in halite from the lakes, M.G. Valyashko (1941, 1951, 1952) discovered typical sedimentary properties. In contrast to his predecessors, who indeed were limited to only a general description of mineral inclusions from salt-bearing deposits, M.G. Valyashko employed inclusions in halite as an indicator of the formative and morphological conditions of the salt deposits; this has made it possible for some authors to develop specific conclusions on the genesis of salt deposits (Chirvinsky, 1948; Fiveg, 1948; Lobanova, 1949, Dubinina, 1951, 1954; Korenevsky, 1954).

Lately the published literature from mineralogic and petrographic research almost continually mentions the presence of a gas or liquid inclusion in carnallite, sylvite, and halite, but the inclusions themselves are generally not investigated (Vakhromeyeva, Chirvinsky, 1943; Cherepannikova, 1949; Vakhromeyeva, 1954). An exception is the inclusion of gas in the minerals of potassium deposits: methods have been developed for extracting gas from minerals and methods have been proposed for studying certain gaseous components in inclusions (Nesmelova, 1959, 1961; Cherepannikova, Rogozina, 1961; Aleksandrovich, 1963; Vakhromeyeva, 1964). Liquid inclusions were first studied in connection with research on the patterns of distribution and forms of occurrence of trace elements in saline deposits; it was found that some liquid and trace elements are found only in solutions of liquid inclusions (Petrichenko, 1962; Bilonizhka, 1965; Slivko, Petrichenko, 1967). Liquid inclusions in minerals of salt-bearing deposits have been drawing more attention from researchers as possible sources of information on the composition of the salt solution of ancient saliferous basins and on the crystallization conditions of a particular mineral. The chemical composition of solutions of individual inclusions in gypsum, halite, and sylvite has been analyzed (Briggs, 1958; Kramer, 1963; Holser, 1963; Petrichenko, Shaydetskaya, 1965; Rosset, 1965; Petrichenko, 1968; Dellwig, Evans, 1969; Montoriol-Pous Soaquin, 1969; Shaydetskaya, 1971, Petrichenko, 1971). Reports appear in the literature from time to time on unusual inclusions in halite, whose formation is associated with crystallization from melts and the gaseous phase (Piyp, 1956; Naboko, 1959; Pavlov, Ryabchikov, 1968; Pavlov, 1971).

Considerable attention has been given to experimental studies which, to a great extent, explain the causes of formation and their mechanics for inclusions in halide minerals. On the basis of experiments, thus, authors concluded that the zonal distribution of inclusions in halite is not a reliable sign of crystallization conditions of minerals (Hiller and Keller, 1965); and some inclusions in artificial halite can not be used to study the temperatures of mineral formation (Gerbach and Heller, 1966).

Thermometric tests are important in studying inclusions. The first attempts to use these tests on gas-liquid inclusions in halite were made in the late 1940's (Dreyer, Garrels, Howland, 1949). The tentative data obtained, however, were incomplete owing to an insufficient number of observations. Critical comments made on this point were logical (Peach, 1949; Yermakov, 1949, 1950); many researchers gathered the impression that inclusions in halite were not hermetic and would explode upon ordinary heating of a specimen. Attempts were later made to thermometrically study inclusions in halite, but their number was so insignificant that the results did not clarify these issues (Dellwig, 1955; Malashevsky, Bilonizhka, 1964; Touray, 1970). Some studies have been devoted to gas-liquid inclusions in artificial halite; these authors concluded that thermometry was not suited for studying two-phase inclusions in halite (McCulloch, 1959; Gerlach, Heller, 1966; Wilcox, 1968; Butuzov, Khatchikov, Shaposhnikov, 1968). The results of decrepitation analysis of liquid inclusions in minerals with perfect cleavage were obtained, but the data are inadequate for any conclusions to be reached (Montoriol-Pous, Font-Altaba, 1969, Sokolov, 1970). There are some data on thermometric study of inclusions found in halite only, but there are no data on the homogenization of inclusions in other halide minerals.

Thus the study of inclusions in halide minerals encompasses a considerable period, but the material obtained from this research is not highly informative and is random. Consequently, the view exists that inclusions in the minerals of salt-bearing deposits can not be utilized to decode the conditions of the salt-forming medium. But our many years of research certainly demonstrate that we can establish the chemical type and composition of the natural brine of ancient evaporite deposits, the physical and chemical conditions of formation of salt deposits in salt basins, and the thermodynamic parameters of the sediment conversion medium as they all apply to inclusions. In studying primary and secondary multiple-phase inclusions we may obtain concrete data on the role and site of diagenetic processes in salt deposits, the recrystallization medium of sedimentary minerals and the formation of epigenetic minerals. Data obtained in studying inclusions in halite and other minerals can be used to prospect for potassium salts, to analyze and compare barren halide series, and to resolve many genetic questions. Results of analysis of inclusions provide us with an idea of the form of occurrence of certain trace elements in minerals, and these aid in decoding the composition of mineral salts. Data on gaseous inclusions provide evidence of saturation, composition and forms of occurrence of gas in salt deposits.

Our work primarily sums up the author's experience in studying inclusions in halide minerals. It does not deal with the general topics of theory and methodology, which have been elaborated in specialized guidebooks (Yermakov, 1950; Kalyuzhny, 1960; Lesnyak, 1964; Roedder, 1962, 1963, 1970).

CAUSES FOR THE FORMATION OF INCLUSIONS IN HALIDE MINERALS

The formation and growth of halides in nature occurs, as a rule, from low-temperature salt solutions which evaporate on the earth's surface. Only in special cases are they formed at somewhat elevated temperatures and pressures from hydrothermal waters or by condensation of the gaseous phase of magmatic fumaroles. In addition, some observations show that the crystallization of halite and sylvite from the corresponding melts occur in halides under the influence of magmatic cores**(sic.)** Finally, the crystallization of salts without a liquid or gaseous phase rather often occurs as a result of plastic deformation of the initial primary crystals: similar transformations are very characteristic of salt blocks (domes? ER).

The occurrence of various defects in natural minerals during growth and recrystallization, leading to the formation of inclusions, is almost inevitable, owing to many factors. The major factors are those which govern the mechanics of formation of inclusions in minerals: degree of mobility of mineral-forming substances, concentration of solutions, energy of adsorption of secondary components on crystal surfaces, properties of crystal growth, etc. Each factor has some significance in the crystallization of minerals in aqueous solutions, melts, and gaseous fluids, but the formation of inclusions during plastic deformation has only a very slight effect on them.

The mechanics of trapping components of the medium during halide growth has not been thoroughly examined and there are relatively few reports on this subject. More complete data have been gathered on halite, so this mineral has most often been selected as an object for decoding the patterns of crystal growth from aqueous solutions. Some data deal with sylvite, gypsum, astrakhanite, and epsomite; others deal with langbeinite, kainite, carnallite, bischofite, etc. and are very sparse and sketchy.

FORMATION OF INCLUSIONS DURING GROWTH FROM SOLUTIONS

Research has shown that in the enumerated salt solutions, the growth of minerals occurs via diffusional translation of matter to the crystal as a result of convective flows and the motion of fluids under the influence of external force (Bakli, 1954; Kuznetsov, 1954). In steady-state solutions, the rate of translation of matter is governed only by the rate of diffusion and natural convection; therefore, it is considerably lower than the interphase growth rate of crystal faces. Consequently, some portions of a mineral grow irregularly, leading to the formation of liquid inclusions in the central portion of the face. Thus, where the mineral crystallizes in solutions which freely intermix, inclusions are generally not formed (Treyvus, 1963).

According to the degree of supersaturation of a solution, different forms of crystal growth occur, affecting the pattern of distribution of inclusions in minerals. In highly-mineralized brine, the vertices and faces (edges? ER) of crystals grow intensively; consequently, sectorial and skeletal dendrites are formed: liquid inclusions in such minerals intermix between the growth sectors (Smitt, 1968). A clear example of such crystallization is halite, which crystallizes out on the surface brine of salt lakes (Valyashko, 1962). The growth of epsomite from supersaturated brines occurs as a result of the more rapid growth of the faces: large tubular inclusions occur as a result (Vadilo, 1950). In addition, in many supersaturated salt solutions, the crystallization of many minerals (sylvite, halite) occurs as a result of the formation and addition to the crystal of submicronic associated minerals (Bakli, 1954; Peibst, Noack, 1962). Their random orientation with respect to the faces generates additional conditions for entrapment of fluids by the mineral (Kuznetsov, 1954). At a lower level of supersaturation of solutions, the rate of face, vertex and edge accretion gradually equalizes: there is progressive growth of the faces by means of screw dislocations. In some screw dislocations, numerous elongated microscopic inclusions are formed on one face, situated between unit cells. In solutions whose degree of supersaturation is less than 1%, the increase of the entire solid phase is virtually interrupted, and the minerals recrystallize. Inclusions in them are of irregular form and are quite rare; typical representatives are halite (salt spar), gypsum, sylvite, and langbeinite.

The entrapment of allogenic substances by crystals can also occur under the influence of adsorption on the mineral surface (Bakli, 1954; Petrov, Treyvus, Kasatkin, 1967). The energy of adsorption and adsorbed components regularly affect the rate of growth, appearance, and purity of the mineral. Impurities which are highly adsorbed govern the formation of a large number of microscopic inclusions in the crystal; these color it. It is not unusual that adsorption of NaCl-associated minerals on the surface of sylvite would form milky varieties of this mineral in the potassium deposits of the Ciscarpathians and other salt deposits. The bonding force, which is determined by the nature of the reacting substances, is different for different portions of the mineral surface. As a rule, the energy of adsorption is less on the faces and greater on the edges and vertices of the crystal; it increases near double dislocation boundaries, fractures, etc. (Lemmlein, 1948). For example, the energy of adsorption may be demonstrated by the bonding force between molecules of water and the halite surface; it has been found that adsorbed water is completely removed only at a temperature of 500°C (DeBur, 1959). The presence of certain components in solution reduces the bonding force between the crystal surface and the secondary components; consequently, the crystals that form are relatively pure, without inclusions. Thus, from Na and K chloride brines, which contain $CaCl_2$, NaOH, $FeCl_2$, crystals of sylivte and halite are formed that are transparent, without visible defects.

Under certain conditions, impurities found in solution can form so-called epitaxial inclusions in the host mineral. Experimental research has shown that these inclusions are formed as a result of the similar structural properties of the crystal and solid inclusion (Frank-Kamenetsky, 1964). In the early studies of L. Rouaille (Bakli, 1954), data are cited on the growth of halides of alkali metals whose structure is similar to that of halite. The author concludes, on the basis of comparison of the dimensions of the basic cells, that epitaxial growth of sodium and potassium chlorides is possible. Perhaps it is by epitaxial growth in natural salts that we observe the peculiar regularly-oriented inclusions of halite in sylvite and sylvite in halite (Slivko, Petrichenko, 1963).

Entrapment of the mother liquor by the mineral can also occur in the formation of eutectic mineral growths. This phenomenon is observed in the crystals of natural gypsum, syngenite, langbeinite and also in artificially-grown kainite, bischofite and carnallite. In addition, the formation of inclusions in minerals is affected by the rate and stage of evaporation of brines, temperature conditions of evaporation, and so forth. It has been found that at elevated temperatures with intensive evaportation of natural brines, the number of inclusions in halite and other minerals increases, but their dimensions on the average decrease compared to minerals formed at low temperatures with free evaporation. The opposite association has been studied experimentally: as the number of inclusions in a crystal increases, their rate of growth rises proportionately (Sheftal', 1957).

Under natural conditions, the formation of inclusions in minerals is also linked with the effect of secondary substances on the crystal surface. It has been found that their interrelationships are governed by the crystalline strength of the mineral (crystallization force? ER), the properties of the solid, and the nature of the ambient medium (Shubnikov, 1935, Bakli, 1954; Grigoryev, 1961). In some cases the crystal surface repels impurities without any traces; in other cases, (its) mechanical action on the surface causes the formation of many liquid inclusions; in yet other cases, solids are entrapped (Sheftal', 1957; Kliya, Sokolova, 1958; Khaimov-Mal'kov, 1959, Shubnikov, Parvov, 1969). The distribution of entrapped material in the crystal itself depends on the properties of the host mineral. The uniform distribution of impurities is typical of astrakhanite, glauberite and syngenite. Halite absorbs secondary substances during growth only on its faces. Gypsum absorbs mechanical impurities over its entire surface in some* cases; in other cases, only on one or more areas. Carnallite absorbs solid inclusions in areas of (001) and (110).

In contrast to other minerals, epsomite and mirabilite sometimes crystallize completely transparent under similar conditions; solid inclusions with a pattern may from time to time be observed in them. According to the nature of the impurities and their quantity, minerals acquire certain coloration: familiar black halite (Dzens-Litovsky, 1957), red sylvite (Razumovskaya, 1927), brown gypsum, etc. The entrapment of mechanical impurities is generally accompanied by the entrapment of liquids and gaseous-liquids; their proportion in inclusions varies considerably. Large liquid inclusions are encountered where small secondary bodies have served only as an external cause of their formation. More often we observe crystal inclusions with a relatively insignificant amount of entrapped solutions or gases.

The regular distribution of inclusions in a mineral in the form of strata which alternate periodically creates a zonal growth structure. According to modern theories (Lemmlein, 1948, Grigoryev, 1961; Shubnikov, Parvov, 1969), the zonality of minerals is evidence of their irregular growth resulting from unstable physical and chemical conditions of the mineral-forming medium, and as a result of spontaneous rhythmic crystallization. The zonality of minerals which formed in evaporite deposits is primarily associated with seasonal and daily changes in salt-formation conditions. As we know, this summer-fall period for salt-forming basins is characterized by the more intensive precipitation of sediments as compared to the winter-spring season. Similar changes are set by the inclusions, whose quantity differs in different stages of crystal growth. In modern evaporite deposits, zonal crystals have been found for gypsum, halite, astrakhanite, thenardite, and epsomite (Dzens-Litovsky, 1957). In some such zones the duration and rate of crystallization of a particular mineral has been established. According to gypsum, for instance, one may judge past climatic conditions which existed in the region of a salt-forming basin (Fersman, 1952).

According to the research of M. G. Valyashko (1952, 1962), the zonality of halite in modern evaporite deposits is associated with daily and yearly changes in the conditions of crystallization. Owing to the zonality and specific properties of growth of this mineral at the bottom of the basin, salt deposits have a feather-like structure in cross section, which may serve as a genetic marker for rock salt. Unfortunately, some authors of mineral and petrographic research on halides arrive at their genetic conclusions only on the basis of zonality present in a particular mineral, ignoring the structural peculiarities of the entire section. Since zonality is also characteristic of crystals formed in closed systems with uniform temperature frops, these conclusions may be erroneous. For example, zonal halite is sometimes found even in

*Repetek gypsum

inclusions in quartz formed from such original liquids (Kureyev, Trufanov, 1965).

We have also investigated halite from the flooded mines of the Ciscarpathians (depth 250 meters), whose crystallization occurred over a period of several years with substantial temperature variations. Despite uniform evaporation of solutions, zoning was noted in this halite rather clearly. Another example is our study of inclusions in Devonian halite from the Dnepr-Donets depression: some grains of this mineral are typified by amazingly clear zoning due to certain juxtapositions of gas-liquid inclusions, in which the internal pressure reaches tens of atmospheres. Of course the formation of such inclusions is improbable under the conditions of a salt-forming basin. For that reason, to arrive at a conclusion on the halite formation conditions merely in terms of the presence of growth zones (which some authors feel is a typical sign of minerals formed in a salt basin) is impossible; one must consider the study of individual primary inclusions and the structure of the rocks themselves.

Studies have shown that, in addition to halite, a zonal structure is sometimes presented by sylvite (Dubnina, 1951; Korenevsky, 1954); kainite (Lobanova, 1949, carnallite and langbeinite. The zoning of these minerals results from the juxtaposition of liquid and solid inclusions on certain crystal faces. According to which faces developed the inclusions during crystal growth we can now observe their arrangement in the form of a triangle, square, or rectangle (for halite; hexagon, rectangle (carnallite), and so forth. A regular geometric shape is usually noted in cross sections perpendicular to the crystal axis.

On the whole, for minerals whose crystallization occurred from solution in free space, inclusions are divided into two classes (Smitt, 1968): inclusions in growth areas and inclusions confined to boundaries between growth sectors and unit cells. This division of inclusions is very systematic; often in a specimen being studied we can not establish the class to which the inclusions belong. In the event that inclusions in a crystal are divided into classes rather clearly, it is possible to establish the stage of the mineral crystals and the nature of its changing conditions of growth. Inclusions in halite, sylvite, and gypsum are quite easily classified.

FORMATION OF INCLUSIONS IN MINERALS DURING GROWTH FROM MELTS AND GASEOUS PHASE

In crystallization of a melt with totally homogeneous chemical composition, for example as we find in pure rock salt, there is only liberation of heat and we do not observe transportation of matter to the crystallization site: to a considerable degree, this distinguishes the mechanics of molten crystallization from processes taking place in solutions. Crystallization in a homogeneous medium in theory precludes the formation of liquid inclusions in the crystal. The crystal faces of halite and sylvite which crystallized from a melt have block structures; in ultramicroscopic study of halite we find very fine inclusions of presumably free sodium (Dir, Khaui, Zusman, 1966).

The formation of crystals from complex melts, as from aqueous solutions, occurs as a result of translation of matter to the crystallization site and the liberation of secondary components with heat. The rate of translation of melts, rate of crystallization, composition of the melt, and so forth, play a major role. The pattern of inclusion formation is subordinate to these factors. In contrast to minerals which crystallize in an aqueous medium, crystals formed from a melt are marked by the presence of substantially gaseous inclusions or two-phase inclusions with a predominance of the gaseous phase.

One cause leading to the formation of gaseous and gas-liquid inclusions in salts is undoubtedly the heterogeneous composition of the halides. At high temperatures, many complex components of rock undergo the most diverse metamorphosis with the liberation of gas. The formation of such gas inclusions was noted by Ye. Mollva (Rodder, 1970) [presumably E. Mollwo, 1941, referred to in Roedder, 1972] in experimental research on crystallization from contaminated melts of potassium bromide. According to the data of D. I. Pavlov and I. D. Ryabchikov (1968), the mechanics of inclusion formation in halite due to crystallization from melts is also associated with impurities. Tests run at 720-790°C give evidence that gas-liquid inclusions which have the form of negative crystals are formed from the intergranular vapor phase. At 790-800°C, there are no gas-liquid inclusions in the form of negative crystals; there are only gas bubbles and amygdules of irregular shape which formed either as a result of liberation of the gas phase in rapid crystallization of the melt during hardening, or "shrinkage vacancies" (Pavlov, Ryabchikov, 1968). We are concerned here, of course, only with anhydrous salts; hydrated sulfates and chlorides undergo many irreversible changes in many cases with a negligible elevation of temperature.

The formation of some minerals in the gaseous phase is known in regions of volcanic activity: halite, sylvite, and anhydrite usually settle there as crystals on the walls of active fumaroles (Piyp, 1956; Naboko, 1959; White, Woring, [Waring?] 1965; White, 1965). Inclusions of sylvite in halite and halite in sylvite are encountered, but on the whole crystals grown from the gaseous phase have perfect structure (Lawson, Nielsen, 1963). The crystallization of halite and sylvite from the gaseous phase at high temperatures (t = 760°C) has been experimentally demonstrated by many researchers (Lukorsky, 1945; Geguzin, Shpunt, 1959, Geguzin, 1970).

Under great external loads the minerals of salts can be plastically deformed, and this process is irreversible. Thus in some cases, plastically-deformed crystals should be viewed as newly-formed minerals with their own specific properties. Based on a great deal of data, it has been found that plastically-deformed crystals of halite, sylvite and carnallite contain both liquid and solid inclusions which are located in the mineral grains in the form of elongated bands in the direction of salt efflux.

The mechanics of inclusion formation in minerals during their plastic deformation has been poorly studied under experimental conditions. It may be assumed that some inclusions in a deformed mineral precipitated from the initial mineral; in the case of explosive disturbances in the crystal, fluids are naturally lost by it irreversibly. During plastic deformation the configuration of inclusions is changed according to the force of external pressure, direction of salt efflux, and so forth. Without a doubt when salts migrate, secondary solids are entrapped in either the gaseous or liquid phases; this genetic type of inclusion is natural for the halite of salt domes. Interesting experimental data were obtained by Ya. E. Geguzin (Geguzin, Dzyuba, Kosevich, 1963) while studying the mechanism of healing of defects in crystals at continuously high temperatures. Observations were also made on gaseous inclusions in halite under manifold pressure (P = 20 atm) and elevated temperature (t = 675-750°C). It was found that due to plastic deformation of the crystal, external pressure is rather easily transmitted to the inclusions: the degree of compression of a gaseous inclusion depends on the external force. Therefore, the impact loads on a crystal of halite, and evidently other minerals, may be ascertained by the internal pressure of gaseous inclusions. Inclusions of compressed gas in carnallite, sylvite and other minerals are also common knowledge.

In analyzing these data one might conclude that dynamic pressure on halite at ordinary temperatures leads to plastic deformation of this mineral only along the periphery of the crystal grain, while its internal part remains without visible changes (e.g., the presence of relics of sedimentary zonal halite in plastically deformed grains from the domes of the Ciscarpathians and Dnepr - Donets depression). The effect of pressure only on the peripheral portion of halite is also demonstrated by measurements of pressure in inclusions of the central portion of halite grains and peripheral zones. These phenomena can easily be explained by solid body deformation theory (McClintock, Argon, 1970; Fridel', 1967).

Under the effect of external forces, during formation minerals undergo precipitation, diagenesis and epigenesis in addition to plastic deformation and brittle fracture (under short-term forces); these effects usually appear in minerals in the form of fractures, often serving as the cause for the appearance of secondary inclusions in minerals (Lemmlein, 1948, 1955; Ermakov, 1950; Kalyuzhnyy, 1960; Lesnyak, 1964; Smit, 1956, 1968; Redder, 1970 [Roedder, 1972?]). These inclusions occur as a result of entrapment of fluid by the fracture and its healing. The rate of these processes in halide minerals is incomparably more rapid than in magmatic minerals. For example, under laboratory conditions complete healing of fractures in halite can be observed within a few months; the disturbances themselves can only be detected by the series of inclusions which mainly retain the configuration of deformation by slip. Diffusion effects (Fayf, 1967) are important in fracture healing; entrapment of matter here involves a gas which forms intrinsically gaseous inclusions.

The causes of formation of inclusions in minerals of salt deposits are not completely covered by the above factors. There are many unresolved questions on the mechanism of formation of many unique inclusions. For example, the causes of formation of intrinsically gaseous inclusions with great internal pressure in milk-white sylvite are unexplained; formative conditions must be deciphered for the occurrence of oriented solid inclusions of sylvite in halite, halite in langbeinite, and so forth.

INCLUSIONS IN HALIDE MINERALS

The Hermeticity of Inclusions

The nature of matter trapped by a crystal during growth is similar to mineralogenic fluids in terms of many physical-chemical parameters (Ermakov, 1960; Kalyuzhny, 1960; Redder, 1970 [Roedder, 1972?]); this provides a certain amount of information about the chemical composition of solutions and the thermodynamic conditions of mineral formation at a certain time in the existence of the system. Of course, these assertions are valid only if there has been total conservation of the fluids in inclusions during the entire period of their existence. Inclusions with disturbed hermeticity offer little information and are only of relative importance.

The question of the degree of hermeticity of inclusions in salt minerals has been debated more than once in previous publications. The study target was the most common mineral in the group, halite. On the basis of visual comparison and specially conducted experiments, some researchers arrived at totally opposite conclusions. Some investigators felt that inclusions in halite could not be utilized as study objects due to their lack of natural hermeticity (Peach, 1949; Ermakov, 1949, 1950; Dreyer, Garrels, Howland, 1949). Further comparisons, however, altered this point of view (Dellwig, 1955, McCullouch, 1959). In the late 1950's, V. A. Kalyuzhnyy set up a special experiment which convincingly demonstrated that the walls in halite inclusions are virtually impermeable to solutions. Evidence in this direction was also provided by other authors (Hoster, 1963; Kramer, 1963; Roedder, 1963; Petrichenko, Shaydetskaya, 1965; Slivko, Petrichenko, 1967; Petrichenko, 1968, 1971).

Because the degree of hermeticity of inclusions in minerals is a very important condition for all impending conclusions and constructs, we conducted research to discover the exchange of solutions and gases between inclusions in halite, sylvite, langbeinite and anhydrite. Unfortunately there are no concrete data on other minerals of salt deposits. There are indirect indicators of hermeticity of inclusions in gypsum, carnallite, picromerite and epsomite.

The hermeticity of inclusions in minerals was investigated in halite and sylvite from non-contemporary salt deposits. Thus, in sedimentary halite from Lower Permian deposits the content of potassium and magnesium in solutions of certain inclusions was studied; they were found in different growth zones of the mineral from the center to its periphery. It was found that the content of these elements in solutions of individual inclusions gradually increases towards the outer parts of the mineral. This pattern is completely logical, since as the halite crystallizes from the brine of a salt basin, the relative content of all other (except sodium) primary components (potassium, magnesium, and sulfate ions) increases (cf. Table 1, Figure 1). The inclusions are mainly liquid; each of them is confined to some mineral growth zone, and their size is 10-60 micrometers in cross section. Table 1 provides the average values of potassium and magnesium content for a group of inclusions. The distance was calculated from the conventional "center,", which symbolized the onset of halite crystallization from solution with a content of potassium and magnesium 2-2.5 times less than in brine from the terminal stage of mineral crystallization. In another specimen it was found that the composition of solutions in the early halite was as follows (in g/l): K' 13, Mg" 35, SO_4'' 20; but final crystallization of the mineral occurred with a greater concentration of elements: K" 28, Mg" 53, SO_4'' 32 g/l. All of these data show evidence about the remarkable hermeticity of original inclusions in halite, and there are no grounds to suggest the circulation of liquid between individual inclusions; if that were so, the chemical composition of solutions of all inclusions in a single mineral would approach some average value.

TABLE 1. CHANGE IN CONTENT (g/l) OF POTASSIUM AND MAGNESIUM IN SOLUTIONS OF ORIGINAL INCLUSIONS IN ZONAL HALITE (ARTEM DEPOSIT, PERMIAN AGE)

Inclusion number	K'	Mg"	Distance from crystal "center", mm
1	14	--	0,1-0.5
2	18	--	0,5-1,5
3	26	30	1.5-2,5
4	—	40	2.5-3,5
5	37	60	3.5-4,5

The role of diffusion in the migration of the inclusion per se in the crystal and in the penetration of secondary ions through the crystal lattice of the mineral is important for the study of inclusions. The published findings of experimental studies and calculations from this issue have usually pertained to high temperatures near the melting point of one mineral or another. It was found that even for such temperatures the rate of movement of an exogenous body 1 micrometer in size through the crystal lattice equals 0.5 micrometers in 300 years; at low temperatures inclusions remain almost motionless. The diffusion penetration of exogenous ions through the crystal lattice is a direct function of temperature and the number of lattice defects. Since natural minerals are far from being ideal formations, it would appear that diffusion processes are important in the process of ion exchange between inclusions. Especially as it happens that in an inclusion zone, the number of defects increase. Experimental research on diffusion in crystals shows that at low temperatures, ion exchange between the fluids of two isolated inclusions occurs very freely and has almost no effect on their chemical composition [sic.] (Shemla, 1959; Geguzin, 1970; Redder, 1970 [Roedder, 1972?])

We carried out special studies to verify the role of diffusion in the mixing of two contiguous single-phase liquid inclusions in a single crystal of halite which was formed in two stages. The distance between pairs of inclusions studied came to 0.1 or 0.2 mm up to 1.0 mm, their size not exceeding 0.15 mm. The chemical composition of the inclusion solutions of two generations was studied: a solution of inclusions formed in a salt basin, and those which occurred during partial recrystallization of initial halite. Characteristically, the solution of inclusions of sedimentary halite belongs to the sulfate type with a relatively high content of sulfate ion (from 14 to 25 g/1), while the solution of inclusions of the recrystallized portion of mineral has a chlorine-calcium composition with the calcium content up to 60 g/1. Consequently, we can assert that the role of diffusion in the penetration of matter from one inclusion into another is negligible, even with a wall thickness of the tenth part of a millimeter. If diffusion penetration were observed, gypsum would be formed on the walls of two contiguous inclusions and the chemical composition of their solutions would equalize.

Potassium in inclusion solutions was also studied: the difference in its content was also substantial (1-2 and 12-16 g/1). Similar findings have been obtained for inclusions in sylvite. The pressure of gas in two-phase inclusions formed in two stages was also investigated. It was found that inclusions which are situated next to each other (distance between them fractions of a millimeter) differ by a value of internal pressure in the tens [of atm?]. Diffusion, therefore, is not particularly important in altering the physical chemical properties of preserved fluid in halite and sylvite at low temperatures.

During their existence salt deposits certainly undergo the most varied of thermodynamic effects, often leading to deformation of minerals. It is natural that the hermeticity of inclusions at a given time may be easily disturbed. We established that up to a temperature of 120-130°C inclusions in halite and sylvite do not explode under normal external pressure. Under conditions of hydrostatic compression of halite, inclusions withstand higher temperatures of heating (Geguzin, Dzyuba, Kosevich, 1963). Based on data of initial liquid inclusions in sedimentary halite from salt domes, we can claim that hydrostatic loads (with negligible temperature rise) on initial inclusions do not disturb them. For example, in a specimen of halite taken from rock salt of a Devonian salt structure, two-phase inclusions were detected where the gas was found to be water vapor; the existence of this low pressure within these inclusions in a salt dome gives evidence of the high hermeticity of the inclusions and their resistance to hydrostatic dynamic effects.

The excellent hermeticity of gaseous and liquid inclusions is proven by comparisons made on inclusions in sylvite, langbeinite and halite which were taken from salt deposits over 10 years ago. Even those which were found near the surface (less than 1 mm) had not undergone any changes. Gaseous inclusions retained their initial internal pressure and liquid ones had not changes substantially. Experience gained in working with inclusions in salt deposit minerals permits us to claim that the hermeticity of inclusions is disturbed chiefly through the fault of the researcher himself. It is true that in some cases under high internal pressures (over 80-100 atm) large (over 0.2-0.3 mm) inclusions near the mineral grain surface can explode spontaneously; this effect was observed for carnallite, sylvite and halite. Gas inclusions 0.0n to 0.00n mm and smaller can not lose their hermeticity even under internal pressure of several hundred atmospheres.

SOME MORPHOLOGIC PROPERTIES OF INCLUSIONS

Inclusions in salt minerals are unusually diverse in their configuration. In each specific instance for a certain mineral, one external appearance of inclusions or another is characteristic. Negative crystal, round, and rectangular forms predominate. Tubular, crab-like, and completely amorphous inclusions are encountered in the form of bent channels, etc. The variety of forms of inclusions is associated with the conditions of their formation, properties of the host mineral, and changes which occurred after their formation (Fig. 2). It is characteristic that the smaller an inclusion is, the more its shape approaches that of a negative crystal or some other specific geometric shape. An irregular shape is more typical of large inclusions.

The size of an inclusion also varies greatly: many defects have minimal dimensions (fractions of micrometer). Inclusions of unique size are encountered, whose magnitude is on the order of tenths of a cubic centimeter. Inclusions ranging from 2 or 3 micrometers to 250 micrometers in cross section can be found. Inclusions can be divided according to size. Microinclusions are inclusions whose size does not exceed 100 microns, while large inclusions belong to the group of macroinclusions. Like any systematization, this division is arbitrary. For example, the use of this terminology for tubular, crab-like and other inclusions is rather relative.

The distribution of inclusions in a mineral is usually very irregular and to a large extent depends on its crystallization conditions. We calculated an overall balance of inclusions in some segments of sylvite and halite. The volume of solid inclusions was measured in sylvite, and the liquid inclusions were measured in halite. In sylvite we found segments where solid inclusions (halite) ranged from 3 or 7 up to 15%; in the zonal portion of halite, the volume of liquid inclusions sometimes reaches 10-28% of the overall volume of the plate. On the whole, disregarding minor inclusions (microinclusions), their balance in the overall volume of all inclusions totals 3-6%; the bulk of matter entrapped by the mineral and preserved in inclusions was over 50 micrometers. The calculated figures for the number of microinclusions per cubic centimeter in zonal halite are rather interesting. Only those inclusions which are clearly visible under the microscope at high magnification were calculated. The following values were obtained: 140, 170, 190, and 250 million microinclusions per cubic centimeter of mineral. These figures show the extent of inclusion-saturation of the mineral.

THE GENETIC DIVERSITY OF INCLUSIONS

In genetic respects, all inclusions in salt minerals can be divided into two groups: primary and secondary. The group of inclusions found by N. P. Ermakov and V. A. Kalyuzhnyy, called "virtual-secondary" or "early-secondary" we could not find in the minerals of salt deposits*.

The formation of primary inclusions in a mineral is wholly linked with the time and processes of crystallization of the host mineral; these inclusions are syngenetic with respect to the crystal and are confined to its growth forms. For that reason they can be formed at different periods of crystal growth and have dissimilar chemical compositions. This has been confirmed by research on the composition and other parameters of solutions of specific inclusions in halite crystals. As we know, in a salt basin the onset of crystallization of this mineral is determined by the appearance of so-called "waves" on the surface of the solution. After reaching a certain magnitude, the halite "wave" [i.e., film of hopper crystals?] drops to the bottom where it is further crystallized; precrystallization often continues in the buried sediment. Therefore, one crystal really undergoes three different mineral-forming modes until it is totally crystallized. Thus data obtained in studying these primary inclusions in a single crystal of halite, while depicting the vicissitudes of the process, do not always come together precisely.

This lack of correspondence was found in the composition of inclusion solutions in sedimentary halite and its recrystallized sections. One crystal of Permian halite from the Don River basin was analyzed for solutions of inclusions in the zonal portion and in water-clear segments. The following results were obtained (g/l): K' 26, Mg'' 30, SO_4'' 38 and K' 13, Mg'' 32, SO_4'' 4, respectively. There are many similar examples. On the basis of a comparison of stages of halite crystallization in a salt basin, it is totally logical to assume that the analytic data of inclusions in zonal halite correspond to the chemical composition of the mother liquor at the moment of nucleation and initial growth of the mineral on the surface of the salt basin; the chemical analysis of solutions of inclusions in the water-clear portion provides us with an idea of the composition of the intercrystalline mother liquor of the sediment. There is a considerable difference not only in chemical composition, but also in thermodynamic indicators; this demonstrates the recrystallization of the mineral under the conditions of a buried deposit. We know of instances where nucleation and initial growth of a mineral occurred from sulfate-type solutions, and its recrystallization took place at elevated pressures and temperatures from solutions of a chloride-calcium composition.

Halite undergoes plastic deformation in forming salt domes: often this only encompasses the outer portions of the grains; initial sedimentary halite remains in the form of microxenoliths in these grains (cf. Fig. 3). When we study them, it is sometimes important to draw a boundary between genetic alterations of halite, but with inclusions we can to some extent reproduce the history of its formation. These and other phenomena compel us to view primary inclusions in the minerals

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*Secondary inclusions which are formed during the growth of a given crystal are early-secondary. The formation of the whole crystal occurs over a rather long period. But if the salts contain secondaries (more precisely, late-secondaries which have no respective syngenetic growth zone), there can not be early-secondaries.

of salt deposits as syngenetic formations only with respect to a specific section of the crystal, and not the entire crystal*.

According to existing classifications (Lemmlein, 1929; Kalyuzhnyy, 1960), all primary inclusions can be divided into authigenic and xenogenic. Authigenic primary inclusions include entrapped fluids from which the mineral itself was crystallized. For minerals in salt formations, these are usually aqueous solutions. All other inclusions which were trapped in the mineral during growth are xenogenic (Figs. 4, 6). These inclusions had no direct relationship to nucleation and growth of the host mineral; they are merely mechanical impurities. The set of these inclusions is quite diverse: terrigenic material, crystal particles of gypsum, dolomite, calcite, quartz, etc.; xenogenic inclusions may include ozocerite, petroleum, and sulfur. Xenogenic inclusions aid in understanding mineral formation which occurred before crystallization of the host mineral.

Secondary inclusions in minerals generally occur as a result of the penetration of foreign matter through fractures or vacancies in the crystal after total crystallization. Matter entrapped in this way is preserved by means of healing of mechanical defects in the crystal. As a result of internal recrystallization, entrapped material becomes isolated as a certain series of inclusions, whose relative location in the mineral is most wide-ranging. The most common secondary inclusions are situated along the cleavage: this is especially characteristic of halite, sylvite, gypsum, and syngenite. In other minerals inclusions are situated in clearly visible fractures (Fig. 7, 8).

Secondary inclusions are likewise divided into xenogenic and authigenic, but we feel it is not reasonable to divide authigenic secondary inclusions in the minerals of salt deposits: all secondary inclusions are xenogenic.

SYSTEMATIC CLASSIFICATION OF INCLUSIONS BY STATE OF AGGREGATION

According to the proportion of phases and the nature of entrapped material, all inclusions in the minerals of salt deposits can be systematized in the form of a paradigm in which their state of aggregation at room temperature is calculated. There are one-, two-, three-, and multi-phase inclusions with various proportions of phases.

The nomenclature of inclusions according to the compositional state of aggregation has a particular order. If an inclusion is composed of a single phase, it is basically gaseous, liquid or solid. If some certain phase dominates the composition, the nomenclature first lists the phase whose content is less [sic.] in the inclusion. For example, gaseous-liquid inclusions are those inclusions in which the liquid dominates. There are inclusions with a state of aggregation in which there are simultaneously solid, liquid and gaseous phases; liquid phases can be represented by an aqueous solution and petroleum. Multi-phase inclusions are indicated by Latin (Kalyuzhnyy, 1960) or Russian letters (Ermakov, 1966). In describing inclusions according to state of aggregation, we first list the letter which denotes the phase in the larger volume. the notation L+G+S shows the predominance of the liquid phase over the gaseous, and the gaseous over the solid. Yermakov suggests

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* The primacy of an inclusion is firstly a crystallographic feature which is defined by the degree of genetic affinity of this defect to a given crystal as a whole (syngeneticity of crystal inclusion in general), or to an element of its growth (syngeneticity of inclusion to growth zone in which it is found)

adding subscripts for more accuracy: L_p liquid petroleum, L_w aqueous solution, G_v gas-vapor, etc.

Table 2 presents various inclusions according to state of aggregation and composition. These data are based on the results of a study of minerals from halide formations common in the Ukraine. Further studies of inclusions in minerals from other salt deposits will surely supplement the list we propose.

TABLE 2. SYSTEMATIZATION OF INCLUSIONS IN MINERALS OF HALIDE ROCK ACCORDING TO STATE OF AGGREGATION AND COMPOSITION

Inclusions	State of aggregation of matter in inclusion	Approximate composition of matter in inclusion
Liquid	Basically liquid	aqueous solution petroleum aq. solution and petroleum
	liquid with gas phase	aq. solution and vapor aq. solution and gas mixture petroleum and gas mixture aq. solution, petroleum, gas mixture
	liquid with solid phase	aq. solution with captive mineral aq. solution and xenogenic material petroleum and solid xenogenic matter
	liquid with gas and solid phase	aq. solution with captive min. & gas aq. solution with gas and xenolith aq. solution with captive min. & vapor
Gaseous	basically gaseous	complex gas mixture
	gas & liquid phase	gas and petroleum gas and solution
	gas & solid phase	gas and solid xenolith
	gas with liquid and solid phase	gas and solid xenolith and water solution
Solid	basically solid	xenolith
	solid and gas phase	xenolith and gas (mixture)
	solid and liquid phase	xenolith and aq. solution

Liquid Inclusions

Liquid inclusions are the most typical of minerals in salt deposits. They are found in almost all minerals that were studied. The liquid is almost always a water solution or a water solution with petroleum, pure petroleum, or water solution with liquid carbon dioxide (Figs. 2, 9, 10). In addition to a liquid, during crystallization a mineral can entrap a foreign solid, coal and gas (Figs. 11, 12). The gas in liquid of basically liquid inclusions (especially in halite and sylvite) is sometimes completely dissolved and its presence can only be established by boiling brines to detect inclusions [sic.]. The presence of basically liquid water solutions in a mineral suggests that crystallization took place from solutions whose temperature did not rise above 40-45°C. Inclusion fluids in minerals whose formation took place from chemically-complex solutions at elevated temperatures and pressures, undergo certain phase shifts as the system cools. Because the coefficient of volumetric shrinkage of the solution is much greater than the coefficient of shinkage of the crystal substance of the host mineral, with a temperature drop the liquid shrinks a little more than the inclusion cell; this leads to the formation of gas-liquid inclusions. Furthermore, with a temperature drop minerals sometimes precipitate from highly-mineralized brines: these are customarily called "captive minerals" (Ermakov, 1950) [i.e., "daughter crystals"]. The captive minerals in halite are sylvite, carnallite, bischofite and other halide salts. Thus as a result of change of a homogeneous system into a heterogenous one, two-phase and multi-phase inclusions are formed (Figs. 13-17).

Multiple phase liquid inclusions are also formed as a result of entrapment of xenogenic material during crystal growth (primary inclusions) or in the process of fracture healing (secondary inclusions). The xenogenic material in a liquid inclusion may be gypsum, anhydrite, terrigenous material, gas, petroleum, and ozocerite. This entrapped material is usually easy to distinguish from daughter minerals (Figs. 12, 15).

Gas-liquid inclusions are sometimes formed from substantially liquid inclusions under the effect of elevated temperatures (above 150°C). Relatively high temperatures which occur in salt deposits due to magmatic processes lead to decrepitation of the mineral around inclusions because of expansion of the liquid; a solution penetrates into microfractures and is thus lost to the inclusion (Fig. 18). When the temperature falls, the loss of solution leads to the formation of a vacuum which is filled by dissolved gases or water vapor. Large inclusions decrepitate and smaller ones remain without noticeable changes, typically under the same conditions.

In a mineralogic and petrographic description of halide rock, many authors indicate the presence of gas bubbles in primary liquid inclusions, attributing its appearance to the entrapment of air during mineral crystallization. We feel that this viewpoint is erroneous: gas in a primary inclusion of sedimentary halide is already entrapped during the formation of crystallographic sections and has no relationship to the origin of salts. We examined many mineral specimens from different salt deposits of the Ukraine and Belorussia, but in no case did we find any entrapped gas in the primary inclusions of sedimentary halite.

Liquid inclusions in crystallized rock minerals, as we know, have a very typical representative: liquid carbon anhydrite [Translator's note: should be carbon dioxide]. V. S. Shaydetskiy was the first to find it in inclusions in minerals of salt formations while studying halite of the salt domes of the Dnepr-Donets depression.

Gaseous Inclusions

Substantially gaseous inclusions are rather typical of minerals in salt deposits, but they are primarily interesting as a result of their secondary formation. Substantially gaseous primary inclusions in halite, sylvite and carnallite have some scientific and practical importance. These inclusions are characteristic of salt dome halite around whose periphery occurred near-surface hydrothermal processes; and plastic deformation of halite during formation of the dome took place at elevated temperatures with participation of a gaseous phase. Gas was entrapped together with terrigenous material, petroleum, and other bitumens (Fig. 19). Gas in this type of inclusion is generally under tens or hundreds of atmospheres of pressure.

Substantially gaseous inclusions in milk-white sylvite of potassium deposits differ from gaseous inclusions in halite in terms of their dimensions, internal pressure, location within the crystal, and gas composition. They are usually microinclusions of round form (Figs. 20, 21). The gas is compressed under enormous pressure (hundreds of atmospheres) and the inclusions themselves are uniformly distributed through the entire crystalline mass. Substantially gaseous inclusions are also typical of minerals which were formed as a result of crystallization from melts (Pavlov, Ryabchikov, 1968; Pavlov, 1971).

A subordinate quantity of aqueous solution, petroleum and entrapped allogenic impurities are often found together with gas in mineral inclusions.

Solid Inclusions

The formation of solid inclusions is primarily associated with the processes of entrapment of allogenic mechanical particles during mineral growth (xenogenic primary inclusions) or due to their penetration through fractures (secondary inclusions). This type of inclusion is quite typical of salt deposit minerals, and it is rare to find crystals not containing solid allogenic particles. The "purest" minerals with respect to solid xenogenic inclusions are the secondary minerals of salt deposits: these would include langbeinite, sylvite and transparent halite.

In plastically deformed halite of salt domes, solid inclusions are associated with certain narrow planar zones (Fig. 22). We characteristically find a relatively small amount of liquid and gas with the solid inclusions.

There is a group of solid inclusions whose formation is not completely understood. There is especial interest in sulfur inclusions in halite found in specimens from salt domes of the Dnepr-Donets depression. These inclusions often are round or tear-shaped, and small inclusions commonly are cubic (Fig. 23). Sulfur inclusions in halite probably occurred as a result of entrapment of molten mass during plastic deformation of rock salt at elevated temperatures. Consequently the form of crystallized sulfur is subordinated to the form of the negative crystals of the host mineral (cubes and cubo-octahedrons). The following have a rather interesting nature: solid inclusions of halite in langbeinite (Fig. 24), intergrowths of halite and sylvite, iron oxide inclusions in sylvite and carnallite (Fig. 25). All of these formations we conventionally classify as solid inclusions.

Inclusions in Rock-forming Minerals

Inclusions in halide minerals generally have a typical overall appearance which, in turn, unites them with the mineral inclusions of other genetic complexes. But every mineral often has specific primary inclusions inherent only in itself. Because secondary inclusions are identical in certain minerals, visual inspection is not advantageous[sic].

Halite

Primary inclusions in sedimentary halite are situated along the triple axis, and along ridges and cube faces; the central part of the cube is generally void of inclusions, but in some cases in the central portion large irregular liquid inclusions may be observed. Inclusions in halite from rock salt in bedding position are predominantly one- or two-phase, liquid with daughter mineral which, in certain instances, is sylvite, carnallite, epsomite or bischofite. In addition to daughter minerals, liquid inclusions from time to time will contain a solid xenogenic phase with a very variegated chemical composition (Figs. 9, 10, 16).

In contrast to zonal halite whose primary inclusions are situated in a pattern, the water-clear variant of halite (salt "spur") is marked by the presence of large liquid inclusions of irregular shape (Fig. 26); inclusions are sometimes interconnected via narrow channels. Depending on the crystallization conditions, inclusions in halite may be one-, two-, or multi-phase; for this reason solid phases may be represented by several captive minerals. The composition of these inclusions is often marked by the presence of authigenic minerals, petroleum (cf. Figs. 11-13, 15). In the crystals of transparent halite we encounter solid inclusions of bischofite, sylvite (Fig. 27) and anhydrite.

For example, there are beds of rock salt containing 0.3-1.0% potassium, where sylvite is contained exclusively as solid inclusions in halite. In halite which has been colored blue and violet, liquid inclusions were not found: this mineral typically has round solid inclusions of sylvite and other potassium-bearing materials situated in groups or elongated chains. No relationship has been found between intensity of hue and quantity of solid inclusions. In fibrous halite, inclusions are tabular in shape and are located between individual fibers.

Halite formed by crystallization from a melt is typified by the presence of substantially gaseous cubic inclusions whose size does not exceed 2 micrometers (Fig. 28). The inclusions are situated more or less uniformly in the mineral itself; they sometimes form segregations around xenogenic solid particles. Therefore the configuration of these segregations is similar to the form of the solid inclusion.

Substantially gaseous inclusions are found in halite which formed as a result of recrystallization of rock salt at elevated temperatures (several hundred degrees Celsius) and high pressure: this is characteristic of the formative conditions of certain salt domes. Gaseous microinclusions in halite, in this instance round or cubic, are arranged in the mineral in elongated zones; larger inclusions (100-200 micrometers) are irregularly shaped and often contain a large amount of terrigenous material (Fig. 19). The composition of gas in certain inclusions depends on the degree of metamorphism of the salts. Primary inclusion gas in halite from highly-metamorphosed rock salt is composed mainly of CO_2 (70-90%); the role of methane and other components (water, nitrogen) is negligible. As the degree of metamorphism decreases, the values of methane and water vapors in the gaseous phase of the inclusions increase; their content sometimes reaches 60%. The amount of nitrogen varies from 0.1 to 20%; water up to 5%; and hydrogen sulfide no more than 1-2%. Gases such as O_2, SO_2, Ar, and He were not detected by mass spectrometry in the specimens studied. Gas pressure within primary gaseous inclusions often exceeds the lithostatic pressure of rock strata which lie above.

It is worth noting that inclusions in halite are wonderful objects for study. First of all, this mineral is the most prevalent of all minerals of halide rocks. Secondly, in the course of halide sedimentation, halite accompanies the crystallization of all minerals right down to the bischofite stage. Thirdly, inclusions in this mineral, as in sylvite, are relatively large and are more convenient to study than inclusions in other minerals of salt deposits.

Sylvite

The distribution of primary liquid inclusions in sylvite is sometimes subject to the same patterns which describe halite. As in halite, liquid inclusions create zoning in sylvite. On the whole, sylvite crystals with zonal arrangement of microinclusions are encountered less often and are only typical of certain deposits or certain halide galleries. Sylvite with zonal arrangement of primary liquid inclusions is generally confined to the periphery of red sylvite grains; an impression is sometimes created that zonal sylvite was formed as a result of the healing of vacancies between grains of colored portion of the mineral. Inclusions are gas-liquid, with an invariant proportion of phases: the gaseous phase covers 1.8-2.3% of the entire volume of the inclusion. The gas occurs under several dozen atmospheres pressure (Fig. 29).

It is extremely difficult to look for inclusions in red sylvite because of the insufficient transparency of its crystals. But on the boundary of colored and transparent sections we can sometimes clearly see the substantially gaseous inclusions, ranging in size from 0n (sic.) to 2-3 micrometers (cf. Fig. 20). The gas within these inclusions is also at elevated pressure.

White sylvite usually has substantially gaseous and liquid-gas inclusions (gas 80-90%, solution 10-20%); internal pressure reaches 150-300 atm. Inclusions are fractional 0.n-10 micrometers), in the form of negative crystals of round shape or tubular form, elongated parallel to the faces of the cube and octahedron (Fig. 21). Fractional round gaseous inclusions are uniformly located in the crystal: among the bulk of these inclusions we typically find comparatively large members (up to 60 micrometers in cross section) of cubo-octahedral form (Fig. 21). In addition to gaseous inclusions, white sylvite quite often has liquid two-, three- or multi-phase primary inclusions of cubic shape; the gas in these inclusions is under high pressure. Solid phases are often represented by several captive minerals (halite, carnallite). The presence of a gaseous phase in inclusions may be linked in some way to water dialysis under the influence of the decay of radioactive potassium, or it may evidence the high temperature conditions of formation of this mineral. An answer to this question could help explain the origin of sylvite in salt deposits. The composition of the gaseous phase of individual inclusions is marked by the primary presence of nitrogen (60-90%) with subordinate amounts of CO_2 (4-8%), hydrogen (6-13%) and methane (2-5%); and in some instances, HCl. The solutions of inclusions are characterized by a high content of calcium and low pH (less than 4.0).

A large number of solid inclusions of halite (in white sylvite) and hematite (in red sylvite) is most typical of sylvite. Although many studies describe these inclusions (Razumovskaya, 1927, Poire, 1930; D'Ans, Kühn, 1938, Yarzhemskiy, 1967, etc.), their origin remains unexplained. The shape, size and arrangement of solid inclusions of hematite and halite in sylvite are quite different (cf. Figs. 2, 25, 30).

Carnallite

Primary inclusions in carnallite are represented by xenogenic formations, the most common of which are sylvite, halite and anhydrite. In colored red carnallite there are constantly microinclusions of magnetite, hematite, goethite and other iron oxides (cf. Fig. 25). Primary liquid inclusions in carnallite occur less frequently: they are one-phase inclusions which form oval bodies, somewhat elongated along the zoning of the mineral. One distinctive feature of this mineral is the presences of gaseous single-phase inclusions ranging in size from 0.n to 1 micrometer. These inclusions are arranged in bands in carnallite, parallel to the zoning of the crystal; they can only be detected by freely dissolving the mineral in glycerin. The gas in these microinclusions exists under several dozen atmospheres pressure.

The usually liquid primary inclusions offer some interest to research. Their insignificant size and the mineral's instability during specimen preparation make their study difficult.

Bischofite

Transparent bischofite is characterized by the total lack of liquid inclusions: only rarely can they be detected in the mineral under high magnification. Inclusions are oval, elongated, one-phase liquid inclusions, with dimensions not in excess of several micrometers. With the slightest pressure on a mineral plate the inclusions break open. Since bischofite is unusually unstable, fractures which occur are healed quite easily and rapidly; for that reason, secondary inclusions along fractures are virtually indistinguishable from primary inclusions. Solid xenogenic inclusions are represented by many minerals of salt-bearing strata, most commonly halite, sylvite and anhydrite. Iron oxide minerals are also encountered.

Langbeinite

We conventionally extracted langbeinite from mono-mineral langebinitic rock and langbeinite whose lenses were bedded among intrusive kainitic rock of the Ciscarpathians.

Langbeinite from rock typically contains numerous round liquid inclusions ranging in size from 1 or 2 to 60 micrometers (Fig. 31). Their position in the mineral was sometimes subject to some pattern: they may form elongated zones in the crystal, but they are usually randomly situated. The solution in the inclusions is highly concentrated, as demonstrated by crystallization of the liquid phase by cooling to +5°C. Many large inclusions in langbeinite are decrepitated (Fig. 32), evidently as the result of heating under natural conditions. Due to dehermetization a gas bubble develops whose internal pressure is less than atmospheric, and a captive mineral (halite or sylvite)(Fig. 33).

Langbeinite in lenticular bedding ("augen" extraction) is distinguished from the above by the total absence of primary liquid inclusions. But the inclusions which can be found are two-phase gas-liquid ones with a constant proportion of phases; their aggregation [liquid content?] is 99.5-99.0% (Fig. 14), and the maximum size reaches 50-200 micrometers. Solid inclusions in langbeinite are halite, an anisotropic mineral (kainite?), and sylvite. All these solid inclusions are elongated parallel to each other and are directed perpendicular to the bedding of the langbeinite lens. These regular arrangements of solid inclusions may be associated with the conditions of langbeinite growth, which at first has a fibrous structure due to crystallization in openings. Subsequent recrystallization, as we know, led to the formation of mono-mineralic langbeinitic bodies with a legacy of halite and other mineral fibers. The arrangement and shape of gas-liquid inclusions is thus completely regular.

Langbeinite is very easy to polish, making it possible to prepare excellent plates for the study of its inclusions. The mineral's high transparency also aids in its successful study.

Kainite

Primary inclusions of this mineral are gas-liquid with a constant ratio of phases (liquid comprises 99.2-99.6%); they are round and are several micrometers in size, but some inclusions reach 60-80 micrometers. They are distributed in the mineral without any apparent order; the center of the crystal usually contains larger inclusions. The solution in inclusions is highly mineralized. At reduced temperatures, as in inclusions in langbeinite, its total crystallization occurs, forming a hydrated salt. Inclusions in fibrous kainite are elongated, gas-liquid with varied ratio of phases. All inclusions are confined to the growth zone of individual kainitic fibers. Xenogenic solid inclusions in kainite are represented by terrigenous material, anhydrite, and halite.

Polyhalite

Inclusions in polyhalite are found in groups and are irregularly distributed in the mineral itself. The inclusions are angular, rectangular, or tubular in shape (Fig. 17); their size is no more than 40 micrometers. They are primarily gas-liquid with a constant ratio of phases; in individual inclusions a solid phase may be found whose nature has not been established. In thick plates, polyhalite is opaque, making it necessary to prepare specimens of less than 1 millimeter in thickness for the study of inclusions.

Anhydrite

Inclusions in anhydrite are liquid, single-phase, with tubular or cubic shape. Their size ranges from a fraction of a micrometer to 50-60 micrometers. The elongated forms have the following ratios of width to length: 1:5 and 1:15. Their lengthwise size reaches 10-15 micrometers. In anhydrite from salt domes we encounter two-phase gas-liquid inclusions (liquid comprises 95-97%) with xenogenic halite, hematite, pyrite and rarely, petroleum. The amount of entrapped material may be roughly 80% of the entire volume of the inclusion: much of it is halite.

Syngenite

Primary inclusions in syngenite are tubular, very narrow and long, some with a width-to-length ratio of 1:40; the size of inclusions is several dozen micrometers in length. Inclusions are single-phase, liquid, with a large amount of xenogenic material, represented by terrigenous matter. The formation of tubular inclusions in syngenite is associated with the repulsion of exogenous particles during mineral growth (cf. Fig. 4).

Gypsum

In this mineral we most often encounter single-phase liquid inclusions whose size reaches tens or hundreds of micrometers in length. In cross section, these inclusions are round or rhomboid (Fig. 34). Some inclusions in the mineral may be arranged in chains which are interconnected. We find terrigenous material as the solid phase in some inclusions; the solution in the inclusions has a range of degree of saturation. Inclusions in gypsum easily break open with the slightest mechanical pressure on the mineral. A most typical sign of dehermetization of a primary liquid inclusion in gypsum is the presence of a gaseous phase in it. Secondary inclusions lie along the planes of cleavage. Their shape is very chimerical; the inclusions are flat, and have different ratios of phases.

From the entire group of minerals typical of salt deposits, in addition to the above, inclusions were also studied in astrakhanite, mirabilite, epsomite, picromerite, thenardite and glaserite [aphthitalite]. All of these minerals were selected from a leaching zone of potassium-magnesium rock. A comparatively large number of inclusions is characteristic of mirabilite, picromerite, and thenardite; mirabilite, glauberite and epsomite crystallize under the same conditions with a negligible amount of different impurities. Primary inclusions in these minerals are mainly liquid or solid (xenogenic); gas-liquid inclusions are only formed as a result of deformation of minerals.

Thus each mineral has its own types of inclusions. From all the minerals we studied, it is most useful to study halite, sylvite and langbeinite since their inclusions are more convenient to study than those of other salts. With the appropriate skills certain amounts of information can be obtained from the inclusions of any mineral. Chemical analysis of inclusions is quite easy to perform on minerals such as picromerite, mirabilite, thenardite, and epsomite.

Inclusions in authigenic minerals

According to contemporary data, authigenic minerals can be found in salt deposits: quartz, dolomite, calcite, anhydrite, tourmaline, celestite, fluorite, and chalcedony. Furthermore, new formations [sic] can be found in salt sediments: magnesite, octahedrite, brookite, pyrrhotite, chlorite, sepiolite, and sulfur. Of these authigenic minerals, it is most effective to use the following in the study of inclusions: quartz, anhydrite, tourmaline, calcite, dolomite, and fluorite. Experience gained in studying inclusions in authigenic minerals shows that a specimen may be prepared from crystal grains of almost 0.3 mm. in size. To prepare specimens from anhydrite, calcite and other minerals it is better to use grains of over 1 mm in size.

According to the formative conditions of halide rocks, inclusions in authigenic minerals are characterized by specific properties. For example, in anhydrite and quartz we may encounter inclusions from one-phase liquid to multi-phase. The shape of inclusions is also quite varied, and their size rarely exceeds 10-15 micrometers. The results of the study of inclusions in these minerals is certainly of interest, not only to explain the formation conditions of salt sedimentation, but also to refine the parameters of the mineral-forming medium.

METHODS FOR STUDYING INCLUSIONS IN HALIDE MINERALS

As we know, halide minerals sharply differ in certain features not only from endogenous, but also from sedimentary minerals: high solubility in water and some other solutions, instability in air, variability of hydrated minerals at elevated temperatures, their low hardness and strength. A distinctive feature of solutions of inclusions from salt deposit minerals is their high overall mineralization. For example, the high solubility of most minerals in water makes it possible to easily and rapidly reveal inclusions by gradually leaching certain portions of the specimen over individual inclusions.

Preparation of the specimen for study of inclusions

It is best to select rock material for the study of inclusions in minerals during field trips. Most specimens should be oriented with respect to the bedding of the rock and precisely associated with certain intercalations, foliations, and so forth. Large-crystal rocks are usually selected whose grain size is at least 2-3 mm. It is desirable to have specimens with a low content of undissolved residue, of dense structure, and without visible deformations. Monocrystals of salts which are sometimes found in halide deposits are valuable: they should be collected in a test tube to avoid mechanical injury and the effect of atmospheric moisture on them. In test tubes, even carnallite and bischofite can be kept for many years. The size of specimens depends on the goals of the researcher. Thus for bulk analysis of a gas or solution of inclusions we need the maximum amount of material, 2-3 kilograms. For other forms of research we can use much less material.

Sometimes 10-20 grams of monomineral substance suffice for total investigation of inclusions in a mineral.

Study specimens are prepared from individual transparent or translucent materials of at least 2-3 mm in size. In some instances, inclusions in halite or sylvite may be investigated on a much smaller specimen. Larger specimens facilitate thorough, comprehensive examination: for that reason it is more efficient to find crystals than to study fractional plates.

Study specimens should be ground on two sides, then polished on moist felt with a small admixture of chromium oxide. Relatively hard minerals (anhydrite, polyhalite, syngenite) are polished on a grinder; those such as carnallite, halite and sylvite are polished manually; the entire specimen preparation procedure takes 3-5 minutes. Minerals of salt deposits are easy and quick to polish, and the plane of the specimen has an ideally even surface.

After preparing a slab from bischofite or carnallite, the specimen very quickly turns dark and becomes opaque. In a moist climate the darkening occurs in several minutes; with relatively low humidity their transparency can be maintained for 2-3 hours. To isolate the polished surface of these minerals from atmospheric moisture, anhydrous glycerin or motor oil are used to lubricate the surface of the slab. Such a specimen can be used only for visual microscopic study of inclusions in minerals. If we have to find inclusions, the polished slab is placed in a heat chamber whose temperature is 10-15°C higher than room temperature. The standard biological table thermostat (TOC-1) is very appropriate. The polished surface of other minerals we studied is retained quite long. For example, in sylvite several hours; halite several days; astrakhanite and langbeinite several weeks. This period depends wholly on the conditions of specimen storage.

Slabs are relatively simple to prepare from a mineral with perfect cleavage (halite, sylvite, gypsum): by separating along the cleavage. Such fragments have completely satisfactory transparency; glycerin should be used to improve it if necessary. If the study crystal has very small dimensions and it is virtually impossible to prepare a slab from it, we can get an idea about inclusions after submerging it in the appropriate immersion fluid: glycerin, alcohol or transparent liquid oil. But bischofite and carnallite gradually dissolve, even in anhydrous glycerin and alcohol.

In the preceding study of inclusions we first determined their state of aggregation, genetic type and hermeticity. It is useful to develop a preliminary classification into specific groups according to certain features. In individual minerals it is sometimes possible to isolate 3-4 genetic groups of inclusions; this diversity is especially typical of highly metamorphosed halide formations of salt domes. The presence of diverse inclusions is also typical of some minerals of potassium deposits.

In a morphologic description of inclusions we must establish their shape and size (in three-dimensional or two-dimensional units), number of phases, distribution and orientation of inclusions in the mineral by calculating its crystallographic forms, distance between individual inclusions, etc. For example, in halite, sylvite and langbeinite, inclusions are usually of regular geometric form; in halite and sylvite, they are in the form of negative crystals; in langbeinite they are round. When studying these inclusions it is very easy to compute their volume, volume of the solid (captive mineral) and gas phases. According to calculations and measurements we know the proportion of phases in individual inclusions; on that basis, we can sometimes arrive at conclusions as to the genetic membership of inclusions and the temperature of their homogenization (if preliminary research has already obtained thermometric analysis of the inclusions). Microscopic studies of a specimen, in addition to selected numerical data, should contain detailed or schematic sketches which accentuate the major details: juxtaposition of individual inclusion groups, their relative orientation, genetic distribution, and so forth. In addition to sketches, it is also necessary to make wide use of microphotographs of individual study objects.

After visual microscopic study of the specimen the inclusions are studied; they are also photographed or sketched on a specific scale. According to the state of aggregation of an inclusion the corresponding analyses must be performed. In individual inclusions the chemical composition of the solution and gas is analyzed; internal pressure and pH - Eh parameters of the medium are measured; and captive minerals are diagnosed, and sometimes xenogenic material as well. The temperature of partial and total homogenization of the phases is determined. Of course this number of procedures cannot be carried out on a single microinclusion. In this case each individual inclusion of a certain mineral growth zone is analyzed for one of the elements, and then the results are combined. The large number of microinclusions in halite, sylvite and langbeinite makes it possible to overlap certain analyses.

CHEMICAL ANALYSIS OF SOLUTIONS OF INDIVIDUAL INCLUSIONS

Preliminary data on the chemical composition of solutions of individual inclusions are usually obtained on the basis of a study of their physical properties: according to the fracture indicator [sic.], color, behavior during cooling, type of wetting of the walls of inclusions, presence of one captive mineral or another (Kalyuzhnyy, 1960; Lemmlein, Klevtsov, 1955; Redder, 1970 [Roedder, 1972]; Dobretsova, 1968). But to obtain total representation of this parameter, the most effective is the method of direct analysis of matter. A study solution is usually taken from one inclusion or from a group of inclusions (so-called bulk composition of solutions). Both methods are generally accepted, but the informativeness of the analytic results of individual inclusions is much higher and more valuable. Only study data of individual inclusions make it possible to trace changing physical and chemical conditions during salt formation.

The small dimensions of liquid and gas-liquid inclusions limit the use of ordinary methods of chemical analysis of solutions, because their volume averages out to 0.00 n mm^3. This amount of solution can only be analyzed by a special method, ultramicroanalysis (Malyarov, 1951; Korenman, 1955, 1963, 1967, Alimarin, Petrikova, 1960). This method is based on the classical methods of chemical study of large quantities of material, making it possible to use generally accepted procedures and research technique, but allowing for the microscopic quantities of matter. Ultramicroanalysis is widely used by geochemists which study inclusions in minerals; certain procedures of standard ultramicroanalysis consider the properties of the object which is being studied (Maslova, 1965, 1968; Kalyuzhnyy, 1960, Gryn'kiv, Kalyuzhnyy, 1966).

A second trend of ultramicroanalysis is based on physical methods of studying the elements: spectral emission analysis with a laser device, spectrophotometric and polarographic methods (Morrison, Scogerbow, 1967; G. Menke, L. Menke, 1968). Their high costs still restrict the performance of a large number of analyses of microscopic quantities of matter. They are best used to study rare and scarce elements from inclusion solutions whose content is so low that even qualitative chemical ultramicroanalysis cannot define many of them.

Inasmuch as solutions of liquid inclusions in halide minerals are extremely concentrated (over 350 g/l), the content of primary components in them is very high. Solutions almost always contain chlorine, sodium, potassium, magnesium, calcium and the sulfate ion, whose concentration sometimes reaches the tens and hundreds of grams per liter. Their increased content makes the use of ultramicroanalysis possible.

We developed a method of quantitative analysis of chlorine, sulfate ion, potassium, magnesium and calcium. The analysis is based on calculation of the volume of sediments obtained after adding the appropriate reagent to the solution and then centrifuging it. The reactions occur exclusively in cone-like capillaries whose internal diameter varies from 3-5 to 20 micrometers; the course of the reaction, the nature of the sediment and its volume are studied under the microscope. This method can quantitatively analyze elements in 0.004 to 0.008 mm^3 of a solution. The error of a single analysis for each element is unique and in individual cases ranges from 21 to 43% (Table 3). In calculating small volumes of test substance, we feel this error is totally admissible. To reduce it to 10-17% it is sometimes necessary to perform 2-3 parallel tests. This method of chemical microanalysis allows solutions from individual inclusions 0.0 n mm in size to be studied. The proposed method of ultramicroanalysis of solutions is quite simple to carry out: the time it takes to analyze one element is about 15-25 minutes. Reproduction is also satisfactory: the results of parallel tests performed by two different operators are totally equal, confined within the error of a single analysis.

TABLE 3. ACCURACY OF METHOD OF CHEMICAL ULTRAMICROANALYSIS OF SMALL VOLUMES OF SOLUTIONS

Element	C,%	P,%	D, g/l	V',mm^3	V, mm^3	n
Potassium	23.1	5.8	0.8	0.0003	0.0046	125
Magnesium	21.0	4.7	1.0	0.0005	0.0043	140
Calcium	43.5	13.2	0.9	0.0007	0.0056	112
Chlorine	38.0	10.6	0.5	0.0005	0.0060	91
SO_4''	37.8	11.6	0.5	0.0003	0.0084	105

Legend: C = coefficient of variation of test data; P = error, mean arithmetic; D = minimum quantity of component which can be determined; for qualitative analysis this value decreases by one order; V' = minimum volume of solution which can be analyzed; V = average volume of artificial solution which corresponds to the volume of inclusions in minerals; n = number of assays.

By using the notion of quantitative analysis of elements in solutions in terms of the volume of sediment (Butyrin, 1931; Borenman, 1949; Benedetti-Pikhler, 1951) with some changes and additions we were able to reduce the volume of solution by 1-2 orders vis-a-vis published data.

We first studied artificial solutions having known chemical composition which roughly corresponded to that of underground waters or the brine of salt basins. There were 5-9 of such solutions for each element (K', Mg'', Ca'', SO_4'', Cl): also, the content of each element in each successive solution was doubled. A complex solution was analyzed for a specific element 6-17 times (Table 4). The relationship of the content of an element in a solution and the volume of sediment obtained is expressed by the appropriate mathematical formulas (Table 5). For instance, in assaying potassium in a solution from an inclusion in halite,

TABLE 4. STATISTICAL PROCESSING OF RESULTS OF ULTRAMICROANALYSIS OF SMALL VOLUMES OF ARTIFICIAL SOLUTIONS

Element	Solution number	g/1	V, mm^3	n	Precipitation data		
					$\overline{X}$, %	S	C, %
Cl	1	3.1	0.009	13	2.6	1.1	42.0
	2	6.2	0.007	12	5.7	2.0	34.9
	3	12.5	0.013	13	7.7	3.1	40.1
	4	25.0	0.019	14	16.8	5.9	35.1
	5	50.0	0.023	13	28.4	9.0	32.1
	6	100.0	0.008	13	51.2	20.0	40.0
	7	218.0	0.019	13	93.8	30.7	32.7
SO_4	1	0.57	0.058	11	0.18	0.12	66.7
	2	1.06	0.033	17	0.37	0.18	49.0
	3	2.10	0.046	13	0.57	0.18	31.3
	4	4.20	0.023	17	0.89	0.60	67.4
	5	8.10	0.029	15	1.99	0.77	38.7
	6	24.0	0.033	14	5.27	1.40	26.6
	7	34.0	0.024	11	6.55	1.93	29.5
	8	170.4	0.017	7	35.00	6.14	17.5
K	1	0.82	0.035	16	0.58	0.19	32.7
	2	3.13	0.017	13	1.48	0.44	29.7
	3	4.20	0.010	17	1.89	0.29	15.3
	4	6.60	0.022	10	2.76	0.66	23.9
	5	13.1	0.016	13	5.24	1.35	25.8
	6	26.2	0.028	13	9.90	1.09	11.0
Mg	1	0.3	0.045	6	0.73	0.20	27.3
	2	0.6	0.035	6	1.92	0.26	13.5
	3	1.2	0.030	6	3.06	1.00	32.7
	4	2.4	0.060	6	6.16	1.15	18.6
	5	4.8	0.046	6	12.64	2.10	16.6
	6	12.0	0.033	7	28.65	4.36	15.21
	7	23.9	0.015	6	73.40	14.40	19.61
	8	31.3	0.060	11	85.80	20.25	23.60
Ca	1	0.90	0.031	10	0.24	0.12	50.0
	2	1.76	0.036	14	0.82	0.53	64.6
	3	3.45	0.027	12	1.39	0.63	45.3
	4	7.00	0.012	11	3.30	1.12	33.9
	5	14.00	0.008	10	7.10	3.42	48.2
	6	44.50	0.017	8	23.06	6.27	27.2

(Legend for Table 4: V, mm^3 = average volume of artificial solutions; n = number of parallel chemical ultramicroanalyses; $\overline{X}$, % = average volume of sediment obtained due to sedimentation of elements by appropriate reagent. Volume in % with respect to initial quantity of solution (V); S = standard deviation; C,% = coefficient of variation of n analyses.)

we calculated that the volume of sediment obtained was equal to 4.5% of the solution's volume: the content of K was thus 11.3 ± 2.6 g/l.

Volumes of artificial solutions which were analyzed ranged from 0.000 n to 0.n mm^3 and averaged 0.00 n mm^3. We did a special study of the accuracy of the proposed method of ultramicroanalysis as a function of solution volume being analyzed. It was found that changes in solution volumes within the range 0.000 n to 0.n mm^3 have no theoretical significance in analytic accuracy.

As reagents which precipitate K, Mg, Ca, SO_4 and Cl, compounds were used which interact only with a certain element and produce microgranular reaction products.

Chlorine is precipitated by a 3.2% solution of $AgNO_3$ with traces of nitric acid. Since solutions of inclusions generally contain a considerable amount of this element, it was necessary to add 10-15 times the amount of reagent to obtain total precipitation. The most accuracy was attained with a relatively small amount of chlorine in solutions (under 100 g/l). For that purpose, inclusion brines sometimes should be diluted with distilled water. Bromium precipi- [five lines of original omitted by translator].

The sulfate ion is best precipitated by a 30% solution of $BaCl_2$; precipitates are usually dense, finely crystalline, with sharp outlines.

The reagent theoretically also precipitates CO_3'', but the quantity of this component is extremely small in inclusion brines.

Potassium reacts excellently with a solution of sodium cobaltinitrite, yielding a dark crystalline precipitate. The concentration of the solution of $Na_3Co(NO_2)_6 \cdot 1/2\ H_2O$ can be selected at will, from 2 to 5%. Potassium turns completely to a precipitate under the influence of this reaction. Characteristically, with a low content of potassium in inclusion brine (under 0.8 g/l), this element may sometimes be found in several crystal grains on the walls of the capillary. The reagent must be prepared before each series of tests.

Calcium is precipitated by a 5% solution of $(NH_4)_2C_2O_4$. The precipitates are mostly fine- or medium-grained, of white color. Strontium is also precipitated with calcium.

Magnesium is most conveniently precipitated from sulfate solutions using a reagent composed of equal quantities of a 30% solution of urotropin and a 15% solution of $K_4(Fe(CN)_6$ under the stipulation that the test brine does not contain potassium or its quantity does not exceed 6 grams/liter. The formula proposed in Table 5 for analysis of magnesium in precipitates pertains to brines which are free of potassium. If the test liquid inclusions contain this element in amounts ranging from 1-6 gram/liter, the content of Mg is calculated by the following formula:

TABLE 5. RELATIONSHIP BETWEEN CONTENT OF ELEMENT IN ARTIFICIAL SOLUTION AND VOLUME OF PRECIPITATE

Element	Statistical data			Numerical relationship	Error, %
	n	r	t		
Chlorine	7	0.79	3.36	$L_{Cl} = (2.0 \cdot \overline{X} - 4.80)$	38
SO_4	8	1.00	10	$L_{SO_4} = (4.89 \cdot \overline{X} - 0.65)$	38
Potassium	6	1.00	10	$L_K = (2.73 \cdot \overline{X} - 0.95)$	23
Magnesium	8	0.99	20	$L_{Mg} = (0.34 \cdot \overline{X} + 0.37)$	21
Calcium	6	0.99	19.9	$L_{Ca} = (1.91 \cdot \overline{X} + 0.51)$	43

$$L_{Mg} = [0.33 \cdot \overline{X} - 2.5].$$

With a higher concentration of calcium in the brine, Mg is determined after precipitating out the calcium with a solution of $(NH_4)C_2O_4$. In this instance, the single assay error of Mg virtually doubles. The reagent for magnesium is unstable and thus it must be mixed only just before the start of the reaction.

Sodium. The most accessible and suitable reagents for this element are uranyl, magnesium, zinc, cobalt and nickel acetates, but the reaction products which are produced between inclusion brines and reagent are composed of large yellowish octahedral crystal grains or slabs which are unsuitable for volume calculations. The determination of sodium using these reagents convinced us that the reactions may have only qualitative value.

For ultramicroanalysis of a liquid from an inclusion it is necessary to have a binocular microscope with micrometer reticle, centrifuge (9,000 rpm), reagents, capillary tubes, alcohol lamp and a small electronic calculator.

The capillaries are prepared under laboratory conditions; their shape is elongated with a conical drawn end, whose aperture diameter is 5-10 micrometers; the capillary diameter is 15-30 micrometers; the most convenient capillary length is from 3 to 5 centimeters.

Technique of Ultramicroanalysis

A polished slab of mineral is placed under the binocular, and with gradual solution of the surface (if the given mineral easily dissolves in water), the layer between the surface of the specimen and the inclusion is reduced. The most convenient method for dissolving the mineral is to use a rubber hose (diameter 0.3-0.5 cm) with a glass tube, whose end is tapered to 0.05-0.1 mm. If the mineral does not dissolve in water, the surface of the slab is ground manually or on a mill until the required distance is attained between the specimen surface and the inclusion. This distance can vary according to the size of the inclusion and its internal pressure, within tens of micrometers. Subsequently, the surface of the slab is dried and cleaned of extraneous substances. Inclusions are exposed with a sharp steel or Pobedit [carbide] needle, whose point thickness should be several times less in diameter than the cross section of the inclusion.

The exposure is made under the binocular by simple pressure of the wall; a capillary tube is pushed into the slab with the needle. Under the influence of capillary attraction, the solution either enters the capillary tube rapidly or gradually (according to capillary inlet diameter). If the liquid must be collected in 2 or 3 capillaries, then the size of their aperture should be minimal. Sometimes liquids in inclusions are under pressure and after exposure there is turbulent boiling of the solution due to the liberation of gas. The inclusion becomes almost empty and all the liquid concentrates on the slab surface. The boiling often resembles an explosion: the liquid is then almost impossible to collect, even around the inclusion. The volume of extracted salt solution is measured under the microscope with the aid of a micrometer reticle; calculation is quite simple if the capillary has the form of an elongated conical cylinder. This operation takes 1.5 to 2 minutes. Then the capillary is again placed under the binocular, where a drop of the appropriate reagent is placed on the microscope stage. The reaction between solutions is observed rather clearly if the crystalline grains are fine. These properties easily define the amount of reagent needed for complete precipitation of the component. Immediately after the reaction, the capillary tube is placed over an alcohol lamp, whose flame is not over 0.5-1 cm in height, and the thin end of the tube is sealed. [sic.]

Sealing the tube is accomplished best in the lower portion of the flame, since careless sealing could permit the solution to boil and vanish. Then the other end of the capillary tube is sealed in the upper portion of the flame, leaving a piece 2 times larger in diameter than the capillary on this end. After all these steps, the capillary is transferred to a specially fitted centrifuge where, during revolution of the disc, it should be in a horizontal position; this can be accomplished by drilling holes 0.5-0.6 cm diameter in it. According to the number of planned parallel tests there may be 2-3 of these holes; a larger number of holes is inefficient since it is difficult for one technician to operate several assays simultaneously. To prevent destruction of the capillary tubes, pieces of 0.7 x 0.7 cm photographic film are prepared, and a hole is cut in the center similar in diameter to the thickness of the capillaries. The capillary and the film are placed into the centrifuge; during revolution of the disc, the capillary hangs on the film in the middle of the hole. Then centrifugal force cannot destroy the capillary, as long as it is shorter by the length of the aperture in the disc. After 15-20 minutes of revolution, all the precipitate settles in a compact mass at the thin end, making it easy to calculate its dimensions and find the volume with respect to the initial quantity of solution. The value obtained is used in one of the formulas in Table 5.

The time between the reaction and the beginning of centrifugation should be minimal: it is 45-60 seconds in our data. During introduction of the reagent the reaction products which are formed are primarily situated on the walls of the capillary tube; after several minutes the crystal grains are so solidly occluded that even long-duration revolution cannot precipitate them. As a result, all procedures (reaction, sealing capillary tubes, centrifugation) should be done in one minute. Nevertheless, it is sometimes impossible to get precipitation of the reaction products on the walls of the capillary tube. Such a sample can often be saved by multiple freezing and thawing of the solution: this continues until the walls are totally clean. The effect of freezing can usually be observed under the binocular. Such instances are most frequent for the magnesium reaction, where it is in solution with calcium. Solutions can be frozen on a heating and cooling stage with a selenium rectifier [thermoelectric cooling?] which can produce a temperature of -26°C.

Magnesium in a solution which contains a large quantity of calcium (over 6-10 grams/liter) can be determined in two ways. First calcium is precipitated, and then the precipitate is centrifuged and removed from the solution. For this purpose the head of the capillary is broken off and then only its thin end has precipitate. After this step, the magnesium reaction is carried out in the regular way; the volume of precipitate obtained is equal to the volume of the initial solution. For double reactions we must have slightly longer capillaries with more elongated thin and conical ends.

The time between the conclusion of centrifugation and the measurement of the volume of precipitate must be constant and minimal (about 40-60 seconds) so that after the disc is stopped centrifugal force does not affect the precipitate and it gradually becomes more fragile; its volume often increases by a factor of 1.5 to 2 after 10-15 minutes. For that reason, measurement always begins with the length of the precipitate column and then its diameter.

In the presence of small contents of elements (less than 0.5-1.0 gram/liter) being analyzed, such a small volume is formed that it almost cannot be measured. We can sometimes use terrigenous material of the inclusions for this precipitate since if falls in the capillary with the solution. [sic.]

If analysis cannot be performed immediately after the inclusion has been exposed, the capillary and solutions should be stored in a special moisture chamber. In the open air the solution gradually evaporates from the capillaries and within 3-4 hours its volume decreases 2-3 times (i.e, a solution of NaCl); but if the solution contains magnesium or calcium chloride, its rate of evaporation drops greatly.

Thus in summing up the proposed method of ultramicroscopic analysis of the solutions of inclusions in minerals of salt deposits, we must indicate certain aspects which play a major role in its assessment. Ultramicroanalysis can be performed by the researcher himself while studying the mineral slab. This method is relatively simple, productive, and inexpensive. Using this idea, other methods of analysis can be developed for different elements which are sometimes encountered in inclusion solutions. By improving some procedures and standardizing them it is possible to reduce the single assay error by a factor of two. Errors leading to variation of analytic results are mainly associated with the insufficient precision of solution and precipitate volume measurements, since the capillaries used often have a shape somewhat different than a certain geometric figure (in this case the conical cylinder). The standardized preparation of capillaries should reduce analytic error considerably. Another cause is evidently the heterogeneity of precipitate obtained in each individual case: it not only depends on the duration and speed of centrifugation, but also on the nature of the precipitate itself. In different solutions the degree of crystallinity of one and the same substance is slightly different. It has been found that the nature of the precipitate is affected by the rate of crystallization, solution temperature, solution composition, and so forth. These effects must be reduced or eliminated in order to reduce analytic error.

Naturally a solution of inclusions in minerals of halide deposits contains, in addition to the primary elements, different rare and scarce elements which are very valuable to the researcher as an additional source for interpreting the formation conditions of halide rocks and to discover rare metal deposits. It is theoretically possible to predict which trace elements we can encounter in inclusion solutions. If we are analyzing the inclusions of sedimentary halite we would expect fo find in them all the elements of the final stage of life of a salt basin. Based on research conducted (Boyko, 1963, 1969; Pencheva, Pavlova, 1964; Zherebtsova, Volkova, 1966; Boyko, Buynevich, 1967; Slivko, Petrichenko, 1967; Malikova, 1967) these elements may be the following: bromine, iodine, lithium, cesium, boron, arsenic, tungsten, copper, molybdenum, chromium, and fluorine. No less diverse in composition are the inclusion solutions of recrystallized salts; this particularly concerns inclusions in halite of salt domes around whose periphery occurred magmatic and hydrothermal activity. It suffices to say that even according to preliminary data we have qualitatively detected the following in solutions of many inclusions: ferric and ferrous iron, manganese, boron, strontium, copper, lithium and bromine.

The colorimetric method of analysis of BO_3''', Fe", Fe''', Pb", S", Mg", Cu", SiO_2 developed for liquids of low overall concentration [several references omitted by translator] can be used successfully for highly-concentrated solutions of inclusions in salt minerals; this is borne out by studies with artificial highly-concentrated brines which contain certain trace elements. The reactions produced are clear-cut, but their relative rate of occurrence is much lower than is needed for liquids with low or medium overall mineralization. Trace elements are analyzed by using an organic (egg) film (Kalyuzhnyy, 1960)[1] which is presaturated with colorimetric reagents. This indicator film is quite distinct from standard indicator filter paper in its morphologic qualities; the film has a microscopic fibrous structure which permits the reaction to take place in very small volumes of solution (0.000 n - 0.00 n mm^3) under a binocular microscope. If none of this film is available, the very slow process of test solution absorption can be used for inclusions in salt minerals. In some solutions, the reaction is not even set off due to their high mineralization, and then the test solution must be diluted with double-distilled water or the film must be moistened immediately before the reaction.

Finally, the chemical composition of inclusion solutions in minerals can be judged on the basis of their products of crystallization. A solution from an inclusion is collected by the capillary tube and is transferred to the microscopic slide. The best inclusions for this are those whose size is greater than 0.01 mm; if there is very little solution,

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[1] Editor's note: This is the inner membrane of the egg, just inside the shell (personal communication, V.A. Kalyuzhnyi, 1970).

it is more efficient to use capillary tube of 3-5 micrometer diameter. The end of this capillary tube is crushed on the microscope stage (because it is almost impossible to extract from the capillary), and the microscopic droplets are studied as they dry out. The mineral crystallization sequence varies according to the composition of the solutions. While studying such solutions, we diagnosed gypsum, halite, sylvite, epsomite, picromerite, hexahydrite, kainite, carnallite, and bischofite. Due to their instability, some minerals could not be defined.

Gypsum crystallizes in the form of lamellar, acicular and needle-like crystal grains; it often forms twins and grows in rosettes. Halite and sylvite form transparent cubes or cubo-octahedrons; sylvite, furthermore, produces prismatic discoid and needle-like crystalline grains. Picromerite forms short-prismatic and rhombohedral crystal habits. Hexahydrite forms elongated spear-shaped prisms; it is sometimes a thick acicular crystal formed by the faces of a rhombic prism and pinacoid. The crystals of epsomite are bipyramidal and have a prismatic habit; the most prevalent crystal forms in epsomite are rhombic prism and rhombic tetrahedron. Kainite crystallizes in the form of rhombic plates, sometimes acicular and prismatic crystals forming rosettes. Carnallite is usually barrel-like, bipyramidal, tabular, with polysynthetic twins. Bischofite forms fibrous aggregations which are composed of thin needles; the mineral is very unstable in solution and can only be stored at a temperature above 28-30°C. The size of the crystals is usually on the order of several micrometers, and thus they are hard to diagnose. The course of crystallization and solution can be studied on a microscopic heating stage.

To determine the concentration of inclusion solutions, the method of cooling until complete freezing of liquid is used. The freezing point is the melting temperature of the last crystal (Roedder, 1963; Mel'nikov, 1968); by determining this temperature we can determine the concentration of solutions. According to some data (Roedder, 1963), the freezing point of inclusion solutions in halite ranges from 22-72°C [i.e., -22 to -72°C]; other reports on inclusions in halide formations in the published literature have not been found. The cryometry method (freezing) can be successfully employed in studying highly concentrated solutions which at reduced temperature undergo certain changes and thereby produce additional data not only on concentration but also on composition.

STUDYING THE BULK CHEMICAL COMPOSITION OF SOLUTIONS OF INCLUSIONS

The most widely used method for studying the bulk chemical composition of inclusion solutions is the so-called method of aqueous extraction. The fluid of exposed inclusions is leached by water from the pulverized specimen of mineral or rock; after the filtrate evaporates completely the remaining concentrated solution is analyzed. The method of aqueous extraction still requires some improvements and standardization, to make it possible in the future to compare the findings of different laboratories (Roedder, 1958; Khitarov, 1965; Kalyuzhnyy, Pritula, 1968).

Since minerals in salt-bearing deposits are overwhelmingly water-soluble, the use of this method to study the composition of inclusions would appear impractical at first glance. But its use for halite in some instances yields satisfactory results (Petrichenko, Slivko, Shaydetskaya, 1968).

In the process of halite sedimentation during the precipitation of halite, all other elements, with the exception of a few, remain in solution because of the greater solubility of their salts relative to NaCl. It is also used to study the composition of solutions of inclusions in halite by the water extraction method. Evaporation of a water extract from pulverized halite to the required volume is accompanied by the precipitation of NaCl and potassium sulfate; the remaining solution is enriched gradually by those components which are typical for the inclusion solutions. This entire process was tested out in a water extract from halite of Lake Sasik-Sivash. Since the initial composition of the brine was known, the analytic results of the water extract were compared with the chemical composition of the lake water. It was found that the solution of the water extract was identical with respect to certain elements (lithium, bromine, strontium, magnesium and potassium). For these solutions with respect to magnesium and potassium, there was typically an increased quantity of calcium and ionic sulfate which were formed as a result of solution of gypsum (the presence of this mineral can be recorded in many halite slabs). Similar work was done with artificially constituted solutions which had an increased content of trace elements. The results of a comparison of chemical and spectral analyses of the water extract and the initial solution have been done.

On the basis of the water extract method we can ascertain a general picture of the chemical composition of the initial solutions from which the halite crystallized. When this method is used we must always bear in mind that it yields good results only when studying minerals with a single genetic type of inclusion; the composition of solutions in individual inclusions of different origin is often variable. For example, primary inclusions of zonal halite may contain sulfate solutions, while secondary ones may contain calcium chloride. In this case, the results of analysis of a water extract produce unreliable data. For this reason, material is chosen for a water extract when the inclusions are previously known and identical specimens are chosen for the test. The most "convenient" material in this regard is rock salt in a quiescent bed which has not been metamorphosed. The weight of the initial sample for the water extract depends on the number of inclusions in the mineral. In our experiments we intentionally used a large quantity of material in order to obtain reliable data on the chemical composition of the remaining solution. The weight figures are cited in Table 6 and the volumes can be reduced 10 to 20 times.

The sequence of steps of the water extraction method is as follows. The source rock salt weighing 12-17 kilograms is crushed to natural crystalline size; it is then washed with 4-5 liters of distilled water to leach from the surface segments of halite all intercrystalline solutions and terrigenous material; it is dried (t = 100°C), and sifted. For water extraction, under a binocular we chose plates with inclusions of a single genetic type; this work is usually impossible to do with metamorphic rock, which is rock salt from salt domes. It is most efficient to use halite from salt-bearing seams for this reason. The fragments are ground in a ball mill; the grain size should be sufficient to expose most inclusions. In our research they ranged from 0.0007 to 0.1 millimeter. Based on statistical processing of gross measurements of grain size it was found that these dimensions have a log normal distribution. Fragments 0.0075-0.0375 mm in size constitute 80 percent, those 0.0375-0.0825 mm in size are 18 percent, and those over 0.1 mm are almost 2 percent. This grain size is attained by pulverization in the mill for 50-60 minutes. After pulverizing the sample it is again washed with distilled water for 15-25 minutes; the quantity of water averages 40 percent of the ground weight of the sample. The saturated solution is separated from the washed sample and is evaporated to a volume which usually ranges from 1 to 3 percent of the initial quantity of water. The remaining solution is analyzed chemically and spectrally.

The results of chemical analysis can be used to ascertain the bulk composition and kind of inclusion solutions; spectrographic data and other analyses provide information on trace elements. For example, in some cases we found clear evidence that molybdenum, vanadium, copper and lithium of salt-bearing deposits are associated exclusively with solutions of liquid inclusions.

The average amount of solution which occurs within microinclusions in a sample can be calculated in terms of the loss of moisture during drying of a pulverized rock sample. The drying temperature is quite important for this value. At low temperatures (100-200°C) only free water is removed, while at higher temperatures the water of crystallization of aqueous hydrates and water adsorbed by the surface of halite evaporates [sic.]; for complete evaporation of water the sample must be heated to several hundred degrees (about 400-500°C). In our studies we dried pulverized weighed portions at up to 110°C. For example, in a sample from pulverized zonal halite of sedimentary origin there is about 0.6 percent water; adjusted to 10 kg of sample this yields 50-60 cubic centimeters of solution; consequently, the volume of the residual solution roughly approximates this value (see Table 6).

TABLE 6. SOME EXPERIMENTAL DATA OBTAINED BY WATER EXTRACT METHOD

Weight of pulverized sample, kg	Amount of water for washing, liters	Amount of solution obtained, liters	Characteristics of evaporated solution		
			volume l	density g/cm^3	pH
15.2	3.7	2.6	0.120	1.204	6.65
11.4	5.9	3.1	0.060	1.202	5.65
9.6	4.1	2.8	0.110	1.201	5.95
15.0	8.0	6.2	0.080	1.207	6.30
10.5	4.2	2.8	0.140	1.208	6.55
11.4	5.2	3.8	0.065	1.205	6.15
11.6	4.0	2.2	0.070	1.201	6.65
11.8	4.1	2.8	0.140	1.202	5.70
9.3	3.6	2.5	0.115	1.218	6.40

To obtain data on the gross chemical composition of mineral inclusion solutions, an alcohol extract may also be used (Slivko, Petrichenko, 1967). The sequence of these steps is similar to the aforementioned method of water extraction. A certain weighed sample of the test material is treated with ethyl (or methyl) alcohol at a temperature of 18-19°C after preliminary pulverizing. The proportion of alcohol and sample are 1:1 by weight. After removing undissolved material the alcohol is evaporated and the dry residue, first dried to 105°C, is analyzed. Solutions of inclusions and components of easily soluble salts go into solution in the alcohol extract, in addition to magnesium and calcium chlorides (Table 7).

TABLE 7. SOLUBILITY OF SALTS IN ALCOHOL* (IN GRAMS PER 100 GRAMS OF SOLVENT AT t = 15-25°C)

Salts	Ethyl alcohol	Methyl alcohol
NaCl	0.07	1.39
KCl	0.034	0.50
$MgSO_4 \cdot 7H_2O$	--	29.10
$CaCl_2$	20.50	22.60
$MgCl_2$	5.30	13.80
K_2SO_4	--	undissolved

* from Kratkiy spravochnik po khimii, Moscow-Leningrad, 1965.

According to numerous alcohol extracts from the minerals of potassium deposits it has been found that the weight of dry residue of the alcohol extract with respect to that of the initial sample is 3.0 to 3.6 percent: it depends on the solubility of the mineral in alcohol. Alcohol extracts may be used to study sulfate minerals owing to their low solubility in alcohols and are unsuited for carnallite, bischofite, tachhydrite which are readily decomposed by this solvent. Carnallite, for example, when reacting with alcohol decomposes and forms crystals of sylvite.

The reaction of alcohol and halite or sylvite has been studied thoroughly. The weight of dry residue of the alcohol extract from these minerals is 0.45 to 0.88 percent of the initial sample weight. Alcohol extracts from salt minerals may also contain magnesium chloride (up to 65 percent) with a subordinate amount of sodium and potassium chlorides (Table 8).

TABLE 8. CHEMICAL COMPOSITION OF DRY RESIDUE OF ALCOHOL EXTRACT (in percent)

Mineral	Na	K	Mg	Ca	SO_4	Cl	H_2O
Sylvite	16.48	1.47	6.89	undetected		46.86	28.70
Halite	9.98	1.44	10.53	0.63	traces	58.51	28.71

The process of interaction of solutions of inclusions with alcohol itself was studied under the microscope; at the instant of mixing halite, sylvite and sulfates precipitate out; all other components remain in solution. Due to the low solubility of sodium and potassium chlorides in alcohols, alcohol extracts always are marked by a relatively high content of magnesium and calcium chlorides; thus they cannot give the actual composition of inclusion solutions. Thus this method is useful only to study the presence of elements whose salts easily dissolve in alcohols. The alcohol extract method was justified in studying the distinctive features of lithium geochemistry in halide rock because lithium chloride dissolves easily in ethyl alcohol. This method yields positive results also in the study of inclusion solutions for strontium, calcium, copper, bromine, silicon dioxide and certain other trace elements.

In some instances we may use acetone or other organic solvents for extraction. Acetone extracts have a small volume of dry residue. For example, from 2.5 kg source rock we obtain a residue weighing 0.16 g, which equals 0.006 percent of the weight of the initial rock. These residues contain a large amount of certain trace elements which cannot be established using alcohol extraction.

The presence of rare and scarce elements in inclusion solutions can be ascertained according to the data from spectographic analysis of a specimen (Ermakov, 1950). The sample is selected with the maximum amount of inclusions, for example, in zoned halite or sylvite. Prior to analysis of this plate it must be thoroughly studied under the microscope to calculate the presence of xenogenic solid inclusions which it may lack after dissolving the mineral in water. We usually analyze a dry residue of the filtrate after evaporation using the spectrographic method. This method is useful only because it yields information on elements in inclusion solutions of varied type; sometimes this method is good for establishing strontium, copper, iron and manganese.

Finally, the gross fundamental composition of inclusion liquid may be determined according to solutions which are liberated from inclusions after heating. This method is used most effectively for authigenic minerals from salt-bearing deposits since the inclusions [in such minerals] are very small. The sequence of investigation is as follows. The crystal grain (quartz, fluorite, tourmaline, etc.) with its smooth polished surface is placed into a heating chamber and is heated until complete decrepitation of most inclusions. The solution reaches the surface of the crystal through microscopic fractures and instantly dries up; a dry residue remains in place of the solution. Consequently, since solutions of inclusions in authigenic minerals are for the most part highly concentrated, the dry residue on the polished surface is often clearly visible under the microscope. Then the plate is placed into a moisture chamber where, due to the hygroscopic nature of the salts, the inclusion solutions form liquid microscopic droplets which are collected in capillary tubes. This method can be used to study the composition of inclusion solutions even in non-transparent minerals (pyrite); the results of analysis are qualitative. With simultaneous collection of solution in several capillary tubes (assuming that the concentration of all solutions of microscopic droplets on the plate's surface is roughly identical), the results of several analyses can be compared, if one of the elements (e.g., chlorine) is taken as an arbitrary constant. This method permits the study of solutions from plates of minerals whose size ranges from 1 to 1.5 mm.

To determine the chemical composition of inclusion solutions of authigenic minerals, the method of water extraction is also used, but all steps are done with a small quantity of substance. In the initial sample a certain mineral is selected, whose monomineralic fraction weight ranges from 0.5 to 2.0 grams. The selected material is pulverized in an agate mortar and is washed with distilled water, whose weight is 2-3 times greater than the sample weight. After centrifugation and evaporation of the filtrate to a volume of 0.0 n to 0. n mm^3, the solution is studied using ultramicroanalysis. When using "microwater" extracts one must use certain constants in one's laboratory: weight of initial sample, volume of water for extract, centrifugation time, volume of residual solution and method of analysis. the most labor-intensive operation is to achieve a constant quantity of residual solution. In these instances we evaporated water extracts on watch glasses to the minimum quantity and the residual solution was transferred to glass tubes 0.5 mm in diameter; further evaporation was done there until the required volume was attained. The residual solution in these glass tubes was removed through capillaries for the microreactions. In all these manipulations, all cautionary steps stipulated by the method of chemical ultramicroanalysis must be observed. The extracts were used to study inclusion solutions in authigenic quartz, calcite, pyrite and fluorite.

MEASURING pH - Eh PARAMETERS OF SOLUTIONS OF INDIVIDUAL INCLUSIONS

Among the many variables of the salt accumulating environment, modern methods make it possible to specify rather easily those physical and chemical parameters which are controlled by the activity of hydrogen ions and electrons. According to the pH value and redox potential we can ascertain the detectable forms of many trace elements and their migratory ability in a salt basin. The pH - Eh indicators of inclusion solutions provide evidence on the formation of salt deposits as a whole and on the distinctive features of the crystallization environment of one mineral or another. A correct interpretation of data on measurements of redox potential and pH yields additional information about halogenesis and conditions of diagenetic transformation of a salt sediment.

pH Analysis

In the modern natural salt-forming environment which we find in evaporite deposits of continental and marine origin, the pH value ranges from 2 or 3 up to 10-11; the most common pH values are 6-9. Such wide ranges of pH variation are mainly associated with the genetic peculiarities of individual salt lakes and are governed by the chemical composition of brines and biochemical processes occurring in the salt basin. In one salt lake, alkaline-acid conditions may be different but the magnitude of variation of this parameter is usually negligible and is a function of the composition of sources feeding the lake, the composition and amount of gas dissolved in the brine, and the lithologic features of intrusive rocks. Great importance of pH value is possessed by temperature and pressure: when they increase, pH drops as a result of an increase in the dissociation constant of water and carbon dioxide (Alekin, 1966). The value of this parameter within the limits of a single basin undergoes seasonal and daily changes; pH of solutions of silty bottom sediments generally differ from surface brine; pH of highly mineralized solutions has different values vis-a-vis a solution of lower concentration, and so forth. Of the three basic chemical kinds of solutions of modern evaporite deposits, the highest pH values are typical for the carbonate type, owing to the relatively high content of a strong base (Na, K) and weak acid (CO_3, HCO_3); pH values of sodium lakes can reach as high as 10.5-11.6. The sulfate type of solution is characterized by the predominance of strong bases and acids (K, Na, SO_4), which creates weakly alkaline or neutral conditions.

Variation in the chemical composition of evaporite brines is accompanied by a gradual change in pH values towards lower values in direct metamorphism of the brine. During saline sedimentation pH of a solution generally drops significantly (Strakhov, 1962; Baas-Bekking et al., 1963; Krumbein, Garrels, 1960; Stashchuk, Suprychev, Khitraya, 1964).

Therefore, the results of measuring pH of inclusion solutions in minerals of salt-bearing deposits have considerable value in interpreting salt-forming conditions.

At the modern level of study of inclusions, the pH of solutions can be ascertained according to data of direct measurement of this value in a liquid inclusion, on the basis of pH measurements of residual solutions of water extracts, and in some cases by calculating the pH value (Kalyuzhnyy, 1957, 1960; Ryzhenko, Uchameyshvili, Savel'yeva, 1968). The most convenient method for pH analysis of inclusion solutions in salt minerals is direct measurement of pH in the inclusion.

The colorimetric method proposed by V.A. Kalyuzhnyy (1957, 1960) for analyzing pH of solutions of ultrasmall volumes can be successfully used to establish this parameter in highly concentrated solutions of inclusions of test minerals. As in the analysis of trace elements in solutions, pH is measured with the aid of an organic film. When measuring pH in solutions with a high concentration of sodium, potassium, magnesium and calcium chlorides the film also acquires a characteristic coloration, and the rate of reaction and the accuracy of single assays is somewhat lower than [more dilute?] solutions.

According to pH values of artificial saturated solutions, first measured on the LPM-60M device, it was found that single assay error of pH ranges from +0.3 to -0.6 (see Table 9). Therefore, the average error of one measurement is ±0.25; in our measurements we accepted an error of ±0.3. This method can be used to measure pH of a solution right in the exposed inclusion if its size is at least 0.07 mm. The

TABLE 9. COMPARISON OF RESULTS OF pH MEASUREMENT OF ARTIFICIAL SOLUTIONS USING TWO METHODS

Using glass electrode on LPM-60M	Microcolorimetric method	Analytic error
6.0	6.4	-0.4
6.8	6.6	+0.2
6.7	6.6	+0.1
8.0	7.8	+0.2
7.1	7.8	-0.6
7.1	7.2	-0.1
8.3	8.0	+0.3
5.6	5.4	+0.2
5.6	5.8	-0.2
average value		-0.3
6.80	6.84	+0.2

technique of preparing an inclusion for exposure is similar to what has been already described: after exposing the inclusion a microscopic piece of film is inserted directly into the inclusion solution. After several seconds or minutes the film is appropriately colored; all steps are performed with the necessary magnification under the binocular microscope in ordinary light.

If the inclusion is relatively large (over 0.5 mm), the pH is measured directly in the inclusion using a platinum (quinhydrone method) specially-built electrode (Petrichenko, Shaydetskaya, 1965, 1968). Using micromanipulators, first a mercurous chloride electrode whose intake opening is 15-20 microns is inserted, and then a platinum electrode with a tip diameter of 50-100 microns; on its end is set a capillary tube containing quinhydrone (Alimarin, Petrikova, 1968). To prevent the inclusion solution from drying out, all steps are performed in a moist chamber.

Glass electrodes may be used if there is a relatively large amount of test solution (Maslova, Esikov, 1965).

In studying the composition of liquid inclusions by the water extract method we obtain only qualitative values of this parameter. The resultant solution of the water extract does not reflect any pH value: thus data on pH measurement should not be interpreted regarding inclusion solutions.

When analyzing data on pH analysis of solutions of individual inclusions at normal temperature and pressure we should always remember that the pH of the medium depends a great deal on the composition of the dissolved gas, pressure, temperature and composition of the solution in which the inclusion was isolated (Barnes, Ellis, 1970). When an inclusion is exposed its internal system is disturbed and the true pH values naturally change. This applies in particular to gas-liquid inclusions in recrystallized minerals of salts which were formed under the influence of considerable pressure and high temperature, and the system was enriched with acid gases; the pH of this medium undoubtedly differs from our measurements of inclusion solutions. The negligible difference between the measurement and the true value of this parameter during crystallization of salts can be expected in the study of inclusion solutions in sedimentary minerals.

Our dozens of pH measurements of solutions in individual inclusions give evidence that this value on the whole ranges from 3.5 to 6.4 and only as an exception exceeds this interval. Only one pH measurement gave a value less than 2; this exception can be explained by the presence in solution of free hydrogen chloride (mass spectrometric data). Values of pH above 6.4 were not encountered in our experiments.

Eh Analysis

The redox potential of silty and chemical precipitates of modern evaporite deposits varies considerably: from +400 to -400mV (Bass-Bekking, Kaplan, Mur, 1963). These changes in Eh depend on the intensity of biochemical processes, the action of underground waters on the basin's natural brine, the degree of intermixing of basin waters, and so forth. This phenomenon in salt basins is completely regular, like the change in reduction conditions in silt sediments in oxidative conditions on the surface of the brine. The magnitude of this parameter and its sign are necessary to interpret the forms of occurrence of many trace elements in the brine of ancient salt basins and in solutions which take part in diagenetic processes (Krauskopf, 1963; Garrels, Christ, 1968; Stashchuk, 1968).

There are no Eh measurement data for inclusion solutions in minerals in either the domestic or foreign literature ("Inclusions of solutions and melts in minerals: Bibliography of Russian literature for 100 years," 1971; Redder, 1970 [Roedder, 1972?]). The first attempts to measure this parameter right in salt mineral inclusions using electrodes were made before 1965 (Petrichenko, Shaydetskaya, 1965). These parameters were measured using a specially built platinum electrode with an ordinary mercurous chloride electrode in the LPM-60M instrument.

The standard platinum electrode we replaced with an electrode whose platinum tip diameter was 0.05-0.1 mm; the end of the metal electrode was generally platinum. Before each measurement a conical capillary tube 2-6 mm long was set on the electrode. The internal diameter of the sharp end was 5-10 microns. The capillary is held tightly on the platinum tip by bonding the flat portion of the tip to its inner walls. The mercurous chloride electrode is set in a flat tray 1 x 2 cm in size; it is filled with saturated potassium chloride solution. The mineral inclusions are exposed in the regular fashion; the capillary tube with its platinum electrode are inserted as quickly as possible. The solution of the vacuole moves into the capillary and fills it completely; according to the size of the inclusion the platinum filament and capillary length are selected appropriately. When it fills the capillary, the solution of inclusion envelops the electrode; then the platinum electrode and capillary with the test solution are transferred to the tray containing potassium chloride. Only the end of the capillary is lowered into it, thereby closing the instrument circuit. Since the capillary is completely filled with the test inclusion solution, for some time the potassium chloride does not approach the capillary: this is sufficient time to read off the instrument readings. It has been found that under reducing conditions the fixed position of the instrument indicator is maintained for 15-30 seconds; then the needle begins to move freely, later deviating toward the positive size as atmospheric oxygen penetrates into the test solution. This appliance can be used for measuring inclusion solutions 0.1-0.2 mm in cross section.

Our proposed setup for measurements was checked using standard solutions with known Eh value (see Table 10). The net error for positive Eh values ranged from -3 to +50 mV. On the basis of these data we can assert that the Eh measurement of solutions with a platinum electrode yields rather precise data for small volumes of solution (the volume of the test solution is 0.0 n mm^3). In addition, one and the same platinum microelectrode has been used to conduct a series of measurements of an artificial solution saturated with respect to sodium and potassium chlorides and having a high content of magnesium (Table 11).

The platinum-calomel electrode pair must continuously be checked using the standard systems which are recommended by the corresponding instructions for the instruments. In addition to standard solutions we used

TABLE 10. RESULTS OF COMPARISON OF Eh MEASUREMENT DATA OF STANDARD SOLUTIONS USING PLATINUM MICROELECTRODE (t = 25°C)

Eh of standard solutions	Microelectrode measurement data, +mV		Deviation
	Single measurement	average value	
348	325 345 350 360	345	-3
230	286 284 286 286 284	285	+50
136	167 164 164	167	+30
110	104 100 104	103	-7

TABLE 11. MULTIPLE MEASUREMENT OF Eh OF ARTIFICIAL SOLUTIONS OF HIGH CONCENTRATION USING PLATINUM MICROELECTRODE (t = 25°C)

Solution 1, Eh +mV	Solution 2, Eh +mV	Statistical data
240	304	--
190	296	--
186	272	$\bar{x}_1 = 196$
186	250	$\bar{x}_2 = 251$
188	232	
200	248	$C_1 = 11.7\%$
178	260	$C_2 = 11.5\%$
228	250	-
170	238	--
--	234	--
--	228	--
--	200	--

a Zobella solution (Garrels, Christ, 1968) which produces values of Eh = +480 mV at t = 25°C. During Eh measurement of inclusions of small volumes with the aid of a platinum microelectrode some safety steps must be taken to eliminate the possibility of gross errors. It is desirable to prevent contamination of the platinum electrode: its purity is checked out under the binocular or even under the microscope prior to measurement. The working platinum elecrodes and capillaries are kept for about one hour in an atmosphere of nitrogen before exposing inclusions. We must remember that each platinum electrode has its own indications and differences: for example, a 50 mV potential is sometimes set up between measurements with two microelectrodes. Thus it is necessary to know the performance curve of each electrode and to calculate this factor continually when comparing data.

Our data give evidence that the values of redox potential of solutions of individual inclusions ranges from -260 to +320 mV. There is a clear-cut pattern observed in this regard. For solutions of primary inclusions of sedimentary halite (Permian) oxidizing conditions are typical; for solutions of certain inclusions of recrystallized halite from salt domes Eh values more typically correspond to reducing conditions.

The redox potential in solutions of mineral inclusions can be ascertained on the basis of the proportion and presence of iron (ferrous and ferric) (Garrels, 1962; Garrels, Christ, 1968; Stashchuk, 1968). The method proposed above for ferrous and ferric iron in solutions of individual inclusions by the method of organic film coloring completely satisfies the requirements for evaluation of the quality of Eh of individual inclusions. Parallel assays of Eh have been done for inclusion fluids using a platinum microelectrode and assays of ferrous and ferric iron. There was a totally predictable direct pattern: a solution with ferrous iron has lower Eh values: from -260 to +100 mV. On the other hand, the presence of ferric iron is most typical of inclusion solutions in zoned sedimentary halite in which the value of Eh corresponds to oxidizing conditions.

Some data on the Eh of solutions are obtained from xenogenic minerals (pyrite, anhydrite, goethite, hematite, sulfur), petroleum and others which are sometimes encountered in the inclusions of salt minerals.

THERMOMETRIC STUDY OF INCLUSIONS

The thermometric method, widely used to study inclusions in endogenic minerals, has until now been considered as unfit for multiple phase inclusions in halide inclusions.

The method of thermometry has been verified on inclusions in halite and sylvite. Multiple phase inclusions in other minerals we did not study, though in this respect there is some interest in polyhalite, kainite, anhydrite, langbeinite and other minerals with two-, three-, and multiple-phase inclusions.

In order to observe homogenization of inclusions in salt deposit minerals, we employed a thermochamber consisting of an asbestos housing around a core which was bored into a massive metal rod with openings for the thermometers. In the domestic and foreign literature, many different thermochamber designs have been described (Ermakov, 1950; Kalyuzhnyy, 1960; Redder, 1965 [Roedder, 1962?]; Dolgov, Bazarov, 1965). The primary requirement for the chamber is high precision of temperature measurements, convenience of operation, satisfactory illumination of the specimen, and possible use of lenses for high magnification (300-400 power). The chamber which we used for our research permits measurements of homogenization temperature to within ±0.5°C: the temperature is recorded by two thermometers with 0.5°C divisions. The rate of heating a specimen from room temperature to homogenization temperature is 0.5-1°C per minute.

Thermometric study was carried out on two-phase gas-liquid inclusions, liquid inclusions with daughter minerals, and unusual inclusions of petroleum with gas. To observe the process of homogenization a group of inclusions of the same genetic type was chosen: their size was usually 7-15 micrometers. Preliminary microscopic studies provided values for the phase ratio and percentage of inclusion filling. Inclusions in halite and sylvite have a regular geometric shape (Figs. 11, 15) and thus assays of volumes of the inclusion itself, gaseous phase and daughter mineral (cube of sylvite or halite) are not difficult. Measurements were made using a micrometer reticle. A group of inclusions (3-6 individuals) was studied; most of them are visually measured with adequate precision.

Gas-liquid inclusions in which the liquid phase is an aqueous solution yield homogenization temperatures form 39 to 115°C. We performed hundreds of measurements of homogenization temperatures; some inclusions were homogenized several times over 20-day periods; maintenance of temperature levels was completely satisfactory (Table 12). This is one distinctive feature in multiple homogenization of an individual inclusion: the first measurement of temperature is always 2-4°C lower than the next homogenization. Temperature stabilization is usually observed after the fourth or fifth measurements; consequently, in order to establish a more accurate homogenization temperature, the specimen should be heated at least three

TABLE 12. DATA OF MULTIPLE HOMOGENIZATION OF GAS-LIQUID INCLUSIONS IN HALITE* (temperature, °C)

	test number					
	1	2	3	4	5	6
	52.0	54.0	67.0	67.0	75.5	70.0
	55.0	57.0	70.0	68.0	76.5	72.0
	56.0	52.0	72.0	69.0	77.0	74.0
	54.0	61.0	71.0	70.0	78.0	73.0
	55.0	55.0	71.0	70.0	78.0	71.0
	54.0	55.0	72.0	71.0	79.0	72.0
	57.0	58.0	72.0	71.0	80.0	--
	57.0	54.0	71.0	72.0	80.0	--
	57.0	60.0	71.0	70.0	81.0	--
	56.0	58.0	--	72.0	79.0	--
	55.0	--	--	70.0	79.0	--
	55.0	--	--	70.0	80.0	--
$\overline{X}$	55.3	56.4	70.9	70.0	78.6	72.0
C,%	2.8	5.1	1.7	2.1	2.3	1.6

*Halite from rock salt of salt domes of Dniepr-Donets depression (Devonian)

times [sic.]. In some instances the system of inclusions remains homogenized even after cooling to room temperature; the gaseous phase occurs only after several hours or even on the next day. Sometimes in order to study a system from the state of equilibrium [i.e., renucleate a bubble], the temperature must be reduced to -15 or -30°C. The occurrence of metastable systems is typical of microscopic inclusions, whose temperature of homogenization is less than 60°C and gas pressure within the inclusion is negligible (under 10 atmospheres). Gas-liquid inclusions with a homogenization temperature over 65°C become heterogeneous at 15-20°C below their homogenization point.

On the basis of analysis of homogenization temperatures of gas-liquid inclusions and the volume of the gaseous phase at normal room temperature (25°C), a general direct relationship of these values was discovered. With an increase in the volume of the gaseous phase, the homogenization temperature increases in the following proportion: if the gas volume in the inclusions is 5.0-5.9 percent (volumetric), their homogenization temperature is greater than 120°C. If the gas volume is less than 1.0 percent, the homogenization temperature of inclusions also drops to 39-43°C (Table 13). But sometimes individual measurements on specific inclusions do not fall within this interval: this is associated with the composition and concentration of inclusion solutions. Gas-liquid inclusions with highly concentrated solutions of calcium and magnesium chlorides have a smaller volume of the gaseous phase than those inclusions whose solutions are saturated with sodium chloride alone, despite similar temperature conditions of formation. This is the result of the fact that thermal expansion of solutions of lower concentration is greater than the coefficient of expansion of highly concentrated solutions.

The hundreds of observations provide evidence that in the 40-120°C range, coincidence of homogenization temperatures of gas-liquid inclusions in halite and sylvite totally satisfies the requirements of the thermometric method. Above this temperature microfractures form around the inclusion, leading to destruction of the inclusion walls and the results of homogenization cannot be duplicated and the preliminary proportion of phases is not restored; thus reliable homogenization temperatures of gas-liquid inclusions in halite and sylvite are obtained only below this boundary temperature.

Two-phase, liquid plus daughter mineral inclusions in halite also have certain value for interpreting the conditions of salt formation. As a result of the fact that halite in these inclusions [is] encountered only among potassium deposits, the captive mineral may be sylvite (Fig. 16),

TABLE 13. HOMOGENIZATION TEMPERATURES OF GAS-LIQUID INCLUSIONS IN HALITE AS A FUNCTION OF GASEOUS PHASE VOLUME

Number of observations	Gas phase volume vol. percent	Homogenization temperature, °C
15	5.0-5.9	over 120
32	2.0-2.5	70-95
23	0.8-1.5	40-55

carnallite, epsomite, bischofite. Inclusion solutions are saturated with respect to those salts, which formed the solid phase. Their composition is usually magnesium chloride, but sometimes there is an elevated content of calcium chloride. The high saturation of solutions with salts creates conditions for a metastable system state since the volumetric expansion of these solutions in the 20-100°C temperature range does not differ substantially from the volumetric expansion of the host mineral (halite). Thus slight changes in temperature vis-a-vis the mineral formation temperature do not always lead to the development of a gaseous phase.

A solid phase is more often formed when temperatures drop: microinclusions are more typical of this type of crystallization. In microinclusions there is only one liquid phase of a supersaturated solution whose metastable state can sometimes be disturbed by sudden cooling. In two-phase inclusions the solid may amount to 0.5-4.5 percent (volumetric) if it is sylvite. But if the solid phase is carnallite, bischofite or epsomite, the volume may reach several dozens of percents. In a certain mineral growth zone, the inclusions generally have an identical phase ratio, proving their suitability for study of the lower temperature boundary of halite crystallization. The homogenization point of these inclusions is the temperature at which the daughter mineral is completely dissolved. The maximum temperature which we reached in homogenization of these two-phase inclusions in halite was 90-95°C. The coincidence of homogenization temperatures in multiple analyses in one and the same inclusion yields a difference of ±5°C. Inclusions whose homogenization temperature is 50-60°C remain one-phase liquids for a long time after they are cooled to room temperature; the solid phase does not appear until after several days or even weeks.

The compositon of the new solid phase sometimes differs from the original one. If liquid inclusions with sylvite are homogenized, sylvite also precipitates when cooled. If the solid phase is carnallite, after homogenization of the inclusion and cooling sylvite can also precipitate. A system of certain inclusions, after homogenization, remains in the metastable state for an infinitely long time, even after freezing. Figure 35 illustrates the sequence of dissolving of carnallite during heating to 90°C. In this respect, the inclusion configuration does not change, as typical of halite, since the solubility of sodium chloride at increased temperatures (100°C) hardly increases at all. During heating of inclusions in sylvite, their form changes considerably owing to the high solubility of potassium chloride at elevated temperatures.

When three- and multiple-phase inclusions are heated, a gas bubble forms at first (between 40-55°C [sic.]); then the daughter minerals dissolve between 75-120°C. Multiple phase inclusions more often demonstrate higher homogenization temperatures, but it is still impossible to define them thermometrically. The temperature conditions of recrystallization of salts above 120-150°C quite possibly may be judged on the basis of theoretical methods in which the phase ratio in the inclusions, the composition of the solutions and the coefficients of volumetric expansion of phases and host mineral are calculated.

During the study of inclusions in halite from salt domes of petroleum and gas-bearing regions, liquid inclusions have been discovered which are composed of petroleum and gas (Fig. 6); their volumetric proportions in certain crystals of halite are constant. This demonstrates that at the instant of preservation of hydrocarbons the system was homogeneous; only when the temperature fell to 20-25°C did matter break down into three phases. Homogenization temperature analysis and proportional analysis convince us that these inclusions may be used to interpret the conditions of halite crystallization. The steady state homogenization temperature of certain inclusions is demonstrated by multiple measurements (Table 14).

TABLE 14. DATA OF MULTIPLE HOMOGENIZATION OF GAS-LIQUID INCLUSIONS IN HALITE WHOSE LIQUID PHASE IS PETROLEUM*
(temperature, °C)

Test run number				Statistical data
1	2	3	4	
106.	104.0	93.0	94.0	$\overline{X}_1 = 107.5$
107.	105.0	93.0	94.0	$\overline{X}_2 = 105.5$
107.5	105.0	94.0	94.0	$\overline{X}_3 = 94.0$
107.5	05.0	93.5	93.5	$\overline{X}_4 = 94.5$
109.0	106.0	95.0	95.0	$C_1 = 1.1\%$
109.0	108.0	96.0	96.0	$C_2 = 1.1\%$
109.5	106.5	95.0	93.5	$C_3 = 1.2\%$
108.0	107.0	95.0	94.0	$C_4 = 1.1\%$
107.0	106.0	93.0	96.0	
107.0	105.0	--	95.0	
107.0	105.5	93.0	--	

* Rock salt halite of salt domes of Dniepr-Donets depression

The results of [the first few] homogenization temperature measurements are somewhat lower than in the later ones; a similar pattern is observed in multiple heating of the aforementioned gas-liquid inclusions (see Table 12 [sic.]). In contrast to inclusions which contain aqueous solutions, two-phase inclusions of petroleum and gas can be used to establish the temperature of salt-formation near 140°C; up to this temperature indicators are clear and fixed. Above a temperature of 145°C there was no research. The volume of the gaseous phase in inclusions containing petroleum and gas, whose homogenization temperature is 90-110°C, ranges from 5.3 to 7.5 percent, averaging 6.5 percent (volumetric).

In some cases, we can judge lower values of mineral crystallization temperature by xenogenic material such as sulfur in halite. If it can be established that the sulfur was trapped by the mineral in the molten state, then it is easy to resolve questions about the lower value of the crystallization temperature of the host mineral.

In order to explain the temperature conditions of formation of salt deposits, it is important to have thermometric studies of inclusions in authigenic minerals. The method of decrepitation is successful for inclusions in these minerals; it is based on the recording of intensity of explosion of inclusions during heating of pulverized mineral (Scott, 1948; Ermakov, 1950; Lesnyak, 1964; Dolgov, Serebrennikov, 1968). It is felt that the frequencey of explosions increases sharply at 15-25°C above the average homogenization temperature of these inclusions. This method is widely used since it can yield a large number of results in a shorter time than the method of homogenization of individual inclusions. Effective results have been obtained in the study of inclusions in minerals with imperfect cleavage. Minerals such as calcite, dolomite and anhydrite, yield unclear indicators of microinclusion decrepitation (Smit, 1968; Butuzov, Khetchikov, Shaposhnikov, 1968; Sokolov, 1970).

STUDY OF THE GASEOUS PHASE OF INCLUSIONS

The components of the gaseous phase of inclusions in minerals of salt-bearing deposits can be judged according to the results of analysis of gas in individual inclusions and analysis of their gross composition.

Analysis of a gas in individual inclusions is done by absorbing gaseous components with the appropriate reagents. Its content in a bubble can be calculated according to the quantity of gas removed in a certain reagent. Data of thorough research are evidence of the quantitative values of H_2S, CO_2, NO, O_2, CO, H_2, C_nH_{2n} in a volume of a bubble 0.02 mm in diameter (Dolgov, Shugurova, 1966; Shugurova, 1968). The use of this method to analyze gas inclusions in salt-bearing rock minerals is virtually identical to methods recommended by Dolgov and Shugurova. Based on analyses conducted on the composition of the gaseous phase of many inclusions in halite, CO_2, H_2S and C_nH_{2n} have been identified.

Semiquantitatively, certain components in inclusion gases can be determined by dissolving the mineral in the reagent itself. For this purpose, a plate of mineral (sylvite or halite) 0.2-0.3 mm thick with gaseous or gas-liquid inclusions are immersed in a solution of some reagent which generally dissolves the mineral itself. While the mineral is being dissolved, gas is liberated from inclusions which are exposed. For more accurate measurement of the bubble, observations are made only of the surface of the absorbing reagent, which must be covered with a cover glass. The distance between the mineral and the cover glass should be no more than 0.1-0.2 mm, since if it is increased, a great deal of the gas is absorbed during motion from the inclusion to the surface of the solution. At minimum distances (fractions of a millimeter) gas passes this course within 1 second and, of course, is absorbed in insignificant quantities [sic.]; the total absorption reaction occurs on the surface of the solution within several dozen seconds.

The high saturation of halite or sylvite with gaseous inclusions makes it possible to perform up to ten assays of gas at once; the coincidence of data is completely satisfactory. For instance, in determining heavy hydrocarbons in inclusions of halite several assays were obtained (12 determinations) ranging from 19 to 42 percent (volumetric) with an average content of 30 percent. Thus by dissolving the mineral in the absorbing reagent, we obtain a large number of data on a particular component of the gaseous phase and also simplify the method of extracting gas from individual inclusions. To calculate the volume of gas, we use a bubble whose diameter is no greater than 0.15 mm and shape is most similar to a sphere. Experience gained in studying gas phases in halite inclusions has shown that to determine only a single gaseous component it suffices to have a bubble of 0.015 mm in diameter.

For gross analysis gas is obtained by pulverizing the sample in a vacuum mill with subsequent extraction from the pulverized rock or mineral (Kovalishin, 1962, 1968; Ellinson, 1968; Kalyuzhnyy, 1960). In addition, it may be obtained by dissolving the sample in water (Nesmelova, 1959, 1961; Cherepannikova, 1949; Cherepannikova, Rogozina, 1961). The proposed method of extracting gas from inclusions by dissolving minerals in water, in spite of its simplicity, has one major shortcoming. During dissolution of samples, there occurs selective absorption of certain gases; for example, acid gases almost completely dissolve in water. Furthermore, all other gases are intensively absorbed, regardless of the very high concentration of solvent at the end of the experiment (density of solvent reaches 1.150-1.180 g/cm^3). Studies on extraction of gas from inclusions in halite prove convincingly that their results do not provide a quantitative picture of the proportion of gaseous components in microinclusions. This method can be used only for qualitative description of the gross composition of gases. In addition, a gas which is obtained is constantly contaminated by atmospheric nitrogen and oxygen. Table 15 clearly shows that a large part of the gas is absorbed by water, and for that reason the proportion of individual components in gases is different; hydrogen sulfide contained in the inclusions was not detected by the analyses.

TABLE 15. COMPARISON OF GROSS COMPOSITION OF GAS (IN VOLUMETRIC PERCENTS) OBTAINED FROM INCLUSIONS IN HALITE USING THE METHOD OF DISSOLVING (1) WITH A COMPOSITION OF GAS DISSOLVED IN WATER (2)

Gas type: free gas (1), gas from solvent (2)	Gas volume cm^3	O_2 + Ar_2	N_2	H_2	CH_4	C_2H_6	C_3H_8	C_4H_{10}	C_5H_{12}
1	10	16.45	80.90	2.53	0.039	0.007	0.013	0.019	0.039
2	40	14.56	85.85	0.37	0.003	0.001	0.001	trace	trace
1	18	19.58	77.13	1.95	0.713	0.104	0.210	0.210	0.107
2	40	21.37	78.45	0.15	0.012	0.002	0.005	0.005	undet.
1	120	18.06	81.26	0.31	0.148	0.048	0.058	0.075	0.057
2	50	15.27	84.32	0.34	0.034	0.006	0.009	0.011	0.006
1	28	18.58	77.84	3.22	0.013	0.004	0.015	0.028	0.017
2	55	19.94	79.76	0.03	0.130	0.045	0.044	0.029	0.016

During dissolution of individual samples, the volume of gas depends on the mineral's concentration of gaseous inclusions. The maximum concentration of gas is typical of white sylvite: the volume of gas is 2.5-15.5 cm^3 per 100 grams of substance. A large amount of gas is also typical of salt dome halite: some grains of this mineral contain up to 40-50 cm^3 of gas per 100 grams of sample.

For the most part, gas of inclusions in minerals of salt deposits is under pressure; it can be determined after the inclusion itself has been exposed. The magnitude of pressure wthin inclusions at room temperature roughly corresponds to the relationship of gas volume following exposure of the inclusion to its initial volume (Boyle's Law). To determine pressure, the mineral should be dissolved in a 50 percent aqueous solution of glycerin, making it possible to observe the free process of mineral dissolution and simultaneously calculate the volume of gas in inclusions after exposure. The diameter of a gas bubble in the solvent should be measured right after the inclusion is exposed, since within 10-15 seconds the bubble is mostly absorbed by the glycerin. It is completely feasible to make 8-12 pressure measurements in a single specimen.

RESULTS OF STUDY OF INCLUSIONS IN HALIDE MINERALS

Interpreting Salt-Forming Conditions According to Inclusion Study Data

The chemical composition of solutions of ancient salt basins and conditions of formation of salts have been studied by various methods. The works of M.S. Kurnakov, S.F. Zhemchuzhnyy, V.I. Nikolayev (1938), Yu.V. Morachevskiy (1939), and M.G. Valyashko (1962) have aided in developing a method which makes it possible to employ physical and chemical laws to establish the circumstances of salt deposit formation. The graphic method is used to process material and analyze it. The following assumptions are made in developing this method: the formation of all large salt deposits is associated with sea water whose composition is similar to modern sea water; the process of crystallization of salts developed metastably or stably. Salt rock is the product of sea water which has evaporated, and this determines the initial chemical and mineralogic composition of the rock itself.

The chemical composition of solutions of an ancient salt basin can also be determined on the basis of a thorough study of all halide strata which were formed as a result of total evaporation of the salt basin. This analysis was conducted by Ya.V. Samoylov for a Zechstein sea (Alekin, 1966) and by K.B. Donchenko (1963) for the Ciscarpathian neogenic sea; this method is used only for the total salt rock profile: from gypsum and anhydrite to bischofite deposits.

Practical study of the geochemical aspects of halide deposits permits the assertion to be made that the composition of the brine of ancient salt basins is rather easily established on the basis of analysis of solutions of primary liquid inclusions in pegmatigenic halite [sic.]. Only 6-8 complete chemical ultramicroanalyses of solutions from individual inclusions in various halite samples would have to be done to arrive at preliminary conclusions about the nature and type of solutions which existed during the period of crystallization of the mineral.

On the basis of analyses of solutions from many inclusions in halite through the cross section of salt-bearing strata, we can easily find patterns of change in the composition of the ancient basin brine for its entire period of existence. Sampling of a particular bed along the strike of halide deposits gives us information about the uniformity of evaporite deposit solutions and about the regular change in concentration of certain elements (potassium in particular) in a region of salt accumulation. With the data obtained, it is possible to put together prognostic maps of potassium-magnesium ore prospecting work. By knowing the chemical composition of the salt basin brine, study data on inclusions in halite can be used with adequate precision to determine the concentration of potassium, magnesium, sulfate ion, etc.; this permits us to judge the degree of salination of the basin. According to the results of complete chemical anlysis of inclusion solutions, allowing for data on trace elements, we can understand the effect of metamorphic factors on the evaporite brine and the role of marine and underground waters which are in the salt basin and evaporate.

The study of the isotopic composition of hydrogen, oxygen and sulfur (in sulfate waters) should play some role in resolving these questions. Unfortunately, there are no such analyses for solutions of inclusions in salt minerals; technically speaking, the isotopic analysis of ancient water is completely feasible, in spite of the very small dimensions of inclusions in sedimentary halite. The origin of the waters of a salt basin may to some extent be classified according to analysis of solutions of inclusions in terms of their trace elements. A high content of trace elements in solutions serves as a direct indicator of the effect of underground hydrothermal waters on the composition of an evaporative basin which is drying up (White, 1965; Boyko, 1963, 1969).

As a rule, the chemical type of solutions of primary inclusions in sedimentary minerals of salts and the composition of authigenic minerals have a particular relationship. If salt formation occurred with the evaporation of sulfate type solutions, anhydrite predominates among the authigenic minerals. The evaporation of calcium chloride waters promotes dolomite formation; the predominating authigenic minerals are dolomite and calcite; anhydrite may be absent or it may be in a subordinate quantity.

The results of pH - Eh measurements of solutions of inclusions may be used to judge the redox condition of basins in a past geologic era. We should consider the presence in solutions of ferrous and ferric iron, manganese, certain anions, and also xenogenic minerals (pyrite, hematite, sulfur). In studying inclusions in minerals, we generally get rather voluminous information on pH - Eh conditions of the salt forming medium, but these data are for the most part not recorded by researchers. In addition, the measurements of these parameters may quite well explain the causes for such inclusions in sylvite, carnallite, bischofite, and other minerals such as hematite, goethite, magnetite, etc.

In some instances, inclusions in sedimentary minerals aid in determining the temperature which salts precipitated. In this context, two-phase liquid inclusions with captive minerals are quite interesting. Further work toward the development of a method of thermometric research of these inclusions will aid in judging the temperature conditions of salt precipitation in the past geologic era. Even now we have established the regular sequence of temperature changes from the inception of halite crystallization in certain deposits; it took place at 39-43°C, before the inception of sylvite which precipitated at 65-75°C. With these inclusions, we can even establish temperature change within one seasonal intercalation of salt. Without using thermometric research, and based only on ordinary visual microscopic study of inclusions in minerals of the lower and upper portion of the intercalation, it is sometimes possible to ascertain a change in solution concentration and elevation in salt formation temperature. Within one intercalation among potassium salts, a temperature change has been established ranging from 30 to 65°C. The formation temperature is also shown by one-phase liquid inclusions: their presence in the minerals of salt-bearing deposits indicates temperatures similar to that of the brine in contemporary salt lakes.

One of the inherent composite parts of modern evaporite brines, is the presence of portions of dissolved atmospheric gas. We should thus expect that relicts of solutions of primary inclusions in halite also carry a certain amount of information about the atmosphere of past geologic eras.

Inclusions in sedimentary halite can be used to judge the depth of a salt basin. Since the thickness of the seasonal intercalation of salt in salt sediments is rather easy to determine, we can determine the height of the column of evaporated water. Our calculations and experimental data indicate that the height of the water column is 5.7 times greater than the thickness of rock salt which precipitated, with a density of sediment of 2.1 g/cm^3. To calculate the depth of the basin in a particular month and a particular period of its existence, we must have data on the measurement of thickness of the seasonal intercalation of rock salt and on the presence of sedimentary halite in the intercalational footing and its roof. Then we establish the content of potassium or other element in the solution of the primary inclusions in halite selected at the inception of salt precipitation and in its final stage of sedimentation. The difference in the content of potassium in the solutions of the two sample inclusions will prove the change in concentration (usually an increase) of the solution due to evaporation. Since potassium, magnesium and the sulfate ion do not participate in sediment formation during the formation of rock salt, their content in solution as its evaporates is inversely proportional to the volume of water remaining. On the basis of this proportion, we can easily determine how many times the volume of water changed, as long as no new portions of brine entered the basin during evaporation.

If we designate the unknown depth of a salt basin with X, the height of the column of evaporated water, calculated earlier according to the thickness of the seasonal intercalation, satisfies the equation $X = \frac{X}{a/b}$

and equals 5.7 h. In this equation, b is the initial concentration (g/l) of any element (potassium, magnesium, sulfate ion) in the first period of halite crystallization (a specimen taken from the base of the bed); a is the concentration (g/l) of the same element in the final stage of halite precipitation (a speciment taken from the top of the bed). The formula $X - x/(a/b) = 5.7$ can easily be transformed: $X = (5.7\,h)/(1 - b/a)$, where h is the thickness of the seasonal intercalation of rock salt in centimeters. The depth of the basin is also calculated in centimeters.

Calculations of the depth of certain ancient salt basins in the territory of the Ukraine yielded values ranging from 2 to 4 meters.

Thus inclusions in sedimentary halite and other salt minerals allow us to obtain concrete and totally objective data on the composition of brine and the nature of change in time and space, the patterns of temperature changes in a single season and in some period of existence of the entire salt basin. All of these data are based exclusively on factual material and may serve as the basis not only for reproducing the formative conditions of individual sediment layers, but also to explain paleothermal conditions on the planet's surface.

The formation of salt deposit is not limited to ordinary chemical sedimentation; the processes of [original] crystallization, recrystallization, and nucleation of new minerals alters considerably the basic aspects of sediments of ancient evaporite deposits. The most commonly studied salt deposits are metamorphic rocks which have only retained the external traces of the initial sediment. Rocks in certain salt domes undergo the deepest metamorphism due to the hydrothermal activity around the structure's periphery.

In modern terms (Ivanov, 1953; Valyashko, 1962), there are several stages of metamorphism, each of which has certain characteristic aspects. Inclusion study data also confirm the stages in the changes in halide rock which begins with their formation in an open salt basin and ends with complete recrystallization of rock in response to various external factors.

As we know, sedimentary halite, which crystallizes in the form of waves, takes on holohedral forms only in a salt deposit [sic.]. Inclusions in this type of halite are confined to soluble portions of mineral situated between its growth zones. In terms of chemical composition of solutions and other parameters, these inclusions hardly differ from inclusions in sedimentary halite [sic.]; in some cases these inclusions are typified by more concentrated solutions and comparatively low redox potential. These inclusions are rather clearly differentiated in specimens from sedimentary zonal halite. We have not randomly touched upon halite alone, since other halide minerals with zonal structure did not produce such clear signs by which it is possible to differentiate inclusions of the first two stages of salt crystallization.

In a buried deposit there is partial recrystallization of salt sediment and formation of new minerals. The inclusion fluids in such minerals is generally metamorphosed towards a reduction in sulfate ion (if salt basin brine belongs to the sulfate type), but in some cases the amount of calcium is increased. More profound transformations of sediment lead to the occurrence of multiple phase inclusions in minerals, proving the increased temperature which existed at some time in buried deposits. For the most part, diagenetic transformations of salt sediment are not accompanied by elevated temperatures; the minerals formed contain one-phase liquid inclusions or inclusions with daughter minerals. The metamorphism of bedded deposits (judging by deposits in the Ukraine) usually ends in the diagenetic stage.

More profound metamorphism is typical of halide rock in salt domes. Research on inclusions in salts from domes clearly revealed different kinds of epigenetic metamorphism. During hydrometamorphism of halide sediments, there is a redeposition of minerals, most of whose inclusions are one-phase, liquid, and of irregular shape; at an increased temperature (above 45-50°C) gas-liquid inclusions are formed during metamorphism in minerals: their gas is under pressure. Inclusions in minerals formed in tectonic metamorphism (without the effect of other kinds of metamorphism) are basically liquid, but sometimes they contain dissolved gas. The migration of these inclusions is governed by conditions of crystallization of the mineral under the action of plastic deformation. Thermometamorphism plays a major role in the formation of salt domes in the Dniepr-Donets depression. For salts recrystallized by means of thermometamorphism, there are typically composite inclusions in a state of aggregation which produces a homogenization temperature over 120°C. Profound thermometamorphism leads to the formation of mainly gaseous inclusions in minerals. According to the temperature, the thickness of zones disturbed by thermometamorphism ranges from several meters to 300 meters or more. We have studied specimens of rock chosen from the periphery of a salt dome where hydrothermal outcrops have been recorded. Research on inclusions in halite succeeded in establishing that the effect of the temperature of intrusive rock occurs at a distance of 150-200 meters. Burst inclusions may prove the thermal effect on halide rock.

Thus according to inclusions in minerals within a single deposit, we can quite clearly establish the sequence of metamorphic stages, determine the site and role of sediment transformation processes in formation of the deposit, and refine conditions of crystallization of one mineral or another. Inclusions studies have made it possible to judge almost all the physical and chemical parameters of the mineral forming medium: pressure, temperature, pH - Eh conditions, and chemical composition of solutions and gases.

APPLIED VALUE OF THE RESULTS

In addition to other indicators which aid in the search for potassium salts among halide deposits, the results of analysis of inclusion solutions in sedimentary halite, we believe, can also be utilized as an index of potassium content of deposits. The results of analysis of solutions can very accurately depict the type of potassium ore manifestation, i.e., we can judge the mineral composition of potassium ores of an almost unexposed deposit. Inclusions can be used to trace the pattern of change in potassium content in solutions of evaporites from which rock salt was crystallized. Data on the content of potassium and magnesium content in salt basin brine and the stage of sedimentation of rock salt are very valuable in prospecting for potassium salts. An increased content of potassium in solutions (above 15 g/l) of inclusions in halite proves the possible presence of potassium rock in salt deposits. Unfortunately, this method has not been checked out in practice, but the simplicity of the notion suggests that the results of the study of inclusions to prospect for potassium and magnesium, as well as for other ores in halide formations, can be employed with success.

From research and prospecting work, we know that sometimes halide beds cannot be classified according to generally accepted methods. This assumption was developed in drilling for petroleum and gas in the Dniepr-

Donets depression, where Devonian rock salt has broken through Permian salt deposits which are also rock salt. Many methods have been used to classify the two salt layers, but the results were poor. On the basis of liquid and solid inclusions in halite of Devonian and Permian rock salt, we found the actual difference in the composition of the brine of ancient evaporites. The brine of evaporites of a Devonian basin had a chlorine-calcium-magnesium composition with increased potassium content. By calculating these data, on the basis of analysis of an inclusion solution and the presence of certain solid inclusions in halite, we divided the halide stratum according to age. Of course this differentiation is only possible if there is an actual contrast of the chemical composition of the inclusion solutions.

Inclusions in salt minerals may be used not only to establish the age of some halide stratum, but also to compare salt-bearing deposits within a single region. When this type of work is done, the results of primary inclusions only must be compared in mandatory sequence (for sedimentary minerals), because inclusions in recrystallized minerals only bear information about the conditions of their recrystallization.

The study of inclusions is also of some value for interpreting data on certain rare and scarce elements in salt-bearing deposits. It has been found that many trace elements do not form independent compounds in salt deposits and do not enter as an isomorphic impurity in the composition of minerals. Some of them, especially lithium, iodine and copper, are associated exclusively with solutions of liquid inclusions in salt minerals. The discovery of the natural forms of trace elements in potassium-magnesium rock is of major importance in the development of a technology for comprehensive processing of ores.

In salt mines there is a danger from time to time of contamination of mined products with explosive gases. The cause of their appearance often remains unexplained. Perhaps the comparison of analysis of gas from inclusions in minerals with gas from mined products will shed some light on the origin of gases. The chemical composition of inclusion solutions in minerals is also useful for hydrogeologic scientists at salt mines.

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FIGURE CAPTIONS

Figure 1. Arrangement of tested liquid inclusions in halite (1-5). Start of halite crystallization marked "A". (Don Basin, Permian) 40 X.

Figure 2. Forms of primary inclusions in minerals. A) tubular liquid inclusions in halite, 70 X; B) halite inclusions in sylvite, 40 X; C) round liquid inclusions in langbeinite, 70 X; D) liquid inclusions in astrakhanite, 20 X.

Figure 3. Relic of sedimentary zonal halite (1) in recrystallized mineral (2) due to plastic deformation (Transcarpathia, Neogenic) 180 X.

Figure 4. Liquid inclusions in syngenite formed due to repulsion of mechanical particles during mineral growth (Ciscarpathia, potassium rock leaching zone) 150 X.

Figure 5. Xenogenic solid inclusion of anhydrite in halite (Donbas, Permian) 80X

Figure 6. Inclusion of petroleum (1) and gas (2) in halite (Dniepr-Donets depression, Romensk structure, Devon. 100X

Figure 7. Basic gas inclusions formed due to healing of fractures: A) inclusions in halite (Donbas, Slovyansk structure, Devonian) 130X; B) inclusions in sylvite (Ciscarpathia, Neogenic) 140X.

Figure 8. Secondary inclusions in minerals of salt-bearing rock (60X): A) gaseous inclusions in halite; B) gas-liquid inclusions in syngenite; C) gas-liquid inclusions in anhydrite; D) gas inclusions in sylvite; E) liquid (solution + petroleum) inclusion in halite.

Figure 9. Zonal halite growth structure formed under constant thermodynamic conditions (Ciscarpathia) 25X.

Figure 10. Original liquid inclusions in sedimentary zonal halite. (Don Basin, Permian) 150X.

Figure 11. Liquid inclusions in halite which occurred due to action of exogenous bodies on mineral during growth: A) two-phase inclusion: 1. solution; 2. gypsum; 3. terrigenous material (Transcarpathia, Neogenic) 160X. B) two-phase inclusion: 1. solution; 2. gas; 3. gypsum (Dniepr-Donets depression, Adamov stratum, Devonian), 180X.

Figure 12. Halite-entrapped solution (1) with terrigenous material (2); clearly visible gas bubble (3) of round shape (Don Basin, Slovyansk structure, Devonian) 100X.

Figure 13. Original liquid inclusions in halite: 1. inclusions in zonal sedimentary halite; 2. inclusion in central portion of faces of transparent segments of mineral (Dniepr-Donets depression, Verkhnyolanivsk stratum, Permian) 140X.

Figure 14. Gas-liquid primary inclusion in langbeinite formed as a result of mineral growth (Ciscarpathia, Neogenic) 200X.

Figure 15. State of aggregation of matter in inclusions in halite (70X): A. two-phase inclusion: 1. solution; 2. carnallite (captive); B. three phase inclusion: 1. solution; 2. epsomite (captive); 3. gas; C. compound inclusion: 1. solution; 2. epsomite (captive); 3. xenogenic material, 4. gas, 5. petroleum; D. gas-liquid inclusion with xenogenic phase.

Figure 16. Primary two-phase inclusions in sedimentary zonal halite: 1. solution, 2. sylvite (Starobin deposit, Devonian) 80X.

Figure 17. Gas-liquid inclusions: A. in halite whose crystallization occurred at t = 120°C and pressure about 70 atm (Dniepr-Donets depression, Adamov stratum, Devonian) 250X; B. in polyhalite (Ciscarpathia, Neogenic) 250X.

Figure 18. Decrepitation of liquid inclusions in halite due to increased temperature (Don Basin, Slovyansk structure, Devonian) 250X.

Figure 19. Basically gaseous inclusions in halite recrystallized due to plastic deformation. Clearly visible terrigenous material (1) and quartz grain (2) (Don Basin, Slovyansk structure, Devonian) 250X.

Figure 20. Basically gaseous inclusions found in sylvite on border of colored portion (dark area) and transparent portion of mineral (Starobin deposit, Devonian) 400X.

Figure 21. Basically gaseous inclusions in white sylvite (Ciscarpathia, Neogenic): A. tubular inclusions 200X; B. cubic-octahedral gaseous inclusions (1) and solid inclusion of halite (2), 150X.

Figure 22. Arrangement of solid xenogenic inclusions in plastically deformed halite (Donbas, Slovyansk structure, Devonian) 75X.

Figure 23. Solid inclusion of sulfur in halite (Donbas, Slovyansk structure, Devonian) 300X.

Figure 24. Solid elongated inclusions of halite in langbeinite (Ciscarpathia, Neogenic) 240X.

Figure 25. Solid inclusions: A) halite in sylvite (Ciscarpathia, Neog.) 100X; B) sylvite in halite (Dniepr-Don depression, Romensk structure, Devon) 100X; C) hematite and magnetite in carnallite (Solikamsk deposit, Permian) 200X.

Figure 26. Liquid inclusion in halite (Artemov deposit, Perm.) 20X.

Figure 27. Solid inclusions in halite: A. inclusion of sylvite (Dniepr Don depression, Romensk structure, Devon.) 50X; B. inclusion of bischofite.

Figure 28. Basically gaseous inclusions in halite. Halite was formed due to crystallization from melt (Dniepr-Don Depression, Kaplintsov structure, Devonian, rock salt in contact with diabase) 800X.

Figure 29. Primary three-phase inclusions in zonal sylvite. Dark portion of photo is red sylvite (Starobin deposit, Devonian) 140X

Figure 30. Solid inclusions of halite in white sylvite: A. cube of halite (1) surrounded by finer inclusions of rounded halite (2). Around the large crystal is a clear zone without inclusions (Solikamsk deposit, Permian), 180X. B. elongated inclusion of halite (1) among which are inclusions of sylvite (2) (Ciscarpathia, Neogenic) 130X; C. round inclusion of halite (1) with gas bubble (2), whose inner pressure is 250 atm (Ciscarpathia, Neogenic) 200X.

Figure 31. Liquid inclusions in langbeinite (Ciscarpathia, Neog.) 120X

Figure 32. Burst liquid inclusions in langbeinite (Ciscarpathia, Neog.) 120X

Figure 33. Three-phase inclusion in langbeinite due to dehermetization. Sylvite is solid phase (Ciscarpathia, Neog.) 170X.

Figure 34. One-phase liquid inclusions in gypsum (Donbas, Slovyansk structure, Cap rock) 25X

Figure 35. Sequence of dissolution of captive mineral (carnallite) in liquid inclusions of halite during heating of specimen from 20°C to 86°C (1-4). Reduction of temperature caused precipitation of sylvite (5) at t = 38°C.

Indices

The user should keep in mind the following features of these indices. The indexing procedures and entries are evolving (particularly with this volume) 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 both possible spellings, e.g., Ye and E, ...iy and ...ii, etc. As all entries in the Translation section are also entered 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 are generally ignored. The mineral host for the inclusions studied is indexed except for quartz and decrepitation studies. Entries that would include too many page references are listed without page numbers. Some entries with broad and diffuse applicability (e.g., "Geobarometry, methods and comparisons") have only a few of the most pertinent page references.

LOCALITY INDEX

Notes: See page 275. Individual deposit place names are indexed only when significant data are presented. Inexact place names (e.g., "Soviet Far East") are not entered, nor are individual mines in districts known by a district name. Soviet place names may be listed under various transliterations and in particular, with different endings; thus Began and Began'skii, Blyava and Blyavinsk, Kochkar and Kochkarskoje, Volhynia and Volyn.

Errata

Note: This listing includes corrections to all published volumes, but does not reproduce errata published earlier. The editors would appreciate notice of any other errors or omissions.

TEXT

Volume	Page	Item†	Line	
6	102	6	11	Change bean to beam.
9	141	4		Change to (In English)
10	12	2	7	Change to revealed
11	36	4	6	Change to "...can not be used..."
11	114	4	3	Changes pages to 171-222

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Volume	Page	Item
6	201	Symposia on inclusions - change iv to v
8	222	Electron microprobe - add p. 179
8	222	Equipment for cooling inclusions - add p. 179
8	222	Heavy metals - add p. 179
8	223	Laser microprobe - add p. 179
8	223	Mass spectrometry - add p. 47
10	345	Gemstones, inclusions in - add 72(2)
10	347	Mass spectrometry - Change to See Analysis methods
10	347	Mineral deposits, Gold - delete p. 9
11	281	Under Inclusions in minerals - move Amphibole up 4 lines
11	281	Under Inclusions in minerals - change Aximite to Axinite
11	286	Move items "significance" and "water in" to right, as subheading under Silicate melt inclusions

†Partial items are also counted.

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