FLUID INCLUSION RESEARCH

PROCEEDINGS OF COFFI

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SUBSCRIPTION INFORMATION

Publication of this volume for 1971 follows close to that for 1970, in an attempt to bring Fluid Inclusion Research - Proceedings of COFFI up to date and hence more useful. As this is essentially a one-man, non-profit after-hours operation, the Editor would very much appreciate it if all subscribers would help in cutting down time-consuming and unnecessary correspondence and billing procedures by placing standing orders. These can be revoked at any time.

Price per volume, still $3.00 US, postpaid. Limited stocks of the first three volumes are still available. Make checks payable to COFFI and send all checks and orders to Edwin Roedder, Editor of COFFI, U.S. Geological Survey National Center, Stop 959, Reston, Va. 22092 USA.

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EDITOR'S PREFACE

Fluid Inclusion Research - Proceedings of COFFI was started in 1968 as an offshoot of the Commission on Ore-Forming Fluids in Inclusions (COFFI) of the International Association on the Genesis of Ore Deposits (IAGOD). Although closely connected with COFFI and IAGOD, the publication of Fluid Inclusion Research is independently arranged, and separately financed with a loan from the International Union of Geological Sciences. The original plan was that it would provide abstracts or annotated bibliographic notes of papers published during the volume year that either contain inclusion data or are pertinent to inclusion workers, English translations of inclusion papers from foreign languages, where available and not otherwise published, and notices and programs of forthcoming meetings and symposia.

This volume pertains mostly to the literature for 1971, but a few older items are included that were omitted in previous issues due to oversight or unavailability. Although each abstract and translation is duly credited, the Editor wishes to acknowledge, in particular, the help of Drs. M. Fleischer and B. Poty who provided translations of many Russian titles, figure captions, etc. He is greatly indebted to Dr. Sergius Theokritoff for the translation of three Russian articles and to Drs. Andrusenko, Ermakov, Imai and Manuchariants for supplying translations of their own articles. He is also indebted to Drs. D.B. Vitaliano and D. Alverson, who provided the translations of parts of an important Ukrainian book. Many individuals, too numerous to list, have helped by sending the Editor books, reprints, references, and copies of abstracts. He is particularly indebted to Prof. Ermakov for copies of Russian books. Chemical Abstracts, of Columbus, Ohio, has most graciously permitted the use of a limited number of their copyrighted abstracts, as indicated by "C.A.", or the full abstract citation. Dr. W. L. Marshall of Oak Ridge National Laboratories kindly provided the rare and important volumes of abstracts of the International Geochemical Congress held in Moscow. The Editor has had to revise some authors' abstracts rather extensively, particularly those from foreign language journals, in order to clarify the language, but has not attempted to bring the bibliographic citations in translated articles up to Western standards. To authors of pertinent articles that have been omitted or are misquoted here in his haste, or through language difficulties, his apologies ahd his request to have these things called to his attention; to authors whose Authors' abstracts have been drastically shortened, edited or revised, 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. There are gross inconsistencies in the methods of citation, transliteration, abstracting, and indexing; these shortcomings are blamed mainly on the lack of time on the Editor's part, with the exception of abstracts of articles dealing with decrepitation, to which he gives short shrift due to admitted personal bias. As before, the Editor will be glad to furnish free 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. Otherwise, photocopies of the originals can be provided at $.25 per page.

NOTICES OF MEETINGS AND SYMPOSIA

PAST SYMPOSIA

The Fourth All-Union Conference on Thermobarometry met at Rostov-on-Don, Sept. 1973. The program of the meeting lists 135 papers, almost all on inclusion topics. Translations of these titles will appear in the next volume of Fluid Inclusion Research, and we may expect that, as in the first three such All-Union conferences, printed volumes (in Russian) of the proceedings of the conference will appear within a year or so.

Two symposia on fluid inclusions were organized, under the auspices of COFFI, at the IMA-IAGOD meetings in Japan, Aug.-Sept., 1970. The program for these symposia listed the titles and authors for 43 papers. Of these, 12 appeared as abstracts or full papers in the 1971 Symposium Volume and hence are given here; most of the remaining 31 papers (mainly from the USSR) were scheduled for presentation but not given verbally and hence were not printed in the 1971 Symposium Volume, although abstracts of 18 of these were printed in the 1970 Abstracts Volume and hence were reproduced in the 1970 issue of COFFI. As only titles of the remaining 13 papers are available, they have been ignored here.

FUTURE SYMPOSIA

Aug. 23-Sept. 6, 1974. NATO Advanced Study Institute, "Volatiles in Metamorphism", Nancy, France and Chiareggio, Italy. For information write Prof. P.M. Orville, Dept. of Geology and Geophysics, Yale University, Box 2161, Yale Station, New Haven, Conn. 06520.

Sept. 8-14, 1974. Centenary celebration of The Société Géologique de Belgique, Liège, Belgium.

Sept. 9-17, 1974. International Symposium on Water-Rock Interaction, Prague, ČSSR. Abstract deadline Dec. 1, 1973. For other information write Dr. T. Pačes, Secty. General, Geol. Survey, Malostranské nám. 19, 11821 Praha 1, CSSR.

Sept. 12-18, 1974. Ninth General Meeting, International Mineralogical Association, Berlin-West and Regensburg (FRG). There will be sessions on 1.) Pegmatites, and pegmatite minerals; 2.) Fluid inclusions in crystals; 3.) Secondary minerals in ore deposits; 4.) Gem minerals and gemology; and 5.) Mineral genesis and crystal growth. At least 17 papers on fluid inclusion subjects are scheduled for presentation at one or the other of these 5 sessions. Abstract deadline January 1, 1974: Prof. Christel Tennyson, IMA Meeting '74, Technische Universität, D-1000 Berlin 12, Hardenbergstrasse 42, W. Germany.

Sept. 19-25, 1974. International Association on the Genesis of Ore Deposits, Varna, Bulgaria. Abstract deadline past. For information write Prof. B. Bogdanov, Secty. Organiz. Committee, Geological Institute, "36" Street, block 2, Sofia 13, Bulgaria. One or more sessions are planned on fluid inclusion work.

Oct. 7-10, 1974. Symposium on Metallization and Acid Magmatism, Karlovy Vary, ČSSR.

Oct. 7-12 Swiss Mineralogical Society 50th Anniversary meeting, Neuchatel.

ABSTRACTS, TRANSLATED ABSTRACTS, OR ANNOTATED CITATIONS TO WORLD LITERATURE

Editor's notes: Although most of the references that follow are dated 1971, a few earlier ones are included which were missed in earlier issues of COFFI and are particularly pertinent or had only been given before as a literature citation, without abstract. In general, older literature citations are not given if they are also to be found in the extensive bibliography in the Editor's publication: Data of Geochemistry, Sixth Edition, U.S. Geological Survey Professional Paper 440JJ, Composition of Fluid Inclusions (available from the U.S. Government Printing Office, Washington, D.C. 20402, $2.75, Stock no. 2401-1211).

AKSENOV, V. S., 1971, Geochemistry of elements in the ore-forming process (exemplified by the Zyryanovsk polymetallic ore deposit, Rundy Altai) (abst.): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 1, p. 407-408 (in English). (Author at K.I. Satpsev Institute of Geological Sciences, KSSR Academy of Sciences, Alma-Ata and V.I. Vernadsky Institute of Geochemistry and Analytical Chemistry, USSR Academy of Sciences, Moscow).

In the process of formation of the Zyryanovsk deposit the following elements have played an important role: Cu, Pb, Zn, S, Ba, Au, Ag, Cd, Hg, Se, Te, As, Sb, Ga, Tl, Mo.

The ore deposit has been generated by the hydrothermal process in subvertical zones of intensive schist formation of folded rocks. Ores are represented by pyrite, sphalerite, chalcopyrite, galena and by lesser amounts of tetrahedrite. Near-ore alterations are expressed by chloritization, sericitization, silicification, rarer by carbonatization. The ores were deposited from almost neutral solutions (pH = 5.3 - 7.2) at temperatures from 360 to 150°C at a depth of 3-4 km.

By the time of migration time, elements are divided into two groups: 1) Elements introduced into the ore-localizing structure at the pre-ore stage. They are the following: Ga, Tl, Mo, partly S. 2) Elements, introduced at the ore stage, such as: Cu, Pb, Zn, S, Ba, Au, Ag, Cd, Hg, Se, Te, As, Sb, Bi, partly Mo.

Elements of the first group were chiefly concentrated in laminated alumosilicates (chlorites, sericites), which were deposited at the pre-ore stage of the potassic-magnesia metasomatism.

Elements of the second group were formed in the sulfide part of ores, B, leaving behind all other elements by the time of introduction. Therefore a pyrite stage was singled out. Other elements (Cu, Pb, Zn) were simultaneously supplied and formed two polymetallic stages. At the first stage massive and impregnated fine-grained ores were deposited from strongly saturated solutions. At the second stage macrocrystalline veins of quartz - barite - calcite - sulfide were formed from slightly saturated solutions. A maximum supply of As and Mo took place at the beginning of the stage. Cd and Hg, as analogues of Zn, were almost completely crystallized after pyrite formation. The other elements accumulated in the end-products of crystallization - in chalcopyrite and galena.

Still one element group (Co, Ni, In, Ge) was singled out which had not been introduced into the ore-localizing structure and are contained in ores in small amounts. At the ore-forming stages these elements, like those of the first group, were spread and selectively concentrated in certain sulfides.

The causes of element separation in the hydrothermal process are determined by the properties of their atoms: lithophylic and siderophylic elements were supplied to the pre-ore stage and chalcophylic ones to the ore stage.

External factors of migration (permeability of the ore-localizing structure, remoteness from ore-supplying faults, temperature gradient) conditioned element zonation in the deposit. (Author's abstract)

ANDERSON, B. W., 1971, Gem Testing: New York, Van Nostrand, 384 pp.

Refers to use of inclusion composition (qualitative) in gem identification, and shows photomicrographs of multiphase inclusions in emerald, sapphire, etc. (One photograph (Fig. 12.5, p. 220) shows 3 opaque hexagonal daughter crystals (hematite?) in parallel array - possibly epitaxially arrayed on the sapphire host? Ed.)

ANDRUSENKO, N. I., 1971, Mineralogy and genesis of Iceland spar in the Siberian platform: Moscow, Izdat. "Nedra", 227 pp. (in Russian).

Individual chapters deal with various aspects of the geology, tectonics, magmatism, petrography, petrology and mineralogy of the Iceland spar deposits of the Siberian platform. Chapter 5 (28 pp) deals with the thermobarogeochemistry of the hydrothermal calcite-forming solutions, as deduced from fluid inclusions, and Chapter 6 (11 pages) with the thermodynamic regime and character of the process of hydrothermal mineralization of the deposits, and their genesis. 149 references; 53 tables; 49 illustrations (E.R.)

ANTHONY, T. R. and CLINE, H. E., 1971a, The interaction of liquid droplets with a grain boundary in large accelerational fields: Philosphical Magazine, v. 24, no. 189, p. 695-703. (Authors at General Electric Research and Development Center, Schenectady, New York)

A buoyant water droplet was migrated through a 15° twist boundary in a crystal of KCl in a large accelerational field. On passing through and away from the twist boundary plane, a columnar 15° tilt boundary linking the droplet and the twist boundary plane was generated. The surface tension of this columnar boundary exerted a force, pulling the droplet back towards the twist boundary plane. The accelerational field was adjusted so as to produce a buoyant force on the droplet which just balanced the backward pull of the columnar tilt boundary. The balancing accelerational field indicated that the surface energy of a 15° tilt boundary in KCl is 75 ± 20 ergs/cm^2. (Authors' abstract) (See also Cline and Anthony, 1971a)

ANTHONY, T. R. and CLINE, H. E., 1971b, Thermal Migration of Liquid Droplets through solids, Journal of Applied Physics, v. 42, n. 9, p. 3380-3387 (Authors at General Electric Research and Development Center, Schenectady, New York).

A transparent solid and liquid were chosen to study the thermomigration of liquid droplets through solids. Irreversible processes associated with the transfer of atoms between the solid and the liquid phases at the solid-liquid interface of the droplet were found to have a profound influence on the migration behavior of the liquid droplets. For large droplets, these interface kinetics cause the droplet to disintergrate in a thermal gradient. In smaller droplets where the containing effects of surface tension are relatively greater, the droplets experience a prolonged transient period of thermomigration during which there is a monotonic increase in the velocity of the droplet and a gradual distortion of the droplet shape. Following this transient period, the smaller drops enter a steady-state period during which both their shape and velocity remain constant. The steady-state velocity of droplets in this region decreases with decreasing droplet volume and falls to zero below a critical droplet size. This variation of droplet velocity with size produces an increased rate of collision and coalescence of droplets during thermomigration. (Authors' abstract).

ANTHONY, T. R. and SIGSBEE, R. A., 1971, The thermomigration of spherical bubbles through a transparent polycrystalline solid: Acta Metallurgica, v. 19, p. 1029-1035 (in English with French and German abstract) (Authors at General Electric Research and Development Center, Schenectady, New York).

The velocity of spherical gas bubbles migrating in a thermal gradient through polycrystalline camphor was studied as a function of bubble size and temperature. Above 10 μ diameter, the bubble velocity was independent of size and had the same temperature dependence as the vapor pressure of camphor. Below this size, the bubble velocity apparently decreased with decreasing bubble diameter. Migrating bubbles were observed to drag grain boundaries when the bubble concentration on the grain boundary was large. When the concentration on a boundary was very high, coalescence of these bubbles occurred and mobile lenticular voids similar to those observed in nuclear reactor fuel elements were generated. (Authors' abstract).

ANUFRIEV, YU. N., MOSKALYUK, A. A., and BELIK, D. M., 1971, Evolution of the composition of mineral-forming solutions on the basis of two deposits of rock crystal in the Urals, in Investigations of mineral-forming solutions and melts in inclusions in minerals, N.P. Ermakov and L.N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 30-39, (in Russian), (See Translation Section).

APFEL, R. E., 1971, Tensile strength of superheated n-hexane droplets: Nature Phys. Sci, v. 233, no. 41, p. 119-121.

A novel experimental procedure for measuring tensile strength in superheated droplets is described using test droplets in an immiscible host fluid column having a thermal gradient and a standing acoustic wave to maintain the droplet against gravity. Of interest in the problems of metastability of previously homogenized inclusions. (E.R.)

ARKHIPCHUK, P. Z., 1971, Gearksutite from the Manzhinsk deposit: L'vov Mineral. Sbornik, v. 25, no. 2, p. 181-184 (in Russian with two-line English abstract).

The rare fluoride mineral gearksutite, ($CaAl(OH)F_4 \cdot H_2O$) has been found in the fluorite ores of this deposit. The quartz-fluorite veins formed in three stages: fluorite-bearing (fluorite, quartz, and calcite), fluorite-quartz (fine grained fluorite and porcellaineous quartz), and kaolinite-gearksutite (earthy fluorite, gearksutite, kaolinite, and viseite (a sodium calcium aluminum silicophosphate). Inclusions in the quartz fluorite veins yield temperatures of 130-190° (uncorrected for pressure). (Gearksutite is one of the fluoride minerals that might well turn up as a daughter mineral), (E.R.)

BABKIN, P. V., KLUBOV, B. A., SYROMYATNIKOV, A. L. and FEDOTOV, D. N., 1971, Finds of bitumen in mercury occurrences in Chukotka: Dokl. Akad. Nauk SSSR, v. 198, no. 2, p. 397-398 (in Russian). Translated in Doklady Acad. Sci. USSR, v. 198, p. 51-52 (1971) (Authors at Northeastern Interdisciplinary Research Institute, Siberian Division, Academy of Sciences, USSR, Magadan).

The deposits (Tamvatney and Matachingay) are quartz-carbonate or chalcedony veins in listvenite bodies along a contact of serpentine and sediments. Viscous, dark brown to greenish liquid bitumen, with a very strong petroleum odor, occurs in vugs up to 1cm or larger. It contains 56.79% oils, 5.4% alcohol- and benzene-extractable resins, 27.02 benzene-extractable resins, and 10.81% asphaltenes. Other occurrences consist of black brittle solids (anthraxolite). This is one more of the many reports of organic compounds with mercury deposits, either associated or as fluid inclusions (E.R.)

BAKUMENKO, I. T., 1971, The peculiarities in magmatic processes as found from the study of inclusions in melts, (abst.): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 1, p. 90-91 (in English) (Author at Institute of Geology and Geophysics, Siberian Branch of the USSR Ac. Sci., Novosibirsk, U.S.S.R.).

One of the new trends in thermobaric chemistry is determination of chemico-physical peculiarities in magmatic processes as found from the study of inclusions of melts and those of transmagmatic and postmagmatic solutions. To solve this problem we used mineralothermobarometric methods of investigation.

1. Intervals of temperatures of crystallization of a number of magmatic minerals found in the rocks of different composition and depth were determined for the homogenization temperatures of inclusions of melts. It is shown that phenocrysts of a majority of effusive rocks are crystallized at rather high temperatures of the order of 1150°-1350°C and still higher. Intrusive rocks crystallize at lower temperatures, namely granitoids crystallize between 800 and 1000°C. High temperature of crystallization

of melts suggests their relative "dryness".

Under favorable tectonic conditions melts are capable of becoming rich in water. In this case the temperature of crystallization decreases by 100-200°C. Such "low temperature" inclusions in melts have been so far encountered in the phenocrysts of pumice (740-780°C) and vein formed odinites (sic) (600-620°). They are correlated with later stages of crystallization.

2. From thermometric and ultramicrochemical analyses performed in collaboration with Dr. N.A. Shugurova and N.M. Popova it turned out to be possible to reconstruct the geochemical history of the processes of migration of volatiles during magma crystallization for different tectonic regimes. Rather smooth evolution of the volatiles was found for the magmas crystallized under relatively tranquil tectonic conditions. General tendency observed is accumulation of volatiles with higher solubility and removal of the volatiles with insignificant solubility. This process was fixed for the processes of formation of acid differentiates of the basaltic magmas.

For periodically erupting basaltic centers, an oscillating regime of evolution in volatiles is characteristic. The oscillations reflect periodic removal of the most mobile volatiles at the time of eruption and the new portions of gases supplied from the deeper sites. Under such restless tectonic conditions a stability in the composition of erupting basalts has been observed.

3. Direct analyses of the fluid compounds of inclusions indicate that in the experimental work with the systems approaching natural ones one must use not only water but also CO_2 as volatile components (for granitic systems) and CO_2 and N_2 (for basaltoid systems). In addition to these components the most important volatiles of natural magmas are gases of the group $SO_2 + H_2S + HCl$ and $HF + NH_3$ and sometimes H_2 and hydrocarbons (for alkalic melts).

4. The barometric study of inclusions indicates a wide interval of pressure at which processes of crystallization and transformation proceed in the magmatic minerals. Maximum observed pressures attain several kbars. (Author's abstract).

BALITSKIY, V.S., 1969, Meeting on mineralogical thermobarometry and geochemistry of mineral forming solutions: Geol. Rudn. Mestorozhd., 1969, v. 11, n. 1, p. 99-101 (in Russian).

A brief review of the major papers given at the Sept. 9-15 1968 Conference on fluid inclusion studies, held at VNIISIMS. (E.R.)

BARANOVA, N. N., and SUCHSHEVSKAYA, T. M., 1971, Ore elements in hydrothermal solutions and the conditions of their deposition, (abst.): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 1, p. 278-279 (in English) (Authors at V.I. Vernadsky Institute of Geochemistry and Analytical Chemistry, Academy of Sciences, Moscow, USSR.

Ore elements are transported by hydrothermal solutions in different complex forms.

The solutions, forming the middle-temperature (250-100°C) sulfide ores are characterized by moderate values of salinity (1-10%) and nearly neutral reaction, as found from chemical analyses of inclusions in minerals.

The average values of concentration for major components are close to 0,1-1,0 mole/l, (and) for minor components (Mg, F, sometimes K, Ca) - 0,1 mole/l. It is difficult to estimate correctly the concentration of sulfur in sulfide form and sulfide/sulfate ratio because of absence of redox potential data for our systems. When such data were available (for example in the case of associations with pyrrhotite in sulfide-cassiterite deposits) the most probable range of sulfide ion concentration appears to be near 0,001-0,1 mole/l. The concentration of trace components (Li, Rb, Cs, Sr, NH_4, B) in the solutions, forming the cassiterite-sulfide and middle-temperature base metal ores is in the range 0,001-0,1 m/l.

The concentration of some ore elements (Pb, Cu, Ag) from singular analyses of water leachates from inclusions can be estimated as: 10^{-3} mole/l [at the] stage of deposition of the major part of ore substance) and 10^{-5} mole/1 (after the deposition of the major metal ores).

The data on the composition of the hydrothermal solutions and on the equilibria of complex formation lead to the conclusion that the metals in these solutions exist in the form of mononucleic complexes, positively charged or neutral.

Thus, it can be shown, that lead forms the following complexes in the hydrothermal solutions: $PbCl^+$, $PbSO_4^{\circ}$, $PbCO_3^{\circ}$, $PbOH^+$, $PbHS^+$. Such metals as Cu, Zn, Ag can form along with mentioned anionic ligands, complexes with ammonia as well: $Cu(NH_3)^{2+}$, $Zn(NH_3)^{2+}$, $AgNH_3^+$.

Composition of all metal complexes present and temperature of its solution are decisive in deposition of metal sulfides.

Calculations and preliminary experimental data show that formation of PbS in the solution, containing 10^{-5} m/l Pb and $2{,}4 \cdot 10^{-7}-1{,}4 \cdot 10^{-4}$M [sic] begins at 150° and 300°C correspondingly. Deposition of Zn, Ag, Cu occurs at 1,5-2 orders higher concentration of S than in the case of Pb. (Authors' abstract).

BARSUKOV, V. L, SUSHCHEVSKAYA, T. M. and MALYSHEV, B. I., 1971, Composition of solutions forming pitchblende in a uranium-molybdenum deposit: Atomic Energy, v. 31, no. 1, p. 28-34 July, 1971 (in Russian).

The authors present a paragenetic diagram for the deposit (in andesitic volcanic rocks) showing in sequence from early to late: chlorite, pitchblende, coffinite, calcite, pyrite, marcasite, chalcopyrite, sericite, molybdenite, sphalerite, galena, silver, sulfasalts, and hematite (for the upper levels) and fluorite, calcite, chlorite, pitchblende, coffinite, goethite, anhydrite, pyrite, marcasite, chalcopyrite, sericite, molybdenite, sphalerite, galena, and silver sulfasalts (lower levels). There are two generations of pitchblende in each sequence. Inclusions in calcite formed simultaneously with the early pitchblende have homogenization temperatures of 112-145°, and decrepitation temperatures of 130-150°. Analyses are given of inclusions from pitchblende, calcite, and galena. They show H_2O (% of sample) 0.23 (calcite) - 4.30 (pitchblende), and ions (g/l): Na 0.02-3.8; K 0.01-2.5; Ca 0.2-10.9; Mg 0.2-0.7; Cl 0.3-14.1; So_4 3.0-22.5; HCO_3 0.1 -21.4; CO_2 (in mol/l) 0.22-1.16; pH (calculated from data on carbonate equilibria at 150°) 3.9-6.7. Calculations are presented of the concentration limits for Ca and SO_4 in equilibrium with calcite and anhydrite. (Adapted from partial translation provided by Dr. Sushchevskaya).

BARTHOLOMÉ, P. and PIRMOLIN, J., 1971, Fluid inclusions and stratiform mineralization at Kamoto, Western Katanga: Soc. Mining Geol. Japan, Spec. Issue 3, p. 355 (Proc. IMA-IAGOD Meetings '70, IAGOD vol.)

At Kamoto, copper and cobalt are found as sulfides in two stratiform orebodies. The host rock is dolomite, chert or shale, and is conspicuously laminated. There is no metamorphism and no schistosity. It has been proven that mineralization was emplaced before tectonic deformation.

The two ore bodies are separated by a few meters of a barren dolomitic chert. The texture and structure of this rock will be described in detail, more particularly the chalcedony remnants, the large dolomite crystals which reach several centimeters in size, and the interstitial calcite. The dolomite is ordered.

Fluid inclusions have been found in the large dolomite crystals. Some of them countain a bubble and three daughter minerals; two of these have a cubic morphology and the third one is tabular. The behavior of these inclusions on heating is described. The bubble disappears at 140°C and the last crystal at 240°C. By leaching the crushed dolomite with doubly distilled water, a solution is obtained where Na: K is about 1.4 and (Na + K): Cl is about 0.4.

The meaning of these data is discussed with regard to the genesis of the ore, especially in the light of the close association between mineralization and sedimentary structures on one hand, of the evidence, presented earlier, for an economically important diagenesis on the other. (Authors' abstract) (See next page)

The abstract for this paper was first published in 1970 - see Fluid Inclusion Research, 1970, vol. 3, p. 10 (Ed.)

BARTON, Paul B., Jr., BETHKE, Philip, ROEDDER, Edwin, and RYE, Robert O., 1971, Tentative interpretation of the chemistry of the ore-forming fluid for the OH vein, Creede, Colorado (abst.): Econ. Geol., v. 66, p. 1265.

The compositions and textures of ores from the OH vein record numerous fluctuations in the composition of the ore fluid. Throughout most of the depositional history quasi-equilibrium appears to have been established. However, there is also evidence for periods during which the ore fluid was temporarily under or oversaturated in several minerals. A recirculating ore fluid appears to have dissolved ores at depth and reprecipitated them at the top of a convecting cell as a form of hypogene enrichment. Hydrogen/deuterium measurements indicate that deep-seated rather than meteoric water dominated the fluid.

Studies of fluid inclusions indicate: an ore-forming chloride brine with Na/K-10 (atomic) and 4 to 12 weight percent total salts, a temperature range of ore deposition at 190°-265°C; and a depth of the top of the ore body of 1,500 feet. The presence of both K-feldspar and sericite in and around the vein indicate a pH of 5.5 to 6.0. Fugacities of oxygen and sulfur are buffered by reactions involving chlorite, hematite, and (or) pyrite. The ore fluid was sulfate-rich and sulfide-poor but total sulfide exceeded total metals. The complexing ligand for the ore metals was probably chloride rather than sulfide or bisulfide.

A recurrent, but volumetrically minor, characteristic of the sphalerite is iron-rich (up to 22 mole percent FeS) growth bands in iron-poor (<1 mole percent FeS) crystals. These are attributed to intermittent mixing of a reduced fluid from depth with the cell of convecting, more oxidized, ore fluid. (Authors' abstract, with typo. corrected).

BARTON, P. B., JR., BETHKE, P. M. and TOULMIN, M. S., 1971, An attempt to determine the vertical component of flow rate of ore-forming solutions in the OH vein, Creede, Colorado: Soc. Mining Geol. Japan, Spec. Issue 2, p. 132-136 [Proc. IMA-IAGOD Meetings '70, Joint Symp. Vol.] (Authors at U.S. Geological Survey, Washington, D.C. 20244, U.S.A.)

This estimate (several millimeters per second), based on the size of loose and embedded hematite flakes in the ore, is pertinent to the problems of the distinction of solid inclusions accidentally trapped in fluid inclusions, and true daughter minerals. (E.R.)

BAUMANN, L, HARZER, D., LEEDER, O., and RÖSLER, H. J., 1971, On the nature of mineral forming solutions in some hydrothermal deposits of Central Europe, (abst.): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 1, p. 312 (in English) (Authors at Freiberg, German Democratic Republic, Bergakademie).

The Central-European postmagmatic vein mineralizations belong to the best investigated on earth as regards mineral content, paragenesis and genesis. More recent investigations into the geochemistry of the vein minerals and their liquid and gaseous inclusions confirmed the findings arrived at till now and result, in part, in new genetic aspects.

The liquid inclusions of the fluorite-barite deposits of the Vogtland and the Harz mountains were chemically analyzed for the main constituents Na, K, Cl and H_2O and spectrographically for Mn, Hg, Ba, Ni, Cu, Pb, Zn and Hg. In the gaseous inclusions the contents of H_2, N_2, CH_4 and CO_2 were determined by mass spectrometry. With minerals of the same paragenesis the isotope ratios of the elements O, C and S were found out. Furthermore, by homogenization analyses and from oxygen-isotope values, the temperatures of formation could be established.

Comprehensive O- and S-isotope determinations were carried out on the high-grade thermal sulphide mineralizations and gangues of the Freiberg deposits. Based upon these results and further investigations, interesting statements could be made concerning the origin of the solutions and their changes in the process of mineralization. Especially remarkable is the partial mixing of the hydrothermal water by external waters. (Authors' abstract).

BAZAROV, L. SH., and KOSALS, YA. A., 1971, Thermodynamic conditions of formation of rare-metal-bearing pegmatites and apogranites (abst.): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 2, p. 562-563 (in English) (Authors at Institute of Geology and Geophysics, Siberian Branch of the USSR Ac. Sci., Novosibirsk, U.S.S.R.)

Several different opinions are suggested concerning the genesis of rare-metal-bearing pegmatites and apogranites..

In connection with the relevant need of quantitative estimation of physico-chemical parameters existing in the process of crystallization of pegmatites and apogranites, the authors employed new methods of experimental studies (homogenization, freezing, thermobarometry, gaseous analysis and others) providing the possibility of quantitative estimation of these conditions.

The study was made of sodium-lithium pegmatites and amazonitic apogranites from various regions of the USSR. Below are reported the results obtained.

1. Pegmatites and apogranites had undergone three stages of crystallization in the process of their formation, such as : 1) magmatic (1040-800°) typical of the aggregate state of mineral-forming media-melt; 2) pneumatolytic (760-400°) typical of the aggregate state-gaseous; 3) hydrothermal (450-200°) aggregate state-liquid.

2. In the rare-metal pegmatites, the external structural zones such as aplitic and graphic zones (classical) were crystallized during the magmatic stage, whereas lower lying rock sections such as original biotite granites were formed during the magmatic stage in the amazonitic rock complex.

In pegmatites the block and quartz core zone as well as the earliest of the quartz-clevelandite-spodumene sections of the zone were formed during pneumatolytic stage, whereas protolithionite-microcline-albitic and zinnwaldite-amazonite-albitic and zinnwaldite-albite-amazonitic varieties of apogranites were formed during the pneumatolytic stage in apogranites.

The main part of quartz-clevelandite-spodumene zone and mineral-filled pockets, cavities and veinlets were formed during the hydrothermal stage in pegmatites, and cryophyllite-amazonite-albitic varieties and quartz-amazonitic veins formed in apogranites.

3. The temperature of sodium-lithium pegmatite crystallization varies from the earliest ones (aplite-like, graphic structure) to late ones (mineral filling of the pockets, cavities and veinlets) being equal to 840°, ranging between 1040° and 200°. The pressure interval ranges from 1500 to 60 atm.

4. The temperature of crystallization of all the zones of apogranitic complex ranges from the low altered original biotitic granites to quartz-amazonitic veins to be equal to 820°C, ranging between 1020 and 200°C. The pressure ranged between 1460 and 60 atm.

5. The main role of gaseous and liquid solutions of saline composition in the pegmatitic and apogranitic inclusions in quartz is played by NaCl. The composition of the gaseous phase of gas-liquid and liquid-gaseous inclusions is represented both by H_2O and CO_2 (to 65 vol.% O_2 to 12,7 vol.% H_2 + rare gases (to 20 vol.%). No H_2S, SO_2, NH_3, HCl, HF or CO was found, either. (Authors' abstract).

BAZAROVA, T.Yu., 1969, Thermodynamic characteristics of the formation of nepheline-bearing rocks: Izd. "Nauka", Moscow. (Sic., as quoted in Bogoyavlenskaya, et al., 1971, in this volume).

BEANE, R. E., 1971, Hydrothermal stability of ferromagnesian biotite (abst): Geol. Soc. Amer. Abstracts with Programs, v. 3, no. 7, p. 500. (Author at Department of Geoscience, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801).

Combination of calculated results for biotite end-members with solid solution models defines the stability relations of ferromagnesian biotites in hydrothermal systems from 25° to 300°C at low pressures. Application of the results of this treatment to potassic alteration in porphyry copper deposits indicates that high-magnesian, low-ferric iron biotite compositions, sulfate activities $\sim 10^{-6}$, and oxygen fugacities $\sim 10^{-35}$ (which is consistent with sulfate concentrations in solution several orders of magnitude greater than sulfide) are required for stability of biotite at 300°C. These conclusions are in agreement with natural and experimental observations, and predictions using other theoretical methods. (Author's abstract, shortened).

BENESOVA, Z., and CADEK, J., 1971, Fluorite mineralization in Permian-Carboniferous rocks near Cetenov: Vestn. Ustred. Ustavu Geol. 1971, v. 46, no. 6, p. 339-346 (in Czech.). CA 76 (12) 61693u (1972). (Authors at Ustred. Ustav Geol., Prague, Czech.)

Fluorite mineralization was found in the Permian melaphyres and assocd. sediments in the northern margin of the Bohemian Cretaceous Basin. The mineralization consists chiefly of fluorite and quartz. Four stages of mineralization are distinguished: epidote, quartz-feldspar, quartz-fluorite, and carbonate. By homogenization of fluid inclusions the following min. temps. were detd.: 260-280° for the origin of quartz-feldspar, 126-235° for quartz-fluorite, and 70-110° for carbonate stages. The solns. were medium to low temp., and of low concn. They were derived from meteoric waters which came in contact with subsurface centers of volcanic activity. (Authors' abstract).

BESKROVNYY, N.S., LEVITSKIY, YU. F., and SHCHEGLOV, A.D., 1971, Inclusions of petroleum, kerite and brine in fluorite of the Koh-i-Maran range (West Pakistan): Doklady Akad. Nauk SSSR, v. 201, no. 1, p. 187-190 (in Russian). Translated in Doklady Acad. Sci. USSR, Earth Sci. Sect., v. 201, p. 195-197, 1972. (Authors at All-Union Institute of Petroleum Geology and All-Union Geological Institute, Leningrad).

The deposit consists of steeply dipping fluorite and fluorite-carbonate veins up to 1.5 m thick in shattered zones in Jurassic limestone. The fluorite contains numerous inclusions of liquid bitumen (sic.) up to 0.5 cm, and a strong ordor of crude oil is present in the workings. Primary inclusions in the fluorite contain only aqueous solution and vapor, petroleum and vapor, or are multiphase, with fluorescent light yellow petroleum, aqueous solution, solid bitumen and gas. Both primary and secondary inclusions of all types homogenized between 100 and 120°C, with no visible change in the droplets of aqueous solution or bitumen. Decrepitation occurred at 150-200°C. A crude estimate of 20% NaCl in the aqueous solution was made by visual comparison of amount of crystals formed on evaporation. An IR spectrum (shown) of the petroleum extracted by chloroform has intense absorption bands for both aliphatic and aromatic structures, including aliphatic ethers and possible C-S and C-F bonds. These and the bitumens are interpreted to be from interaction with hydrothermal fluids. (E.R.)

Editor's note: an oil-water inclusion from this same material is illustrated in Plate 9 of USGS Prof. Paper 440-JJ. Unpublished data from my laboratory show freezing temperatures of -8.45, -8.9 and -9.4°C for the aqueous solution in individual primary inclusions; secondary aqueous inclusions in these same samples show -3.70 to -4.75°C freezing. The maximum salinity found (-9.4°C) corresponds to 13.5% NaCl equivalent. The solution must be essentially all NaCl and not include significant amounts of other salts, as the first melting temperature is -22.3°, very little below the eutectic for pure $NaCl-H_2O$ (-21.1°C).

BETHKE, P.M., and BARTON, P.B., JR., 1971, Distribution of some minor elements between coexisting sulfide minerals: Econ. Geology, v. 66, p. 140-163 (Authors at U.S. Geological Survey, Washington, D.C. 20244)

The distribution of cadmium, manganese and selenium between coexisting sphalerite and galena, and of cadmium and manganese between wurtzite and galena has been studied experimentally over the temperature range 600°-800°C. The most serious barrier to the application of these data to ore deposits is the necessity for an accurate paragenetic interpretation coupled with precise sampling. The materials analyzed must represent samples that equilibrated with respect to the partitioned components at the time of deposition and that have preserved their compositions throughout the post-depositional history of the deposit. The common occurrence of growth zones suggests that in many cases it will be necessary to sample contemporaneous and internally homogeneous zones in each of the minerals. A nearly absolute degree of sample purity is required, particularly for the depleted phase. The rapid rates of solid state reaction in galena and chalcopyrite imply that both phases should be considered suspect even in low temperature environments. Concordant temperature estimates based on the partitioning of two or more elements should provide an excellent test of the degree of approach to, and preservation of, equilibrium compositions. (Ed's. note-the problems of interpretation of paragenetic data are very pertinent to fluid inclusion work, as well).

The authors show, e.g., that their data on the distribution of Mn between galena and sphalerite can be combined with P-V-T data on fluid inclusion fluids (p. 160) to give both pressure and temperature, within surprisingly narrow limits (Authors' abstract, shortened and modified) (E.R.).

BLACKBURN, W. H. and DENNEN, W. H., 1971, Reply to the discussion on "Aluminum in quartz as a geothermometer": Cont. Min. Petrol., v. 30, p. 359-360.

The sample preparation was done with sufficient care that inclusions were not a significant source of the aluminum found. (ER)

BOGOLEPOV, V. G., NAIDENOV, B. M., and POLYVYANNY, E. YA., 1971 Isotopic composition of argon in gas-liquid inclusions of quartz of some Kazakhstan deposits and its genetic significance, in Investigations of mineral-forming solutions and melts in inclusions in minerals, N. P. Ermakov and L. N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials, (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 98-102. (in Russian)

Mass spectrometric determinations of the isotope composition of argon in gas-liquid inclusions in quartz crystals from occurrences at Akchatav, Gul'shad, Bektav-Ata, and Belogorsk (Northern Kazakhstan) of different types of ore mineralization were made. A comparison of these data with the effective age of the ancestral underground waters occurring in the inclusions leads to the conclusion that the age of the ancestral underground waters that took part in the formation of fluids and hydrotherms is different for occurrences of the same age that differ in their ore mineralization (S. Theokritoff).

BOGOYAVLENSKAYA, I.V., 1969, History of scientific knowledge and practical use of inclusion microsystems of mineral forming media: Avtoref. Kand. Diss., Moscow. (A dissertation) (as quoted in Bogoyavlenskaya, et al., 1971, in this volume.)

BOGOYAVLENSKAYA, I. V., ERMAKOV, N. P., and NAUMOV, V. B., 1971 Inclusions of solutions and melts in minerals: Bibliography of Russian literature for 100 years (1870-1970): Moscow, Moscow Univ. Press 181 pp (in Russian)

This volume lists 1178 references to inclusion studies alphabetically by author. It was issued under the joint auspices of VNIISIMS (The All-Union Institute for the Synthesis of Mineral Raw Materials), The Academy of Sciences, and the Geological Faculty of the Univ. of Moscow. This sold for the ridiculous price of 20 kopecks (22¢). It is probably unavailable, since the entire printing was only 600 copies. The Editor has one, which can be duplicated if required.(ER)

BORODIN, S.A., 1971, Distorted and mosaic crystals of pyrite as an indicator of the temperatures of formation of hydrothermal deposits, in Geochemistry of hydrothermal ore formation, ed. by V.L. Barsukov: Moscow, Izdatel. "Nauka," p. 91-105 (in Russian).

Comparison is made with fluid inclusion temperatures (E.R.).

BOZHKO, M. T., POLYKOVSKII, V. S., and PEREKHODTSEV, A. V., 1971, The small-scale decrepitometric apparatus, SAIGIMS-2, *in* Investigations of mineral forming solutions and melts in inclusions in minerals, N.P. Ermakov and L.N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 162-166, (in Russian).

BROBST, D. A., PINCKNEY, D. M., and SAINSBURY, C. L., 1971a, [Barite-fluorite-galena veins near Nome, Alaska]: U.S. Geol. Survey Prof. Paper, 750-A, Geological Survey Research 1971, p. A-51.

A suite of samples from the barite-fluorite-galena veins of the Quarry deposit on the Seward Peninsula near Nome was examined. The fluorite and barite have been sheared and recrystallized. Fluid inclusions, trapped during recrystallization, contain three phases: liquid water, liquid carbon dioxide, and gas. Upon heating, the inclusions homogenize at 245° ± 3°C. No evidence of boiling was found, indicating a depth of cover of at least several thousand feet.

The structure along with the relatively high temperature and pressure indicates a potentially large area of mineralization. (Authors' abstract, shortened).

BROBST, D. A., PINCKNEY, D. M., and SAINSBURY, C. L., 1971b, Geology and geochemistry of the Sinuk River barite deposit, Seward Peninsula, Alaska: U.S. Geol. Survey Prof. Paper 750-D, p. D1-D8.

The deposit consists of pervasive mineralization of thrust sheets of marble and schist with barite, fluorite, galena, sphalerite, boulangerite, silver and gold. Two types of secondary fluid inclusions in fluorite, along healed cleavage fractures and recrystallized grain boundaries, both contain liquid CO_2, liquid water, and gas. The CO_2 liquid and gas homogenize at (unspecified) temperatures around the critical temperature (+31.1°C); the manner in which homogenization of these two phases occurs (in liquid, in vapor, or at critical point) is not specified. The resultant CO_2 fluid and liquid water phases were homogenized in 8 inclusions at temperatures of 237-256°C. This is taken to be the formation temperature, since "corrections for salinity of the fluid" and pressure are assumed to be insignificant. A sample of fluorite, after acid leaching to remove calcite, was decrepitated in vacuo at 425°. The released gases consisted of 3.2 mole percent CO_2 (the unspecified balance was presumably all H_2O). From this composition, a pressure estimate of 233 bars at 250°C is made, equivalent to about 3000 feet of rock, based on the vapor pressure of CO_2-H_2O mixtures. (ER)

BROWNE, P. R. L., 1971, Mineralisation in the Broadlands geothermal field, Taupo Volcanic zone, New Zealand: Soc. Mining Geol. Japan, Spec. Issue 2, p. 64-75 (Proc. IMA-IAGOD Meetings '70, Joint Symp. Vol.)

Small quantities of sphalerite, galena and chalocopyrite have been found in cores and cuttings from 6 drillholes in the Ohaki-Broadlands geothermal field of the Taupo Volcanic Zone, New Zealand. They occur in horizontal and near-horizontal Quaternary-Recent silicic lavas, tuffs, ignimbrites, volcanic sediments and in the underlying Mesozoic basement greywackes and argillites. The base-metal sulphides occur, and appear to be most abundant in fracture zones, at depths between 920 and 7593 ft, where temperatures vary from 120° to 298°C. Associated hydrothermal minerals include quartz, K-feldspar, albite, K-mica, chlorite, calcite, pyrite, pyrrhotite and rare epidote.

Textural evidence suggests that the hydrothermal minerals in most parts of the base-metal zones are in equilibrium with one another and with the weakly saline solution of low metal content (Zn + Pb + Cu = 0.05 ppm) now being discharged from the boreholes. Sinters rich in arsenic, antimony, mercury, thallium, and gold are currently precipitating from boiling pools near the boreholes and also from steam discharged by one bore which at depth penetrates rocks with base-metal sulphides. This suggests that a crude metaliferous zoning is operating with crystallisation of Cu-Pb-Zn minerals at depth and Ag-Sb-Hg-Au material under cooler surface conditions. (Author's abstract) Ed. note: This abstract, with minor modifications, was first published in 1970 in Collected Abstracts, IMA-IAGOD Meetings '70, Science Council of Japan, p. 127.

BUTUZOV, V. P., KHETCHIKOV, L. N., and SHAPOSHNIKOV, A. A., 1971, Inclusions in synthetic crystals and their significance in thermobarometry of minerals, in Investigations of mineral-forming solutions and melts in inclusions in minerals, N.P. Ermakov and L. N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 7-14, (in Russian). (See Translations section).

CARSTENS, H., 1971, Plastic stress relaxation around solid inclusions in pyrope: Contr. Mineral. and Petrol, v. 32, p. 289-294, (Author at Norges geologiske undersøkelse, Trondheim, Norway)

Misfit between primary (syngenetic) inclusions and pyrope host is usually due to differences in the coefficients of thermal expansion and compressibilities. It is shown that the misfit stresses are relieved by the generation and rearrangement of dislocations. Zones of plastic flow have been recognized around inclusions in pyropes from Bohemian garnet peridotites and in kimberlite pyropes from South Africa and Yakutia. The extent of plastic yield is determined by the history of the pyrope in the ductile regime. Implications for using the piezothermometric method of Rosenfeld and Chase (1961) which is based upon the elastic strain, are discussed. (Author's abstract).

CHERNUKHA, F.P., TEREMETSKAYA, A.G., & DAVYDOVA, G.N., 1969, Determination of temperatures of formation of the rare metal pegmatites of a region in eastern Siberia: V sb. "4. Nauchno-Otchetnya Konferentsiya Geologicheskove F. MGU", 1969. (Sic., as quoted in Bogoyavlenskaya, et al., 1971, in this volume).

CHERNYKH, N.V., and PILOYAN, G. O., 1971, Whewellite in hydrothermal uranium deposit: Dokl. Akad. Nauk SSSR, v. 201, no. 6, p. 1449-1452 (in Russian). Translated in Doklady Acad. Sci. USSR, v. 201, p. 188-191 (1972). (Authors at Institute of Economic Geology, Petrology, Mineralogy and Geochemistry, Academy of Sciences, USSR, Moscow).

Whewellite was found in a U-Mo type deposit in volcanics and sediments of Jurassic age that contain lenses and partings of organic matter up to 4cm thick. The whewellite is in quartz-fluorite-calcite veins cutting disseminated uraninite. It was presumably formed by reaction of calcite with hydrothermal solutions containing oxalate ions from the organic matter (ER).

(Ed. note: This is important as a possible daughter mineral, and particularly as evidence for the presence of an effective reducing ion that has never been looked for in inclusion fluids, particularly in Mississippi Valley-type deposits).

CLINE, H. E. and ANTHONY, T. R., 1971a, The thermomigration of liquid droplets through grain boundaries in solids: Acta Metallurgica, v. 19, June 1971, p. 491-495. (Authors at General Electric Corporate Research, Schenectady, New York). (See also Anthony and Cline 1971a)

Brine droplets were migrated in a thermal gradient through a twist boundary in KCl. On passing through and away from the grain boundary plane, the brine droplet generated a columnar tilt boundary between itself and the twist boundary plane. The surface tension of this columnar tilt boundary exerted a force on the droplet, pulling it back towards the twist boundary plane. From the thermal gradient necessary to balance the backward pull of this columnar tilt boundary, it was determined that a 15° tilt boundary about a ⟨100⟩ direction in KCl has an energy of 32 ergs/cm^2. (Authors' abstract)

CLINE, H. E. and ANTHONY. T. R., 1971b, Vaporization of liquid inclusion (sic) in solids; the Philosophical Magazine, v. 24, December 1971, no. 192, p. 1483-1494.

Saturated water inclusions inside single crystals of NaCl and KCl were heated until gas bubbles nucleated in the inclusions. The highest vaporization temperatures were 420°C and 395°C, respectively, for NaCl and KCl, indicating superheatings of about 115°C for both types of salt samples. By taking into account the differential thermal expansion between brine and salt, the change of salt solubility with temperature and pressure, and variation of the yield strength of salt with temperature and applying homogeneous nucleation theory, the observed vaporization temperatures can be explained. (Authors' abstract) Editor's note-In the General Electric Co. reprint of this (Report no. 71-C-229), Figs. 2 and 3 are interchanged.

CLINE, H. E. and ANTHONY, T. R., 1971c, The shape relaxation of liquid droplets in solids: Acta Metallurgica, v. 19, March 1971, p. 175-180, (Authors at General Electric Research and Development Center, Schenectady, New York).

The shape relaxation of artifically extended brine droplets in solid KCl was followed through the entire relaxation process with an optical transmission microscope. Irreversible processes associated with the transfer of salt atoms between the solid and liquid at the solid-liquid interfaces of the droplet significantly slowed the relaxation process and prevented the droplets from ever attaining their equilibrium shapes of minimum surface energy. This departure from shape equilibrium increased with droplet size in a manner predicted by a model extending the equilibrium work of Gibbs to the non-equilibrium situation. By comparing the droplet relaxation rate with this model, the brine-KCl interface energy was estimated to be 12 ergs/cm^2 which agrees well with the KCl-brine interface energy independently determined by measuring the contact angles of brine droplets on grain boundaries of KCl. (Authors' abstract).

CLOCCHIATTI, R., and TOURAY, J. C., 1971, Remarques sur la note "Aluminum in quartz as geothermometer", by Dennen, W.H., Blackburn, W. H., and Quesada, A.: Cont. Min. Petrol., v. 30, p. 356-358.

The proposed geothermometer is very difficult to use mainly for magmatic quartz because such samples always contain aluminous glassy and crystalline micro-inclusions. (ER)

CONQUÉRÉ, F., 1971, The amphibole lherzolite from Caussou (Ariège, France): Contr. Mineral. and Petrol., v. 30, p. 296-313, (Author at Laboratoire de Minéralogie, Muséum d'Histoire Naturelle, Paris).

Petrographic and chemical analysis of the two types of rocks and their constituent minerals in the outcrop lead to the conclusion that a spinel-lherzolite recrystallized locally as amphibole lherzolite in the presence of a gas phase containing water, and probably Ti and alkali elements as well, at approximately 7 to 8 Kb and 1100°C (for $P_{H_2O} = P_{total}$). Two hypotheses are presented for this local recrystallization; in either case the original peridotite that produced the two existing types at Caussou could be considered as an undifferentiated fragment of the upper mantle. (Author's abstract, abbreviated).

COVENEY, R.M., Jr, 1971, The geology and mineralogy of the Oriental (gold) mine, Alleghany, California (abstr.): Michigan Academy of Science, Arts & Letters, Geology and Mineralogy Section; Program with Abstracts for 1971.

COVENEY, R. M. and KELLY, W. C., 1971, Dawsonite as a daughter mineral in hydrothermal fluid inclusions: Contr. Mineral. and Petrol., v. 32 p. 334-342, (Authors at Department of Geology and Mineralogy, The University of Michigan, Ann Arbor, Michigan 48104).

Traces of dawsonite ($NaAlCO_3(OH)_2$) are extremely common as a daughter product in fluid inclusions in gold-quartz veins and altered wallrock of the Oriental mine, Alleghany district, California. A very similar daughter salt occurs in hydrothermal inclusions in quartz from 19 other mining localities of worldwide distribution.

Vein fluids of the Oriental mine were probably CO2-rich sodium bicarbonate brines that contained at least 1 weight percent dissolved aluminum. These fluids precipitated quartz and oligoclase in the veins and adjacent altered rocks. The precipitation of dawsonite rather than albite or oligoclase in the cooled inclusion brines suggests either that sodic plagioclase gives way to dawsonite plus quartz as the stable pair at low temperatures or that the dawsonite is a metastable daughter mineral. The rarity of dawsonite as a separate vein mineral or alteration product at the Oriental mine and elsewhere is attributed to its high solubility under normal conditions of mineralization.

Dawsonite contributes 190 ppm or more to the aluminum content of some Oriental mine quartz. Large errors would result if the dawsonite were overlooked and the aluminum geothermometer of Dennen et al. (1970) were applied to this quartz. The combination of high primary inclusion filling temperatures and very low aluminum contents of optically clear quartz indicate that major revisions are needed in the published thermometer curve. (Authors' abstract).

DAVIDENKO, N.M., 1969, Mineralogical association and conditions of formation of the gold-quartz veins, Malo-Ayuyskiy region, north Chukotsk: Avtoref. Kand. Diss., Moscow. (a dissertion) (as quoted in Bogoyavlenskaya, et al., 1971, in this volume).

DAVIDENKO, N.M., 1970, Scheelite associated with alluvial gold, western Chukchi: Vyssh. Ucheb. Zaved., Izv., Geol. Razved., no.3, p. 161-162.

DEICHA, Georges, 1971, Geochemical solvents and crystallogenesis; examples from the Pyrenees and the Aquitaine basin: Congr. Natl. Soc. Savantes, 94th, Sect. Sci. C.R., v. 2 (1969), p. 189-192 (in French).

DEICHA, George, and SELLA, Claude, 1971, Investigation of intergranular cavities by scanning electron fractography: Soc. Geol. Fr., C.R., no. 3, p. 179-181 (in French).

DELITSYN, L.M., and MELENT'YEV, B.N., 1971, Coexistence of liquid phases at high temperatures: relation between diopside and alkali halides; Geokhimiya, 1971, no. 5, p. 570-577 (in Russian). Translated in Geochem. Internat. , v. 8, no. 3, p. 350-357. (Authors at Geological Institute, Kola Branch of the Academy of Sciences USSR, Apatity.)

The systems diopside - LiF, diopside - NaF, diopside - NaCl, and diopside - KCl have been investigated. The systems diopside - MeF are of the simple eutectic type, but, in the systems diopside - MeCl, two immiscible liquids coexist above the melting temperatures of both components. (Author's abstract).

DENNEN, W. H., BLACKBURN, W. H., and QUESADA, A., 1971, Aluminum in quartz as a geothermometer (abst.); Trans. Amer. Geophys. Union, v. 52, no. 4, p. 371.

Quartz forming in aluminum-saturated environments has a trace aluminum content which varies linearly and directly with its temperature of crystallization. The aluminum content varies at a rate of approximately 1 ppm Al per 3.6°C change in temperature. Use of this geothermometer gives temperatures which are consistent with those expected by geologic reasoning or through the use of other geothermometers. (Authors' abstract).

DERRÉ, C., and TOURAY, J.-C., 1971, Late stages of crystallization of fluorite and barite at Chavaniac (Haute-Loire, France), from studies of solid and fluid inclusions: Mineral. Deposita (Berl.), v. 6, p. 292-301, (Authors at Laboratoire de Géologie Appliquée, Université de Paris VI, Paris, France, and Laboratoire de Géologie de l'Ecole Normale Supérieure, Paris, France).

Fluid inclusion studies in late stage minerals from Chavaniac mine (mainly fluorite and barite) show that temperature and salinity fell during crystallization. Crystallization of fluorite began at around 140°C ± 10°C, in a solution containing about 20% NaCl. The temperature of formation of barite never exceeded 40°C and the dilute solutions sometimes contained emulsified hydrocarbons. Relations have been established between paragenetic succession, fracture phases, and the above results. (Authors' abstract).

DIXON, J. M., and PHILPOTTS, A. R., 1971, Composition of fluid phase solutes in a basalt-H_2O-CO_2 system: Discussion: Geol. Soc. Amer. Bull., v. 82, p. 2673-2674, (Authors at Department of Geology and Institute of Materials Science, University of Connecticut, Storrs, Connecticut 06268).

A discussion concerning the attainment of equilibrium in results given in an earlier paper on this subject (Holloway, 1971). Followed by a reply by Holloway (pp. 2675-2676) (E.R.).

DMITRIYEV, S. D., 1970, Reliability of methods of investigation of mineral-forming solutions and pneumatolytic deposition of minerals: Vyssh. Ucheb. Zavedeniy Izvestiya, Geologiya i Razvedka, 1970, no. 4, p. 81-86 (in Russian). Translated in International Geology Review, v. 13, no. 5, 1971, p. 681-684 (Author at Leningrad State University).

An important article, since Dmitriyev points out a series of serious errors in statement or logic about pneumatolysis vs gas inclusions, and pressure corrections, by the inclusion greats of the USSR - Ermakov (1966); Zakharchenko, et al. (1958); Laz'ko, Lyakhov and Piznyur (1965), etc. - but then introduces a few new ones himself. He also points out the shortcomings of some "standard" Soviet techniques, such as decrepitation ("The prospect of refining this method seems hopeless to me".) and pH measurements at room temperature on opened inclusions, as well as the <u>non</u>-equivalence of "honeycomb" quartz from pegmatites of Central Kazakhstan and Volynia.(E.R.) (Editor's note - This was inadequately reviewed in the previous volume of COFFI, before the English translation was available).

DOLGOV, Yu. A., 1968, The composition of gases.... (See Translation Section.)

DOLGOV, YU. A., POGREBNYAK, YU. F., and SHUGUROVA, N. A., 1971, Gas composition and pressures in inclusions in some tektites and silica glasses: Doklady Akademii Nauk SSSR, 1971, Vol. 198, no. 1, pp. 202-205 (in Russian). Translated in Doklady Acad. Sci. USSR, Earth Sci. Sect., v. 198, 1971, p. 208-211. (Authors at Institute of Geology and Geophysics, Siberian Division, Academy of Sciences, USSR, Novosibirsk).

Microscopic features of gas inclusions in Libyan desert glass, Darwin glass, bediasite tektites, Ivory Coast tektites and synthetic glass are described and analyses of their gas content (and the host glass chemistry) are presented. The gas analyses were made by an ultramicrochemical volumetric method (reference cited "Shugurova, 1967" - probably 1968), and includes (H_2S + SO_2), CO_2, CO, O_2, H_2 and residue (N_2 + inert gases). Inclusions in the bediasites and Ivory Coast tektites contained only CO_2, whereas the Darwin glass gas appears to be 1/4 CO_2, 3/4 air and the Libyan desert glass gas consists of CO_2, H_2 and N_2. The gas pressures are highest in the Darwin glass inclusions (several percent of atmospheric). The authors suggest that these data confirm a terrestrial source for the Darwin glass. (E.R.)

DOLOMANOVA, E.I., BOYARSKAYA, R.V., RAKCHEEV, A.D., & YAKOVLEVSKAYA, T.A. 1969, Cassiterite and its typomorphic properties: v. Sb. "Tipomorfizm Mineralov", Moscow, "Nauka" (sic., as quoted in Bogoyavlenskaya, et al., 1971, in this volume).

DOLOMANOVA, E. I., KOROLEV, N. V., and ELINSON, M. M., 1971, Features of the formation of the Ushmun Sn-W deposits in Transbaikal from data on gas-liquid inclusions in quartz: Izvestia Acad. Nauk SSSR, 1971, no. 4, p. 65-75 (in Russian).

The general geology and paragenesis is summarized, and eight gas analyses for H_2, CO_2, H_2S, N_2 + Ar, CH_4, and O_2 are presented. The gases are high in CO_2, H_2, and H_2S in individual samples (E.R.).

DUNHAM, K.C., 1970, Mineralization by deep formation waters: a review: Inst. Min. Metal. Trans., Sect. B, v. 79, p. B107-B170 and B208-B212.

This is the title of one of a series of 8 papers (63 pages) by various authors, covering several aspects of the origin and nature of natural brines, and their possible connection with metalliferous deposits, particularly the Mississippi Valley type, and fluid inclusion studies. (See also Discussion, next item - E.R.).

DUNHAM, K.C., (et al.), 1971, Discussion of the series of papers, Mineralization by deep formation waters: a review". Inst. Min. & Metal. Trans., Sect. B, v. 80, p. B50-B69; author's replies, B292-B296.

Further discussion of the subjects covered in the series of papers noted in the preceding item. (E.R.).

DURASOVA, N.A., 1971, Distribution of Sn and Pb between chloride and silicate melts, in Geochemistry of hydrothermal ore formation, ed. by V.L. Barsukov: Moscow, Izdatel. "Nauka," p. 30-34 (In Russian).

Distribution coefficients were found as follows: K_{Pb} 0.01-0.02; K_{Sn}<0.01, for 800-1100°C (E.R.).

DURISOVA, Jana, 1971, Geothermometric study of cassiterite from the Preiselberk deposit in the eastern part of the Krusne hory Mts.: Vestnik Ustredniho ustavu geologickeho, v. 46, p. 223-228 (in Czech. with English abstract)(Author at Ustredni ustav geologicky, Praha 1, Hradebni 9.)

Cassterite from the quartz vein of the Preiselberk tin deposit (Eastern part of the Krusne hory Mts.) was subject to thermometric analysis. Fifty-eight homogenization temperatures of inclusions were measured with the use of homogenization method in a thermo-chamber. Freezing tests on CO_2 in inclusions were negative. From the ratio of liquid and gaseous phases at room temperature the inclusions with a dominant proportion of gas (60 vol. %) and those with predominating liquid have been distinguished. The former showed homogenization temperatures about 420°C; they are distributed along the growth zones and may be denoted as primary with respect to cassiterite. The latter homogenized at about 325°C and are postgenetic in relation to the enclosing cassiterite. From the thermometric results it can be inferred that cassiterite originated from solutions of low density (homogenization to gas), the minimum temperature of which varied around 420°C. (Author's abstract)

DUSMATOV, V. D., and MARKOV, A. B., 1971, Bituminoids in rock-forming and accessory minerals of alkaline pegmatites: L'vov. Gos. Univ. Mineralog. Sbornik, v. 25, no. 3, p. 231-237 (in Russian).

Bituminoids are widespread in all minerals of the alkaline pegmatites. Maximum content is characteristic for micas (0.15%), a smaller quantity is contained in aegirite and quartz (0.0044%), and minimum content is found in calcite and microcline (0.002%). An endogenous genesis is suggested for their origin. (Authors' abstract).

DUYK, F., 1971, A few observations related to synthetic emerald: Jour. Gemmology, v. 12, no. 7, p. 253-255.

Gilson synthetic emerald shows channel-like inclusions containing liquid, birefringent "crystallites", and gas (ER)

DZHAFAROV, Ch. D., 1969, On the temperature zonation in the Dashkesansk iron deposit, based on data from magnetite crystals: Trudy Azerb. Otd. Vses. Min. Ob., t. 1. (sic., as quoted in Bogoyavlenskaya, et al., 1971, in this volume).

EBY, G. N., 1971, The rare-earth and yttrium geochemistry of the Oka carbonatite complex, Oka, Quebec (abst.): Geol. Soc. Amer. Abstracts with Programs, v. 3, no. 7, p. 552-553.

E. concludes that the carbonatite probably formed from a volatile-rich phase, fractionated from a differentiating alkali peridotite magma; these volatiles may have concentrated the light rare-earth elements in the carbonatite. (Editor's note - of pertinence to the several studies of Oka fluid inclusions). (E.R.)

ELIASH, K., 1968, Apparatus for thermosonic and thermovacuum studies of minerals: Mineralogical Thermometry and Barometry v. 2, p. 290-295 (in Russian).

ELINSON, M. M. and ALEKSANDROVA, E. S., 1971, Study of the composition of gases in inclusions in small samples of minerals and rocks by means of gas chromatography, in Investigations of mineral-forming solutions and melts in inclusions in minerals, N. P. Ermakov and L. N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 84-86, (in Russian)

ELINSON, M.M., POLYKOVSKIY, V.S. and MERKULOV, E.V., 1971, Gas composition of the solutions producing the Lyangar rock-crystal veins in the west Pamir: Geokhimiya, 1971, no. 6, p. 654-659, (in Russian).

Determinations of CO_2, H_2, N_2, Ar, and O_2 in fluid inclusions from rock-crystal veins in the West Pamir and for quartzites and quartzitic sandstones are presented. The highest gas contents occur in the early parts of the solutions, while the later parts have much less gas. The principal gaseous component is CO_2, while H_2 and (especially) N_2 are present in much smaller amounts. The results substantially extend the information on the geochemistry of the production of the rock-crystal veins of the West Pamir. (Authors' abstract).

ERMAKOV, N.P., (ed.), 1968, Mineralogic thermometry and barometry; v. 2, New methods and results of study of the parameters of ore formation: Izd. Nauka, Moscow, 310 p. (in Russian).

ERMAKOV, N.P., 1969, Perspectives on the applications of mineralogical thermobarometry to the solution of petrologic problems: Materialy IV, Vses. Petrograf. Soveshchaniya, Izd, A.N. Az. SSR, Baku. (Sic., as quoted in Bogoyavlenskaya, et al., 1971, in this volume).

ERMAKOV, N. P., 1971a, Origin and relative time of formation of normal inclusions of the geochemical medium in minerals and their genetic classification, in Investigations of mineral-forming solutions and melts in inclusions in minerals, N.P. Ermakov and L. N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ra), Trudy, v. 14, p. 15-26 (in Russian).

This paper presents (1) the characteristics of the genetic classes, types, and varieties of normal inclusions of geochemical media in minerals, (2) the problems of real crystal formation from liquid media applicable to the formation of primary fluid solutions is illuminated, (3) the variety in the methods of preservation of mother mobile substances by minerals. (S. Theokritoff).

ERMAKOV, N. P., 1971b, (transliterated Yermakov in original), The principal trends of the development of thermobaro-geochemistry of the endogenous processes of mineral formation: Soc. Mining Geol. Japan, Spec. Issue 3, p. 319-320, [Proc. IMA-IAGOD Meeting '70, IAGOD Vol.].

A presentation of a block diagram identical to that given at the Third All-Union Conference in 1968 (see Yermakov, Proc. of COFFI, v. 1, p. 75, 1968).

ERMAKOV, N.P., BOGOYAVLENSKAYA, I.V., and MEL'NIKOV, F.P., 1970, History of the use of inclusions of mineral-forming media in the development of the theory of endogenous ore-formation (abstr.): in History of concepts on mineral deposits, Int. Symp. Sum. Pap., p. 162-165, Int. Comm. Hist. Geol. Sci., Freiberg.

ERMAKOV, N. P., BOGOYAVLENSKAYA, I. V., and MEL'NIKOV, F. P., 1971, History of the use of inclusions of mineral-forming media in the development of the theory of endogenous ore formation: Geologie (Berlin), v. 20, no. 4/5, July, 1970, p. 417-423. A review with 14 references (E.R.).

ERMAKOV, N. P. and GROMOV, A. V., 1971, Experiments on the decreptophonic and concentrate-bursting method for prospecting for some deposits of Central Kazakhstan, in Investigations of mineral-forming solutions and melts in inclusions in minerals, N. P. Ermakov and L. N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials, (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 130-139, (in Russian).

ERMAKOV, N. P. and KHETCHIKOV, L. N., (eds.), 1971, Investigations of mineral-forming solutions and melts in inclusions in minerals: Alexandrov, Ministry of Geology of the USSR, All-Union Institute for the Synthesis of Mineral Raw Materials, Trudy, v. 14, 100 pp. (in Russian).

This volume includes only forty of the papers presented at the Third All-Union Conference on Mineralogical Thermobarometry, held in Alexandrov in 1968. Additional papers from this meeting, concerning thermobarometry of ore deposits, are expected to be published as a separate volume by Izdat. Nauka under the auspices of the Acad. of Sci. The individual papers are listed in this issue of COFFI alphabetically by author. (E.R.)

ERMAKOV, N.P., and KUZNETSOV, A. G., The use of thermobarogeochemistry methods in the search for hidden ore deposits (Authors at Moscow State University and Shakhtinsky Polytechnical Institute). (Editor's note: This paper was submitted for the 1972 COFFI Symposium at Montreal, but was only read by title there, and was received too late for inclusion in the previous volume of COFFI. (See Translations Section)

ERMAKOV, N. P., and MELNIKOV, F. P., 1971, Physico-chemical characteristics of pneumatolytic and hydrothermal mineralogenetic solutions as a result of mineral inclusion investigations (Accompanied by a demonstraction film), (abst.): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 1, p. 340 (in English) (Authors at Moscow State University, Moscow, USSR.

(The paper discusses the following):

Geochemical systems of mineral inclusions as a source of genetic information about the processes and phenomena of deep-seated mineral formation. A variety of mobile geochemical environments within the earth's crust, their gradual transitions and rapid transformations depending on the changes in geological environment and intensive physico-chemical parameters.

Magmatism, pneumatolysis and hydrothermal activity, homogeneous and heterogeneous mineralogenetic media and their fixation in mineral inclusions. Retrospective regeneration of melt primary states and condensed liquids, as well as gaseous, hydro-liquid and hydro-carbonated solutions.

The role of true and colloidal liquid solutions in hydrotheraml activity, deep-seated pnematolysis and decoding of them by the inclusions.

Some methods of thermodynamic and chemical investigations of inclusion systems and the most important results of these investigations. Thermobarogeochemistry as a branch of geochemistry of endogenetic mineral-forming processes, main trends of its development and use both in theory and practice (diagram added). The film shows the experiments of thermodynamic tests of geochemical systems in natural inclusion microclaves in two-three parts 25-36m [sic], sound tracked in Russian and English. (Authors' abstract).

ERMAKOV, N. P., 1971, POLYKOVSKII, V.S., and KOLIBAEVA, I. V., 1971, Decreptocoring of drill cores in searching for hidden bodies in fluorite deposits of Agata, in Investigations of mineral-forming solutions and melts in inclusions in minerals, N. P. Ermakov and L. N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 143-146 (in Russian).

ERMAKOV, N. P. and RAKHMANOV, A. M., 1971, Cryometric studies of inclusions in crystals of rock crystal from pegmatites of southern Gissar, in

Investigations of mineral-forming solutions and melts in inclusions in minerals, N.P. Ermakov and L.N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 153-156, (in Russian).

ERYOMENKO, G. K., 1970, The dislocation structure of Volynian topazes: Akad. Nauk Ukr. RSR, Dopovidi, 1970, Series B, no. 4, p. 313-317, (in Ukrainian with brief English abstract).

Etching of topaz cleavages with potassium hydroxide revealed two kinds of etch pits, both formed at dislocations. Screw dislocations generate microchannels on etching. (Editor's note - this may be the mechanism for formation of some tubular topaz inclusions).

FAIZIEV, A. R., 1971a, Temperature formation conditions of mercury-antimony deposits in the northern slope of the Gissar Ridge (southern Tien-Shan): Izv. Akad. Nauk Tadzh. SSR, Otd. Fiz.-Mat. Geol.-Khim. Nauk 1971, no. 4, p. 78-88 (in Russian). CA 77 (4) 51147a (1972). (Author at Tadzh. Gos. Univ. im. Lenina, Dushanbe, USSR).

The low-temp. hydrothermal Hg-Sb deposits of the title area in the Zeravshano-Gissar structural-facies zone contain fluorite, calcite, barite, stibnite, and cinnabar. Decrepitation and homogenization studies of the gas-liq. inclusions indicate that fluorite of the ore deposit was formed at 46-108°, barite at 104-42°, and calcite at 50-169°. Fluorite is paragenetically related to the ore minerals.

FAIZIEV, A. R., 1971b, Temperature formation conditions of fluorite occurrences in Tadzhikistan: Izv. Vyssh. Ucheb. Zaved., Geol. Razved., 1971, v. 14, no. 5, p. 45-50 (in Russian). CA 75 (4) 128 (1971). (Author at Mosk. Gos. Univ. im. Lomonosova, Moscow, USSR)

Geothermometric studies of the gas-liq. inclusions indicate that the fluorites of Tadzhikstan were formed in the range 40-250°. The low-temp. forms occur as veins in granitic rocks and limestones, and the high-temp. fluorite is derived from pegmatites. The temp. interval between the beginning and end of crystn. is <20-30°. Fluorites from calcite-fluorite veins have a lower homogenization temp. than the fluorites from quartz-fluorite veins. Fluorites in pegmatites and skarns are formed by hydrothermal solns. with an insignificant role played by pneumatolytic processes.

FOLINSHEE, R.E., KIRKLAND, K., NEKOLAICHUK, A., and SMEJKAL, V., 1972, Chinkuashih - a gold-pyrite-enargite-barite hydrothermal deposit in Taiwan: Geol. Soc. Amer. Mem. 135, p. 323-335.

At Chinkuashih, an important Pleistocene copper-gold producing mine in Taiwan, the arsenical copper-gold ores are similar to those of Butte, Montana, in mineralogy, geochemistry, and temperature of formation. Electron microprobe analysis established the presence of antimony in the enargite (luzonite), as in the enargite at Butte. Octahedral pyrite crystals, characteristic of the ore zone, contain copper and arsenic in solid solution, producing anomalous areas of anisotropism. Sulfur isotopes for sulfides and sulf-arsenides yield values close to meteoritic and typical of magmatic hydrothermal deposits, but the equilibrium sulfate species barite is 25% heavier in S^{34}. Data on the barite-pyrite pairs suggest temperatures of formation in the range of 255°C to 305°C (using Sakai's 1968 geothermometric curve), a range compatible with fluid inclusion temperatures in barite (for the most part between 228°C and 305°C) and quite comparable to Meyer's (1950) figures of 275°C to 335°C for the Butte deposit. Extensive chloritic, argillic, and silicic alteration preceded mineralization and suggest that large amounts of water, perhaps meteoric, were involved in the hydrothermal processes. (Authors' abstract).

FOURNIER, R. O., and TRUESDELL, A. H., 1971, An empirical geothermometer based on Na, K, and Ca dissolved in natural waters (abst.): Geol. Soc. Amer. Abstracts with Programs, v. 3, no. 7, p. 570 (Authors at U.S. Geological Survey, Menlo Park, California).

Erratic results have been obtained using the ratio Na/K in natural waters as a geothermometer because Ca^{++} as well as Na^{+} and K^{+} is important in many controlling reations. Using data on subsurface water compositions and temperatures in geothermal wells, the effect of Ca^{++} was investigated by plotting the log of an approximation of the equilibrium constant, K^*, vs $1/T$ ($°K^{-1}$) for various reactions, assuming constant aluminum and excess silica. A resulting curve serves as an excellent reference for geothermometry of most hot spring and many fluid inclusion waters. (From the authors' abstract).

FRANCK, E. U., 1971, Gas-liquid and gas-solid equilibria at high pressures, critical curves, and miscibility gaps, Chapt. 4, pp. 367-401 in Physical Chemistry, Vol. 1, Academic Press, Inc., New York.

A very thorough discussion of the phase equilibria and phase diagram topology, and their theoretical derivations, of pertinence to a variety of systems involved in inclusion studies such as CO_2-H_2O. (E.R.).

FRIEDMAN, Irving, 1971, [C^{13}-C^{12} ratios of CO_2 from Hawaiian lava lake (abst.)]: U.S. Geol. Survey Prof. Paper 750 A, Geological Survey Research, p. 126.

Ten days after eruption and the filling of Aloi crater in Kilauea, holes were drilled through the thin crust to the lava. Friedman collected several samples of the CO_2 given off by the cooling lava by pumping the gases (mainly SO_2 and H_2O?) through $SrCl_2$ solution. The $SrCO_3$ precipitates were then used for δC^{13} analyses. The δC^{13} values were approximately -15‰ PDB, a value which is significantly lighter than the value of 0.6‰ measured in liquid CO_2 inclusions in Hawaiian olivine nodules by J.R. O'Neil. These measurements bear on the perplexing problem of the carbon isotope geochemistry of igneous rocks.

FUTERGENDLER, S.I., SHIMANIN, V.I., & KHATELISHVILI, T.V., 1969, Composition and distribution of inclusions in synthetic diamonds: Zap. Vses. Min. Obshch. v. 98, no. 5, p.568-573 (in Russian).

Metals (Ni, Mn, or Ni-Mn alloy), carbides and manganocalcite were found. Graphite was never detected as an inclusion in these diamonds. (B. Poty).

GHORMELY, J.A. and HOCHANADEL, C.J., 1971, Amorphous ice: density and reflectivity: Science, v. 171, p. 62-64.

Amorphous ice prepared under a wide range of conditions has a density, determined from its buoyancy in liquid oxygen, of 0.94 ± 0.02 gram per cubic centimenter, the same as that of ordinary hexagonal ice, with no indication of the glassy superdense ice (2.32 grams per cubic centimeter) reported recently. The diffuse reflectivity shows a small increase as the ice crystallizes at 153°K. This increase is followed by a much larger increase (probably associated with crystal growth) as the sample warms, and the reflectivity reaches a maximum well below the melting temperature. Although the ice deposits appear translucent, the specular reflectivity is low, thus indicating a dull rather than a glassy surface (Authors' abstract; of pertinence to cryometry of inclusions, Ed.).

GOLIKOV-ZAVOLZHENSKIY, I.V. and TRUFANOV, V.N., 1971, P-T conditions for the production and hydrothermal resynthesis of aeschynite: Geokhimiya, 1971, no. 8, p. 974-979 (in Russian).

Results are given for the hydrothermal resynthesis of aeschynite at 350-500° and 760-800 atm. These are the T and P ranges indicated by homogenization and decrepitation for gas-liquid inclusions in the minerals of rarer-metal greisens. It is found possible to identify metamict titano-tantalo-niobates by simulating the natural conditions of formation. (Authors's abstract).

GONCHAROV, V.I., & NAYBORODIN, V.I., 1969, On the temperature of formation of the Khakandzhidinsk gold-silver deposit: "Kolyma", Magadan, 1969, no. 1. (sic., as quoted in Bogoyavlenskaya, et al., 1971, in this volume).

GORBACH, A. M., SOKOLOV, E. M., LEBEDKO, G. J., 1971, Some geochemical peculiarities of hydrothermal paleosolutions in the Kti-Teberda ore field (North Caucasus), (abst.): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 1, p. 358-359, (in English) (Authors at Rostov State University, Rostov-on-Don, USSR).

Ore-bearing quartz veins of Kti-Teberdian ore field occur in the crystalline schist, gneiss and amphibolite zone of the main Caucasus range and particularly in the roof of the upper Paleozoic biotite granites, intruding the Proterozoic metamorphic rocks. Most ore-bearing quartz veins fill fissures of two types (fractures and faults). The ore field is characterized by a considerable range of tungsten ores as well as by change of the wolframite-scheelite association in lower horizons to the scheelite-sulphide associations in upper horizon.

The interrelation of hydrothermal veins with vein derivations of the Upper Paleozoic granites (pegmatites, granite-porphyries and felsites) is not simple as there are mutual intersections. Only the intersection of the ore veins by the Lower Jurassic diabases and spessartites is established exactly.

There were carried out the thermometrical investigations of inclusions by the methods of decrepitation and homogenization, microchemical analyses and the determination of the hydrogen ion concentration of mineral-forming environments for a number of minerals of hydrothermal veins and granites (quartz, acid [sic], plagioclase, microcline, scheelite and calcite).

It was established that the relative amounts of alkaline solutions generally decreased simultaneously with the fall of temperature of homogenization of gas-liquid inclusions in the order: pegmatites, wolframite-scheelite veins and scheelite-sulphide veins.

The solutions are characterized by a considerable general concentration of the salts, running to 400-600 gram/liter. Among of cations the alkaline metals (sodium and potassium) are the most abundant constituents, the anions (HCO_3, Cl, SO_4) are present in approximately equal quantities. This conclusion is confirmed by the cryometric data and by the presence of daughter crystals (halite and sylvite) in the vacuoles. Mineral-forming solutions are enriched by magnesium in the places of intersection of the amphibolites by the hydrothermal veins.

The temperatures of decrepitation and homogenization fall from feldspar to quartz and calcite (above 350°C to 150-180°C) in similar vein systems, and it coincides in general with the order of deposition of these minerals, found from mineralogical study. According to the microchemical analyses of water leachates from the inclusions the salinity of the mineral-forming solutions decreases in the same direction and especially abruptly after crystallization of the scheelite.

On the whole the formation of studied veins from hydrothermal solutions ran through a [partially permeable] series of screened rocks in consequence of the filtration effect. The solutions had considerable mobility and avoided the strong limiting pressure. The first stages of crystallization are characterized by the deposition of the substance from the saturated water-salts solutions, after that the concentration and temperature are lowered. The wall rocks have negligible influence on the composition of the ore veins. (Authors' abstract).

GORNITZ, Vivien, & KERR, P.F., 1970, Uranium mineralization and alteration, Orphan mine, Grand Canyon, Arizona: Econ. Geol., v. 65 p. 751-768 (Errata, v. 66, p. 983, 1971).

The published version of a dissertation abstracted in <u>Fluid Inclusion Research</u> v. 3, p. 23. (E.R.)

GOVOROV, I. N., 1971, Thermodynamics of the greisen process: particularly in the far-eastern deposits, (abst.): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 1, p. 321-322, (in English) (Author at Far-Eastern Geological Institute, Vladivostok, USSR).

1. There are three formations of the rare-metals deposits in the Far-East: albitite-greisen, apocarbonatic-greisen and quartz-vein-greisen ones.

The deposits of the two former formations are confined to the transition zone between the Khanka and Bureya ancient massifs and the Sikhote-Alin fold region; they are characterized by the abundance of fluoride minerals and are connected with leucocratic and alaskite granite of the lithium-fluoride-raremetals type. The deposits of quartz-vein-greisen formation occur everywhere in connection with normal biotite and leucocratic granites, which sometimes belong to the tin-boron type.

2. Geological and geochemical data available suggest that genetic cycle of fluoride granites and greisens is closely connected with distillation of volatile components derived from the [melts] of the hypabyssal fissure intrusive bodies (Govorov, 1964; Tauson et. al., 1970). This mode of occurence contrasts with the convective model (Kadik, Khitarov, 1966, 1968), describing the formation of granitoid intrusives of considerable radial extent which are accompanied by deposits of cassiterite-silicate-sulphide group (Govorov, 1969).

3. The study of gas-liquid inclusions in minerals enable to establish four main stages in the formation of greisen deposits. They differ in temperature and composition of included solutions (g-equiv./kg H_2O):

Stages	t°C	Na^+	K^+	Ca^{2+}	Cl^-	F^-	HCO_3^-	SO_4^{2-}
I microcline	650-550	1,05	0,87	0,16	0,51	0,15	1,00	0,25
II albite	550-450	1,98	0,01	0,00	0,28	0,47	0,80	0,12
III greisen	450-250							
a) mica-quartz		0,41	0,14	0,16	0,31	0,05	0,23	0,15
b) mica-fluorite		0,61	0,21	1,04	0,20	1,66	0,13	0,26
IV quartz	350-250	0,34	0,06	0,12	0,27	0,01	0,21	0,03

4. The fluorine-rich deposits of albitite-greisen and apocarbonatic-greisen formations are characterized by vertical zoning of metasomatic minerals (from bottom up): microcline + albite → albite + muscovite → albite + topaz → topaz → topaz + pyrophyllite + diaspore → topaz + fluorite → fluorite + muscovite (apocarbonatic greisen). It is established by means of thermodynamic calculations that paragenesis albite + topaz is formed at a fluorine activity not less than 0.1m and pH-5 and paragenesis topaz + pyrophyllite + diaspore is stable at pH 2-3. The formation of similar zoning is dependent on the following factors: 1) differential change of dissociation constants (Frank, 1956) and activity coefficients (Govorov, 1965) of KCl, NaCl, HCl which take place along with the decrease in temperature and increase of solution density; 2) increase in acidity of solutions due to bonding alkali metals in solid phases and disintegration of acid complex compounds; 3) increase in stability fields of feldspars at the expense of muscovite and topaz above 400° and 500 bars.

5. Two successions of minerals - acidophile (a) and abyssophile (b) ones are established for the conditions of greisen process (250-650°, 250-1500 bars): a) albite → microcline → tourmaline → muscovite → topaz → pyrophyllite; b) topaz → pyrophyllite → tourmaline → muscovite → microcline → albite. (Author's abstract).

GOW, A. J., 1971, Relaxation of ice in deep drill cores from Antarctica: J. Geophys. Res., v. 76, p. 2533-2541.

Ed. note: Several of the phenomena caused by the expansion (up to 0.6%) of ice containing gas inclusions under pressure result in features similar to those observed on natural or laboratory overheating of fluid inclusions.

GREIG, J. A., BAADSGAARD, H., CUMMING, G. L., FOLINSBEE, R. E., KROUSE, H. R., OHMOTO, H., SASAKI, A., and SMEJKAL, V., 1971, Lead and sulphur isotopes of the Irish base metal mines in Carboniferous carbonate host rocks: Soc. Mining Geol. Japan, Spec. Issue 2, p. 84-92, [Proc. IMA-IAGOD Meetings '70, Joint Symp. Vol.].

Sulphur isotope compositions were determined for 30 samples of pyrite, sphalerite, galena and barite from Mogul mine.

Two distinct ore zones exist at Mogul. A lower orebody lies along the hangingwall side of the steeply dipping Silvermines fault. A stratiform and massive upper orebody within Lower Carboniferous units, dips gently to the north away from the fault. The δS^{34} values of the sulphides range from +4 to -7% in the lower orebody, and from -8 to -35% in the upper orebody. The use of sulphur isotope geothermometry (Rye and Czamanske, G.S.A. Ann. Mtgs., Abstract, 195, 1969; Kajiwara et al., Earth and Plan. Sci. Letters, 7, 271, 1969) and the measurements of filling temperatures of fluid inclusions indicate the ores of the lower zone were formed at temperatures centered around 225°C though ranging from 150 to 275°C. A pronounced trend in the δS^{34} values is observed whereby the sulphides progressively become lighter upward along the fault and away from the fault in the stratiform ore. Barite, which occurs above and at the distal end of the stratiform orebody, shows consistent δS^{34} values of + 18%. The observed trend of the δS^{34} values of the sulphides and the occurrence of barite in the peripheral areas can best be explained by increase of pH and oxidation state of the hydrothermal fluids through reactions and host rock carbonates. As hydrothermal fluid moved upward and away from the fault, reduced sulphur species became less abundant and progressively more negative in δS^{34} values. Oxidized sulphur species became more abundant and more positive.

δS^{34} values for 13 sulphide samples from Tynagh and Gortdrum mines similarly are negative and fall within the range for Mogul mines.

Lead isotope ratios were determined for 29 galena samples from 24 different localities. Leads are progressively more radiogenic southwards across the area of study, suggesting a deep regional rather than a local origin. Isotope values fall close to a single growth curve defined by a μ (U^{238}/Pb^{204}) ratio of 8.79 corresponding to a conformable lead pattern. Model lead ages range from 270 to 75 m.y., appreciably younger dates than the 350 m.y. age of the host rocks. (Authors' abstract).

GRIGORCHUK, G.U., 1969, The importance of some minerals in altered wall rocks in defining conditions of hydrothermal mineral formation: L'vov Gos. Univ. Mineral. Sbornik, v. 23, no. 3, p. 281-292 (in Russian).

The appearance in near vein metasomatose either of quartz and sericite or feldspars and carbonates respectively in the first or the last stage of mineral formation from separate portions of solutions proves the distinction of thermodynamical conditions. (Author's abstract). A review, based in part on fluid inclusion evidence, with 44 references (E.R.)

GROMOV, A. V., NOVIKOV, V. P., SVESHNIKOVA, V. I., and MEL'NIKOV, F. P., 1971, Possible causes of variation of hardness of quartz, in Investigations of mineral-forming solutions and melts in inclusions in minerals, N.P. Ermakov and L.N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 189-191, (in Russian).

GROMOV, A. V. and SMERTENKO, V. M., 1971, Study of inclusions in secondary albite granite and pegmatite, in Investigations of mineral-forming solutions and melts in inclusions in minerals, N. P. Ermakov and L. N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 80-83 (in Russian).

GRUSHKIN, G. G., 1969, The composition of gas-liquid inclusions in fluorite of the Khingan tin deposit: Zap. Vses. Min. Ob., 1969, v. 98, no. 6, p. 748-752 (in Russian)

Analytical data from this article, not available for the abstract in the previous volume of COFFI, include the following two analyses of leachates made on 1-2 kg samples (weight % relative to water) (see next page) The following were not detected: Fe^{++}, SO_4, NO_3, BO_3, Ti^{+4}, Sn^{+4}. The change in concentration from the early to the late generation corresponds to a change in homogenization temperature from 400-435 to 292-333, (B. Poty).

	Early green octahedral fluorite	Late pink cubic fluorite
K	1.59	1.30
Na	5.65	3.37
NH_4	1.10	1.03
Mg	.81	.23
Sum cat.	9.15	5.93
SiF_6	1.86	0.85
F	2.44	0.64
Cl	4.88	2.25
HCO_3	6.49	7.69
Sum anions	15.69	11.45
Total salts	25.55	18.46
H_2O	100	100
Total CO_2	9.93	7.86

GÜBELIN, E., 1968, Gemstones of Ceylon. (Privately printed), 152 p. (in German).

A very thorough study of the many gem occurrences of gem materials in Ceylon, the mining methods and the native lapidary procedures. Includes many excellent color photomicrographs of the solid and liquid inclusions in gems. (E.R.)

GÜBELIN, E., 1971, New analytical results of the inclusions in Siam rubies: Jour. Gemmology, v. 12, no. 7, p. 242-252.

A study (with 7 color plates) on the origin and nature of solid inclusions of apatite, garnet, pyrrhotite, plagioclase, diopside, etc., in Siam rubies, using the electron microprobe. (E.R.)

GUNTER, B. D., and MUSGRAVE, B. C., 1971, New evidence on the origin of methane in hydrothermal gases: Geoch. Cosmoc. Acta, v. 35, p. 113-118.

A 250°K difference between calculated hydrogen isotope temperatures and calculated carbon isotope temperatures, the presence of other aliphatic hydrocarbons, and negative radioactive data are collectively interpreted to mean that chemical reaction between carbon dioxide and molecular hydrogen is probably not the primary source of methane in these features. (Authors' abstract). (Ed. note: Of interest in view of the many analyses of methane in fluid inclusions).

GUROV, E. P., MARCHENKO, E. YA., METALIDI, S. V., and SHVAKOVA, A. A., 1971, Formation of phenakite in apogranite metasomatites: Dopov. Akad. Nauk Ukr. RSR, Ser. B 1971, v. 33, no. 5, p. 391-394, (in Ukrainian). CA 75 (5) 134 (1971). (Authors at Inst. Miner. Resur., Simferopol, USSR).

Geothermometric study of gas-liq. inclusions in phenakite from metasomatic rock showed that the mineral was formed at 360-405°. The secondary reworking of phenakite occurred at 270-335° and resulted in formation of gas-liq. inclusions in the form of linear zones. F played the main role during formation of Be mineralization. This caused spatial assocn. of phenakite with fluorite in rocks rich in Ca. The prosopite ($CaAl_2(F, OH)_8$), cryolite, and other F minerals were formed, in addn. to fluorite, in aluminosilicate medium (apogranitic metasomatites). The close paragenetic relation with fluorite, prosopite, and other fluorides is typical of phenakites from metasomatic rocks. The F-bearing emanations promoted both transfer of B in soln. and removal of Be from the country rocks. (Authors' abstract).

GUSTAFSON, Lewis, B., and HUNT, John P., 1971, Evolution of mineralization at El Salvador, Chile, (abst): Econ. Geol., v. 66, p. 1266-1267.

An andesite-rhyolite volcanic center was active in the vicinity of the El Salvador porphyry copper deposit 45-50 million years ago. 41 million years ago the deposit underlay a steaming geothermal area associated with a shallow and cooling granodioritic porphyry complex, intruded near the end of the volcanic period. Most of about 6 million tons of copper had been deposited simultaneously with, adacent to, and within recurrent intrusions of porphyry. Early mineralization was characterized by Kspar-biotite alteration, bornite-chalcopyrite and chalcopyrite-pyrite assemblages, and granular quartz-Kspar-anhydrite-sulfide veins. Subsequent and relatively coarser textured quartz-anhydrite-molybdenite veins with inconspicuous or no alteration haloes mark a transition to late Kspar-destructive alteration (mostly sericitic), and pyrite veins formed after intrusion of the last major porphyry stock. Fluid inclusions in the early and transitional veins contain concentrated NaCl brine coexisting with vapor and have filled temperaturers greater than 600°C to 350°C. Fluid inclusions in late veins contain low salinity fluids and have filling temperatures from 350°C to less than 200°C. Distribution of late mineralization was controlled by the thermal-chemical regime of the cooling intrusive center interacting with groundwater. A shallow hot spring system continued to be active at higher levels after cessation of sulfide mineralization as evidenced by pebble dikes related to late porphyry dikes, and advanced argillic alteration producing pyrophyllite, diaspore, and alunite. Supergene sulfide enrichment and kaolinitic alteration followed within 6 million years. (Authors' abstract)

HAAS, J.L., Jr., 1971a, The effect of salinity on the maximum thermal gradient of a hydrothermal system at hydrostatic pressure: Econ. Geol. v. 66, p. 940-946.

The effect of salinity on the temperature-depth relations of a brine of constant composition, enclosed in a vein system, but freely connected to the surface, and everywhere at the boiling point for the hydrostatic head, was calculated by using a mathematical model. The Na-Ca-K-Cl brines which are found in thermal springs and in fluid inclusions in ore minerals were approximated by the available data for vapor-saturated NaCl-H_2O solutions. In general, the results are similar to those calculated by D.E. White in 1968 for H_2O, except that the gradients are steeper because of the increase in density and the decrease in vapor pressure caused by the dissolved salt. As a practical rule, the depth to an isotherm in a 5. 10, 15, 20 and 25 wt. percent NaCl brine system is, respectively, 92, 84, 77, 70 and 63 percent (± 2 percent) of the depth to the same isotherm in an H_2O system. From the data presented, the minimum depth to the growth site of crystals containing fluid inclusions which indicate boiling of the brine can be estimated. Among other applications, these results are useful toward the understanding of the behavior of brines in geothermal sreas which may or may not contain compositional stratification. (Author's abstract).

HAAS, J.L., Jr., 1971b, Thermodynamic correlations for brines: NaCl-H_2O liquid-vapor equilibria: (abst.): Amer. Geop. Union Trans. (EOS) v. 52, no. 4, p. 379.

Handling of thermodynamic data is facilitated by the "reference substance technique" developed since 1940 by Othmer and coworkers. The method compares the behavior of a substance to some well-known reference substance, permitting a similar description of the less well studied substance. From the Clapeyron relation, vapor pressures for fixed brine compositions are fairly well described by linear equations of the form $\log T_x = m \log T_0 + c$, where T_x is the temperature (°K) of the brine and T_0 is the temperature of H_2O (reference substance) at the same pressure. In the current study, improved correlation over a temperature range exceeding 350° is obtained by taking $c = 0$ and expressing the slope by $m = a + b\,T_0$. As few as two accurate points define the vapor-pressure curve at fixed molality. These and linearly related functions give simple but accurate predictions of boiling point elevation, activity of H_2O, and the Clapeyron enthalpy (at T_x and vapor pressure). For NaCl-H_2O to 300°c and all molalities x, the coefficients are:

$$a = 1 + 1.70544\cdot10^{-6}x - 5.2859\cdot10^{-5}x^2 + 1.23617\cdot10^{-5}x^3$$

$$b = 1.17405\cdot10^{-6}x + 1.3845\cdot10^{-7}x^2 - 1.6205\cdot10^{-8}x^3 - 2.084\cdot10^{-9}x^4 + 1.15\cdot10^{-10}x^5$$

Standard error of T_x is 0.02 per cent; standard error of vapor pressure is 0.3 per cent. (Author's abstract)

HALL, W.E., FRIEDMAN, Irving, & GLEASON, J.D., 1971, [Chemical and isotopic analyses of the Climax deposits, Colorado]: U.S. Geol. Survey Prof. Paper 750A, p. A-126.

Seven samples of quartz molybdenite ore and late-stage fluorite from the Climax mine, Colorado, were crushed in vacuum for isotopic and chemical analyses of fluid inclusions. The δD (SMOW) values of the fluid inclusions ranged from -87‰ to -138‰, and the salinities ranged from approximately 10,000 to 300,000 ppm, low salinities being associated with low deuterium contents. Thus the ore-depositing fluid ranged in origin from dominantly magmatic hydrothermal initially to dominantly unaltered meteoric water in late-stage mineralization.

The O^{18} content of quartz in the veins was depleted with distance from the center of mineralization. This is opposite to the direction expected with a temperature decrease and may be correlated with an increase in amount of isotopically light meteoric water in the ore fluid. (Author's abstract).

HARANCZYK, Cz., 1971, Colloidal transport phenomena of zinc sulfide (Brunckite) observed in the Olkusz mine in Poland: Soc. Mining Geol. Japan, Spec. Issue 2, p. 156-162 [Proc. IMA-IAGOD Meetings '70 Joint Symp. Vol.].

It is postulated that nucleation and preliminary growth of individual crystals of zinc sulfide took place when suspended in hydrothermal solution, and that these small particles were colloidally transported by water current and deposited as a subtle suspension. (Author's abstract, greatly abbreviated).

HARKER, R.S., 1971, Some aspects of fluid inclusion geothermometry with particular reference to British fluorites: Ph.D. dissertation, Univ. of Leicester, 155pp.

The development of fluid inclusion geothermometry is described from its nineteenth century beginnings down to the present time. A method for the preparation of samples for fluid inclusion work and the experimental technique using the Leitz 1350 heating stage are described.

The problems involved in obtaining representative geothermometric data are outlined. When a sample consists of well-formed crystals it is relatively easy to determine the thermal history of the sample but not so with massive material. A preliminary investigation was undertaken to assess the variation of data obtained from different sections cut from the one sample and on arbitrary grounds a minimum number of sections and of temperature measurements is suggested so that approximately representative data may be obtained.

An investigation of the relationship between filling temperatures of fluid inclusions and the thickness of the enclosing section is described. It was found that on reducing the thickness of a section, the filling temperatures of inclusions decreased. Statistical tests showed the decrease in filling temperatures to be significant and it is suggested that the rate of heating adopted by the writer is too fast to allow equilibrium between the inclusion and the heating stage to be achieved and that the observed filling temperatures are somewhat higher than the actual filling temperatures.

A preliminary investigation into the problems of leakage in fluid inclusions is described. Experiments showed that moderate overheating above the filling temperature of an inclusion did not cause leadage but that heating to 100°C. above the filling temperature usually induced leakage. A theory that over-heating may cause fluid to migrate into inter-atomic spaces and that, on cooling, this fluid may move back into the inclusion cavity was not proved.

All the recent published works on British geothermometry are reviewed and the published data are compiled as an appendix. (Author's abstract.) (See next page).

This includes new data on homogenization temperatures for fluorite from a variety of British localities. The samples came from localities listed in the Appendices, and many have no indication of their geological environment. The localities include the Geevor mine (one of the Cornish tin mines), with homogenization temperatures of 118-337°C, and a series of localities listed only as follows:

"South Crofty mine" (297-314°C); "Wheal Mary Ann, Menheniot" (99-150°C); "Scordale, Westmoreland" (126-139°C) "Grassington, Yorkshire" (88-114°C); and "Appletreewick, Yorkshire" (96-113°C). (E.R.)

HARPER, C. T. and SCHAMEL, S., 1971, Note on the isotopic composition of argon in quartz veins: Earth and Plan. Sci Letters, v. 12, p. 129-133.

Vein quartz from the Monte Antola Nappe (Italy) contains excess ^{40}Ar in amounts ranging from 9.73×10^{-7} s. cm ^{3}/g to 38.89×10^{-7} s.cm^3/g, correlating with structural depth within the nappe. (Author's abstract). This argon is from the degassing of surrounding pelitic rocks during deformation and recrystallization; it is trapped in fluid inclusions, in amounts similar to those found by Rama et al. in 1965 (J. Geophs. Res., v. 70, p. 509). Isotopic analysis of quartz would be useful for establishing the presence of excess ^{40}Ar in metamorphic terrains, and for determining the true, "initial" $^{40}Ar/^{36}Ar$ ratios in metamorphic systems. (ER)

HAYWARD, A.T.J., 1971, Negative pressure in liquids: can it be harnessed to serve man? : American Scientist, v. 59, p. 434-443.

A review of the history of negative pressure experiments and discussion of current work and applications (also applicable to explain some fluid inclusion phenomena; E.R.).

HEMLEY, J.J., & MONTOYA, J.W., 1971, Some mineral equilibria in the system K_2O - MgO - Al_2O_3 - SiO_2 - H_2O : (abstr.): Geol. Soc. Amer. Abstracts with Programs, vol. 3, no. 7, p. 597. Authors at U.S. Geol. Survey, Washington, D.C. 20244 and The Anaconda Company, Salt Lake City Utah 84116.

Experimental studies were made of metasomatic reactions in the system K_2O-MgO-Al_2O_3-SiO_2-H_2O at 15000 psi and 300°, 400°, and 500°C. The following reactions were observed and evaluated in terms aqueous KCl, HCl, and $MgCl_2$; K-feldspar to phlogopite, phlogopite to chlorite, muscovite to chlorite, K-feldspar to chlorite, and chlorite to andalusite, pyrophyllite, and montmorillonite respectively. Excess quartz was present and total chloride ranged from approximately 2 to .001 m. The chlorite used as starting material was synthetic, iron-free clinochlore. The tendency of Mg to be fixed in solid phases relative to the aqueous phase increases with increase in temperature with concomitant increase in total acidity. At 500°C the K-feldspar-phlogopite and chlorite-andalusite phase boundaries are determined and log m $MgCl_2/m^2HCl$ of the quench solutions is 2.6±.2 + 2.2±.1 respectively. Other boundaries, such as phlogopite-chlorite, are fixed only tentatively. The phlogopite-chlorite equilibrium exists only at relatively low aqueous Mg concentrations as high Mg converts phlogopite to talc-chlorite. Studies have not been completed on the stability of K-feldspar-chlorite, but phase boundary slope relationships plotted in terms of aqueous concentrations suggest that the pair is stable or very nearly stable at 500°C, and stable at the lower temperatures. (Authors' abstract)

HEMLEY, J.J., MONTOYA, J.W., NIGRINI, A., & VINCENT, H.A., 1971, Some alteration reactions in the system CaO-Al_2O_3-SiO_2-H_2O: Soc. Mining Geol. Japan, Spec. Issue 2, p. 58-63 [Proc. IMA-IAGOD Meetings '70, Joint Symp. Vol.].

Alteration reactions in the system CaO-Al_2O_3-SiO_2-H_2O have been investigated in the temperature range 300°-500°C at 1000 bars total pressure in an aqueous chloride environment with excess quartz present. Ca-montmorillonite is the hydrolytic decomposition product of anorthite and pyrophyllite is the decomposition product of montmorillonite over most of the temperature range studied. At 300°C, in terms of total molal concentrations, the montmorillonite field is about two log units wide in m_{CaCl_2}/m^2_{HCl}; it narrows with increasing temperature and disappears at about 460°C. The value of log $CaCl_2/HCl$ for anorthite decomposition is 3.1 ± 0.2 at 500°C and 8.2 ± 0.5 at 300°C, and is approximately linear in that temperature interval.

Pyrophyllite is unstable relative to andalusite + quartz above 400°C and kaolinite + quartz is unstable relative to pyrophyllite above about 300°C at 1000 bars pure water pressure. The pyrophyllite-andalusite reaction is sluggish, however, and between 400 and 460°C Ca-montmorillonite converts to a persistent mixed-layer phase, montmorillonite-pyrophyllite or montmorillonite-margarite. The temperature range of stability of montmorillonite and mixed-layer phase may be considerably smaller than the range of formation, judging from results in the corresponding Na-bearing system.

The results, together with corresponding data in the Na system, show the greater susceptibility of calcic plagioclase to hydrothermal alteration and provide greater insight into albitization, the compositional origin of natural thermal waters and perhaps the origin of some fluid inclusions. (Authors' abstract)

HEWITT, D.A., & VIDALE, R.J., 1971, A comparison of two common types of calc-silicate zoning (abstr.): Geol. Soc. Amer. Abstracts with Programs v. 3, no. 5, p. 319-320. Authors at the Department of Geological Sciences, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061; and the Department of Geology, State University of New York at Binghamton, Binghamton, New York 13901.

Two types of calc-silicate zoning formed by chemical potential gradients commonly occur at the contacts between metamorphosed carbonates and pelites: (1) Metasomatic zoning, produced at constant temperature and pressure in a chemical potential gradient by differential diffusion of chemical species additional to CO_2 and H_2O; and (2) fluid composition zoning, produced at constant temperature and pressure by a gradient in the CO_2/H_2O ratio of the fluid phase.

Metasomatic zoning is characterized by intermediate assemblages of altered chemical compositions containing relatively few mineral phases and by the decrease in the CaO-content of the silicate phases from the center of the carbonate towards the schist. Fluid composition zoning is characterized by isochemical zones with multiphase assemblages and commonly by an increase in the CaO-content of the silicate phases from the center to the edge of the carbonate.

Both types of zoning are normally present to some extent in natuval calc-silicate bands. The critical factor in determining which of the two will predominate is the rate of diffusion of material through the fluid phase. Fluid composition zoning predominates only in situations where a gradient in the CO_2/H_2O ratio of the fluid can exist stably for relatively long periods of time. Factors which increase diffusion, such as increased temperature, deformation, increased amounts of pore fluid, and concentration of salt solutions, favor the development of metasomatic zoning. (Authors' abstract)

HITCHON, Brian, & HOLTER, M.E., 1971, Calcium and magnesium in Alberta brines: Research Council of Alberta, Econ. Geol. Report No. 1, 39 pp.

Approximately 850 subsurface brines from Alberta containing more than 20,000 mg/l calcium and more than 3,000 mg/l magnesium were studied, and analyses for 35 are presented. Regional compositional gradients, hydraulic-head distribution, volume and origin of the brines are discussed. Brines with more than 60,000 mg/l calcium and more than 9,000 mg/l magnesium are similar in composition to commercial brines in the United States. The similarity to some inclusion fluids is striking. (E.R.)

HOLLOWAY, J.R., 1971, Composition of fluid phase solutes in a basalt-H_2O-CO_2 system: Geol. Soc. Amer. Bull., v. 82, p. 233-238.

Analyses were made of the fluid phase after equilibration at 800-1100°C and 2-8 kb. It contained 0.5-2 wt percent solutes, mainly SiO_2, Al_2O_3 and MgO. (see discussion- Dixon and Philpotts, 1971). (E.R.)

HOLSER, W.T., 1968, Chemistry of brine inclusions in Permian salt from Hutchinson, Kansas (abstr.), in Saline deposits-Internat. Conf. Saline Deposits, Houston, Tex., 1962, Symposium: The Geol. Soc. Amer. Special Paper 88, 1968, p. 537.

Brine inclusions from halite crystals in the Permian Wellington Formation at Hutchinson, Kansas, have been extracted, analyzed, and compared with inclusions of other localities and ages as well as with formation waters. Those studied were from very coarse (2-20cm) cleavages of halite that occur as irregular white masses crosscutting the bedded halite in the Carey mine and in a drill core from the Naval Air Station.

Bromide, magnesium, and potassium are not precipitated in significant amounts in the halite facies, so their ratios remain constant. Most of the Br/Mg ratios in the brine inclusions from Hutchinson are close to that of sea water and to modern bitterns. This indicated both that the inclusions are virtually unchanged samples of the bitterns left behind in Permian time and that the Br/Mg ratio of the sea has remained constant since the Permian. On the other hand, the ratios of bromides, magnesium, and potassium to chloride each increases steadily as salt is crystallized through the halite facies, so any of these ratios is a measure of the degree of evaporation of the bittern. The ratios in the Hutchinson inclusions indicate a high degree of evaporation, almost equivalent to the potash facies. The composition of these inclusions contrasts strongly with (1) highly saline "connate" waters permeating deep sandstones and limestones in the midcontinent, which are low in Br, Mg, and K; and (2) brines due to re-solution of salt by fresh water, which are even lower in these elements.

Brine inclusions from the Silurian of the Michigan basin have a similar composition, but some from the Permian Salado Formation at Carlsbad, New Mexico, have an anomalously low Br content.

This investigation has shown that at least some of the large inclusions are good samples of Permian bitterns despite the recrystallization that was evidently necessary to form the large crystals. Bromide in solid solution in the halite itself corresponds to a much lower stage of evaporation, which may indicate that the inclusions have lost some water since crystallization of the main mass of halite. (Author's abstract)

HUGHES, C.J., 1971, Anatomy of a granophyre intrusion: Lithos, v. 4, p. 403-415. Author at the Department of Geology, Memorial University of Newfoundland, St. John's, Newfoundland, Canada.

Various structural and textural features of a drusy granophyric ring-dyke intrusion can be explained in terms of the behavior of magmatic water. Initial crystallization of water-rich magma close to ternary eutectic composition resulted in textures grading from granophyric to microgranitic. Eventual entrapment of water-rich pockets resulted in crystallization from a silicate liquid and a hydrothermal liquid simultaneously, probably at magmatic overpressure, to form isolated bodies of pegmatite containing giant euhedral quartz crystals. Later aplite, rhyolite breccia, and tuffisite veins reflect the escape of magma and magmatic gas through the congealed parts of the intrusion, at first permissively, but later with increasingly explosive effects. (Author's abstract.)

IKORSKII, S.V. and ROMANIKHIN, A.M., 1964, The mode of occurence of hydrocarbon gases in nepheline of the Khibina alkalic massif: Geokhimiya no. 3, 1964, pp. 276-281 (in Russian); translated in Geokhimiya Translations 1964, Suppl. to Geochem. Internat., v. 1, issued in 1973. (Authors at Geological Institute, Kola Branch of the Academy of Sciences USSR.)

Although this article is old, it is listed here since the translation has just been published (E.R.).

IMAI, H., and TAKENOUCHI, S., 1971, Report of the Japanese Committee on Inclusions in Minerals: Jour. Mining Metall. Inst. Japan, v. 87, no. 1001, p. 546-560 (in Japanese). (This is a photo atlas of 103 excellent Japanese photomicrographs. Although the 103 photographs cannot be reproduced here, the captions are translated - see Translations Section.)

IMAI, H., TAKENOUCHI, S. and KIHARA, T., 1971, Fluid inclusion study at the Taishu mine, Japan, as related to geologic structure: Soc. Mining Geol. Japan, Spec. Issue 3, p. 321-326 (Proc. IMA-IAGOD Meetings '70, IAGOD vol.)

The Taishu mine is a zinc and lead deposit, consisting of mesothermal veins. Veins occur in Paleogene sediments around granite mass. The vein fissures are classified into two types; (A) gently dipping bedding reverse faults, (B) strike-slip faults. The ore-forming fluid from the granite magma ascended upward and outward along the bedding faults and moved into the strike-slip faults.

Fluid inclusions in quartz crystals from the veins as well as from the granite in the mining area are studied by means of heating stage and freezing stage microscope. Both homogenization temperatures and the salinities of the inclusions drop gradually upward and outward from the granite mass. This could be due to mixing of the ore-forming fluid with meteoric and connate water. The CO_2 liquid-bearing inclusion is found at the marginal part of the deposit. (Authors' abstract)

A more extensive abstract of this paper than given in this publication was first published in 1970 - see Fluid Inclusion Research, 1970, vol. 3, p. 28-29. (The text here shows homogenization temperatures ranged from 440-150°, and salinities from 56 to 5%). (E.R.)

ISHAN-SHO, G.A. and MOROZOV, S.A., 1971, Thermodynamic conditions for the formation of calcites of some antimony-mercury deposits of the Shink-Magiansk region: Dokl. Akad. Nauk Tadzh. SSSR 1971, v. 14, no. 3, p. 52-55, (in Russian). Authors at Inst. Geol., Dushanbe, USSR. CA 75(5) 129(1971).

Hg-Sb mineralization in the Shink-Magiansk region, with primary stibnite and cinnabar, is assocd. with hydrothermal-metasomatic altered rocks. Two generations of calcite occur in primary and secondary (sulfide-carbonate-barite) paragenetic mineral assemblages. Decrepitation curves indicate the presence of 3 genetic types of calcite formed in 3 temp. intervals 100-120°, 180-230°, and 250-300°. Homogenization temps. of gas-liq. inclusions (irregular, rounded, ellipsoidal) show 3 temp. intervals 40-80°, 140-220°, and 280-310° corresponding to the decrepitation intervals. Exptl. data indicate that the pressure of formation ranged 130-320 atm.

IVANOVA, G. F., 1971, Physico-chemical factors of tungsten concentration in hydrothermal process, (abst.): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 1, p. 409-410 (in English) (Author at Vernadsky Institute of Geochemistry and Analytical Chemistry Academy of Sciences, Moscow, USSR).

Our barothermometric studies of wolframites of various composition and the paragenetic minerals demonstrated that the formation of hubnerite, wolframite and ferberite in various mineral parageneses proceeds under isothermal conditions in the temperature range 350-270°C and as a rule from dilute solutions. Therefore the temperature is not the predominate factor determining the deposition of wolframites of various compositions. (Partial author's abstract).

IVANOVA, G.F., and MAKSIMYUK, I.E., 1971, Dependence of composition of wolframite on some geological, mineralogical and physicochemical factors: Geokhimiya, 1971, no. 9, p. 1110-1121 (in Russian); abstract only translated in Geochem. Internatl. v. 8, no. 5, p. 795, 1971. Authors at V.I. Vernadskiy Institute of Geochemistry and Analytical Chemistry, Acad. of Sciences USSR and Institute of Mineralogy, Geochemistry and

Crystal Chemistry of Rare Elements, Moscow; Soviet-Mongolian Geological Expedition, Acad. of Sciences USSR and Acad. of Sciences Mongolian People's Republic.

Using 12 tungsten deposits in Mongolia as examples, it is shown that neither the compositions of the enclosing rocks nor the temperatures of formation (determined both by measuring filling temperatures of fluid inclusions and by decrepitation to be in the 205-400°C range) correlate with the relative amounts of $MnWO_4$ and Fe_2O_4 (sic) in wolframites. The higher iron concentration in earlier-formed wolframites is explained by the lower solubility of Fe_2O_4 (sic). The principal factors determining the composition of wolframites are the redox potential and the alkalinity of the solutions, for these determine the activities of Fe^{+2} and Mn^{+2}. (Authors' abstract)

IZYUMSKII, S. I., KOVRIGO, O. A., and CHUGUEVSKAYA, O. M., 1971, Development of the thermoluminescence method of geothermometry, in Investigations of mineral-forming solutions and melts in inclusions in minerals, N.P. Ermakov and L.N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 183-186, (in Russian).

JESSBERGER, E., and GENTNER, W., 1971, Mass spectrometric analyses of gas inclusions in Muong Nong glass and Libyan Desert glass (abstr.): Eos (Amer. Geophys. Union, Trans.), v. 52, no. 4, p. 366.

Noble and non-noble gases in bubbles of Muong Nong- and Libyan Desert glass were released by vacuum crushing at room temperature and measured by high sensitivity mass spectrometry. The N_2:Ar:Kr:Xe ratio as well as the rare gas isotope ratios were found to be atmospheric, indicating the terrestrial origin of these glasses. The concentrations of the active gases O_2, CO_2, CO and SO_2 vary highly between adjacent bubbles. Total gas pressure in the bubbles of these glasses is in the 100 mm range, much higher than that found for other types of tektites. (Authors' abstract)

KALTENEGGER, W., & PREISINGER, A., 1971, Mass-spectrometric analysis of gases of the system C-H-O in minerals: Tschermaks Min. Petr. Mitt. v. 15, p. 291-303 (in German). Authors at Institute of Mineralogy and Crystallography, Univ. Vienna, Austria.

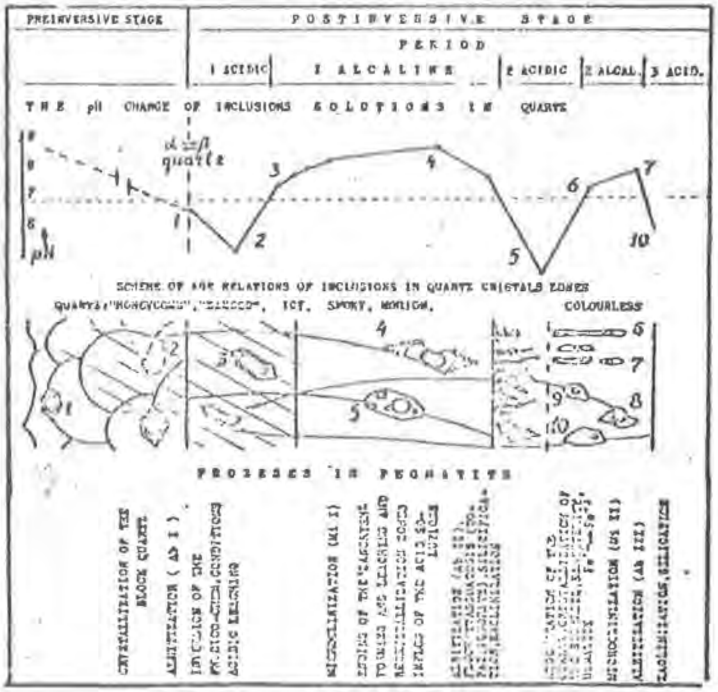
The analysis by mass-spectrometer of very small amounts of gases H_2, O_2, CO, CO_2, CH_4 and H_2O, respectively, meets with considerable difficulties, because of influence by the measuring system, from interactions of the gases with hot metal surfaces on one hand, and glass surfaces on the other hand. By a suitable arrangement of apparatus and procedures, such as heating the samples and separating the gases by cooling traps, the gas amounts in and on minerals can be quantitatively determined to 0.005 mm^3/SPT. The apparatus is calibrated by thermal dissociation of crystals like muscovite, calcite, etc. The application of this method in chemistry and mineralogy is treated as well as the limits and the possibility of the quantitative analysis of residual gas. (Authors' abstract)

KALYUZHNYI, V. A., 1971a, Measurements data of pH of liquid inclusions in minerals and general regularities of the formation of "zanorysh" pegmatites in the Ukraine (abst.): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 1, p. 341-342 (in English) (Author at Institute of Geology and Geochemistry of Fuel Minerals, Academy of Sciences of Ukrainian SSR).

The direct measurement has been made of pH of liquid inclusion solutions whose formation sequence was defined by syngenetic degree with the host-crystal and refilling phenomenon (Lemmlein). The obtained results make it possible to establish the regime of change of pH relative (sometimes actual) value of mineral forming solutions. By systematic pH evaluation, the chemical composition and the refilling degree taken into account, the main age groups of inclusions in quartz and other minerals of "zanorysh" pegmatites were defined.

The pegmatite process splits into two stages - pre- and post-inversive, each stage made up of five periods. The postinversive stage has 3 acidic and 2 alkaline periods (see the table).

The physico- chemical conditions of geochemical processes vary with the pH variations of the mineral-forming solutions. K and Na behaviour is reflected in feldspar composition. The albite (three) and microcline (two) generations, established by ontogenic research, correspond to the process periodicity and are in keeping with the D.S. Korzhynsky's theory. The albite crystallization from acid solutions is proved by its simultaneous growth with topaz. The topaz and accessory beryl, formed mainly during the 2nd acidic period, are destroyed by the alkali solutions of the next period. Thus, the rearrangement of basic petrogenic (K, Na, Si, Al, Fe) and rare (Be, Sn, B, Pb) elements is a function of crystallization conditions, the acidic/alkaline index being of primary consideration. The change of the latter is caused by general temperature drop, broken off by abrupt temperature rises or drops resulting from disruption of the sealing of pegmatite system due to contractional fissures. (Author's abstract).



KALYUZHNYI., V.A., 1971b, The refilling of liquid inclusions in minerals and its genetic significance: L'vov. Gos. Univ. Mineral. Sbornik., v. 25, no. 2, p. 124-131 (in Russian). Author at Inst. Geol. Geokhim. Goryuch. Iskop, L'vov, USSR.

Secondary (early and late secondary) liquid inclusions can be used to determine the genesis of minerals. The sequence in the change of liquid inclusions corresponding to the evolution of the endogenous fluid is determined by the alteration in the contents (refilling) which occurs during the opening of earlier formed inclusions by cracks of later date, subsequently healed up. The most important stages of the alteration of the contents, the changes in the homogenization temperature (600-80°C), pH, and the (state of) aggregation of mineral-forming fluids (of the example of 20 refilling inclusions) of the "zanorysh" pegmatites of the Ukraine are given. (Author's abstract, modified). For meaning of "zanorysh", see Kalyuzhnyi, 1971, in Translation Section. (E.R.)

KALYUZHNYI, V. A., (ed.), 1971a, Mineral-forming fluids and parageneses of pegmatite minerals of the zanorish type in the Ukraine (fluid inclusions, thermobarometry, geochemistry): Kiev, Naukova Dymka Press, 216 pp. (In Ukrainian with 2-page Russian Resume). (See Translation Section)

KARWOWSKI, L., & KOZLOWSKI, A., 1971a, Brownian movements in gaseous-liquid microinclusions in minerals: Bull. Acad. Sci. Poland, Earth Sci. Series, v. 19, no. 4, p. 233-237 (in English). Authors at the Institute of Geochemistry, Mineralogy and Petrography, University, Warsaw, Zwirki i Wigury 93, Poland.

The gas bubble in gaseous-liquid microinclusions in minerals of hydrothermal, pneumatolytic and pegmatitic origin is subject to movements identified as Brownian. The noticeable features of these movements have been described as well as their possible usefulness in the definition of conditions in which the generations of microinclusions and their host-minerals were formed. (Authors' abstract.)

KARWOWSKI, L., and KOZLOWSKI, A., 1971b, Investigation of inclusions in minerals by means of their calcination: Bull. Acad. Sci. Poland, Earth Sciences, v. 19, no. 4, p. 239-248 (in English). Authors at the Institute of Geochemistry, Mineralogy and Petrography, University, Warsaw, Zwirki I Wigury 93, Poland.

The problem of the course of loss of weight during calcination of certain anhydrous minerals and its correlation with the amounts and kinds of inclusions present in these minerals was investigated. It was found that sample granulation has an effect on this process. The methods used in the investigation (with suitable choice of grain class) make it possible to determine the amounts of inclusions and the average concentration of ions in solutions present in the inclusions. A method of discerning between decrepitation and thermal decomposition of minerals is proposed, exemplified by topaz. (Authors' abstract)

KAZANSKIY, Yu. P., KATAYEVA, V.N., & SHUGUROVA, N.A., 1970, Gas and liquid phases in inclusions as relicts of former atmospheres and hydrospheres: Int. Geol. Rev., v. 12, no. 9, p. 1150-1153.

KELLY, W.C., 1971, Review of:Fluid Inclusion Research-Proceedings of COFFI, 1968: Econ. Geol., v. 66, p. 501.

A belated but complimentary review for an even more belated volume. (E.R.)

KERIMOV, A.D., and DZHAFAROV, ChD., 1971, Formation temperature of barite and galena from the barite, lead-barite, and some complex ore deposits of Azerbaidzhan: Izvest. Akad. Nauk Azerb. SSR, Ser. Nauk Zemle, 1971, no. 2, p. 18-24 (in Russian).

Barite and galena decrepitate at 200-120°C (E.R.)

KESLER, S.E., ASCARRUNZ-K, R.E., 1972, Guatemalan lead-zinc mineralization: magmatic-hydrothermal or Mississippi Valley type?: Geol. Soc. Amer. Abstracts with Programs, v. 4, no. 7, p. 561. Authors at Dept. of Geology University of Toronto, Toronto 5, Ontario, Canada.

Lead-zinc mineralization is widespread in carbonate rocks of the Permian Chochal and Cretaceous Cobán-Ixcoy formations in a 400 x 30 km zone that extends (E-W) across central Guatemala. This zone forms the southern erosional edge of an evaporite-bearing sedimentary basin that extends northward toward its Precambrian-early Paleozoic provenance in Oaxaca and Yucatán. Massive galena-sphalerite-pyrite mineralization is concentrated along bedding and fault surfaces in areas up to 1500 x 100 m. Minor barite, chalcopyrite and pyrargyrite are present locally and the silver content of galena increases southward across the mineralized zone. Most mineralization is near the base of the lowest carbonate unit in the local stratigraphic section and shows no observable relation (in surface outcrop) to the depositional and collapse breccias that are widespread throughout the mineralized carbonate rocks. Although the mineralization is "Laramide", no igneous rocks of this age are known in the entire mineralized zone. Limited fluid inclusion and S isotope data suggest depositional temperatures of 50° to 150°C for the sulfides. $\delta_S{}^{34}$ values for sulfides have a range of over 20 per mil and are largely positive. Pb isotope values for galenas are slightly radiogenic and do not fit a simple two-stage model.

These observations suggest that the Guatemalan lead-zinc mineralization is similar to that of the Applachian Valley and some areas of Europe and is transitional in character between typical magmatic-hydrothermal and Mississippi Valley deposit types. Application of newly acquired regional geologic data to stratigraphically oriented exploration in Guatemala could be rewarding. (Authors' abstract)

KHAIBULLIN, I. Kh., & BORISOV, N.M., 1965, Diagrams of phase equilibrium of the sodium chloride-water and potassium chloride-water systems: Akad. Nauk SSSR Doklady, v. 165, no. 3, p. 590-592 (in Russian; translated in Doklady Acad. Sci. USSR, Chemistry, v. 165, no. 3, 1965, p. 1135-1137).

Density, solubility, critical points, and distribution of NaCl and KCl between gas and liquid phases are given (in diagram only) for temperatures up to 450°C. (See next entry). (E.R.)

KHAIBULLIN, I. Kh., & BORISOV, N.M., 1966, Experimental investigation of the thermal properties of aqueous and vapor solutions of sodium and potassium chlorides at phase equilibrium: Teplofizika vysokikh temperatur, v.4, no. 4, p. 518-523 (in Russian; translated in High Temperature, USSR, v. 4, no. 4, 1966, p. 489-494).

Experimental data are presented on the compositions of vapor and liquid phases, specific weights, saturation pressures and temperatures, distribution coefficients in phase equilibrium, and critical parameters for the systems sodium and potassium chlorides-water. The experimental material is analyzed in the form of tables and p-v-t-c- diagrams of state. (Authors' abstract)

KHETAGUROV, G. V., 1971, Technique of studying gas-liquid inclusions in a microthermochamber, in Investigations of mineral-forming solutions and melts in inclusions in minerals, N.P. Ermakov and L.N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 169-170, (in Russian).

KHETAGUROV, G.V. and BEYUROV, M. S., 1971, Some constructive improvements of thermsound apparatus, in Investigations of mineral-forming solutions and melts in inclusions in minerals, N.P. Ermakov and L.N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 166-169, (in Russian)

KHETCHIKOV, L. N., BALITSKII, V. S., and DOROGOVIN, B. A., 1971, Some causes of changes of temperature of homogenization of gas-liquid inclusions in minerals, not connected with change of temperature of crystallization (from experimental data), in Investigations of mineral-forming solutions and melts in inclusions in minerals, N.P. Ermakov and L.N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 174-177 (in Russian).

The experimental investigations showed that the homogenization temperature of gas-liquid inclusions can be affected by many external factors acting on the crystals after or during their formation. Thermometamorphic processes change the homogenization temperature most of all. In these cases the homogenization temperature of the inclusions increases and can be higher than the crystallization temperature. Unilateral pressure, which does not destroy the hermetic sealing of the inclusions does not change their homogenization temperature. (S. Theokritoff).

KHETCHIKOV, L. N. and DOROGOVIN, B. A., 1971, Effect of liquid hydrocarbons on the temperatures of homogenization and decrepitation of inclusions in synthetic quartz, in Investigations of mineral-forming solutions and melts in inclusions in minerals, N.P. Ermakov and L.N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral

Raw Materials (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 159-161, (in Russian)

KHETCHIKOV, L. N., KOKAREV, G. N., DOROGOVIN, B. A., and MAL'SHEV, A. G., 1971, The connection of quartz veins of central Kazakhstan with granitic intrusions (from data on the homogenization of gas-liquid inclusions) in Investigations of mineral-forming solutions and melts in inclusions in minerals, N. P. Ermakov and L. N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 27-30 (in Russian)

KHETCHIKOV, L. N., KOMOV, I. L., and DOROGOVIN, B. A., 1971, Dependence of some physical properties of quartz on the conditions of its formation, in Investigations of mineral-forming solutions and melts in inclusions in minerals, N.P. Ermakov and L. N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials, (Tr. vsesouz. nauchno-issled inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 57-65 (in Russian).

KRAYNOV, S.R., MER'KOV, A.N., PETROVA, N.G., BATURINSKAYA, I.V., and ZHARIKOVA, V.M., 1969, Highly alkaline (pH 12) fluosilicate waters in the deeper zones of the Lovozero massif: Geokhimiya, 1969, no. 7, p. 791-796 (in Russian); translated in Geochem. Internatl., v. 6, no. 4, p. 635-640. Authors at All Union Institute of Hydrogeology and Engineering Geology (VSEGINGEO) and Lovozero Ore Beneficiation Combine.

Ground waters in the deep zones of the Lovozero alkalic massif are highly alkaline (pH 12) and strongly enriched in fluorine (up to 10-15 g/liter) and silica (up to 10-13 g/liter). These waters form as a result of solution of villiaumite (NaF), an abundant mineral in the rocks of the massif. They also contain rather large amounts of aluminum, titanium, niobium, copper, and some other elements. (Authors' abstract).

KOGARKO, L. N., HAMILTON, D., NOLAN, D., 1971, Phase equiliberia during the melting of agpaitic alkaline rocks (abst.): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 1, p. 78-79 (in English) (Authors at V.I. Vernadsky Institute of Geochemistry and Analytical Chemistry, Academy of Sciences, USSR, Moscow, Manchester University, Imperial College (London)).

Phase equilibria in the course of the melting of agpaitic nepheline syenites from the Lovozero massif have been experimentally studied under controlled oxygen fugacities and various values of water vapour pressure.

1. The melting range of foyaites, lujavrites and urtites is about 250° increasing with the rise of the quantities of intercumulus minerals containing volatile components and agpaitic coefficient.

2. The lowering of solidus and liquidus temperatures in urtites, foyaites and lujavrites with the decrease in oxygen fugacity is observed.

The oxygen fugacity controls the stability field of a number of minerals of agpaitic rocks - those of aegirine, alkaline amphibole, aenigmatite, sodalite etc.

3. The experiments have demonstrated that at the latest stages of the crystallization of agpaitic nepheline syenites liquid immiscibility arises, caused by the enrichment of the melt in volatile components.

4. The increase in water vapour pressure (up to 1000 bars) during the melting of alkaline rocks results in the significant decrease in the sizes of the crystallization fields of salic minerals - nepheline and K-feldspar. The liquidus phase in lujavrites and foyaites at P_{H_2O} = 1000 bar is aegirine. However, it was established by petrographic studies that in agpaitic nepheline syenites aegirine has been formed after nepheline and K-feldspar. It probably implies that in the beginning of the crystallization of agpaitic alkaline rocks water vapour pressure was rather low causing leucocratic minerals to crystallize first. During the crystallization of these rocks water vapour pressure had been rising continuously.

The reported experimental investigations permit us to estimate temperature, water vapour pressure and redox conditions in the course of crystallization of alkaline rocks, and they may also be used to elucidate the course of agpaitic magmas differentiation depending upon the variations of these parameters. (Authors' abstract).

KRIVTSOV, A. I., NOVGORODOVA, M. I., and RYABOV, V. V., 1971, Mineralogical and temperature zoning of copper-pyrite deposits of the Makanskii group (southern Urals), in Investigations of mineral-forming solutions and melts in inclusions in minerals, N. P. Ermakov and L. N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 44-48, (in Russian).

Decrepitation temperatures (150-340°) are listed for 14 types of samples. (E.R.)

KUZNETSOV, A.G., 1969, The expulsion of the "cover" of volcanic rocks by new methods: Avtoref. Kand. Diss. Novocherkassk, 1969. (A dissertation) (sic., as quoted in Bogoyavlenskaya, et al., 1971, in this volume)

KUZNETSOV, A. G., 1971, The possibility of using primary high-temperature inclusions for separating the cover of volcanic rocks, in Investigations of mineral-forming solutions and melts in inclusions in minerals, N. P. Ermakov and L. N. Khetchkov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 76-80 (in Russian)

KVENVOLDEN, K. A., and ROEDDER, Edwin, 1971, Fluid inlusions in quartz crystals from Southwest Africa: Geochim. et Cosmochim. Acta, v. 35, p. 1209-1229.

Quartz crystals from calcite veins of unknown age in Precambrian metasedimentary rocks at Geiaus No. 6 and Aukam farms in South-West Africa contain both primary and secondary inclusions filled with one or a variable comination of: organic liquid, moderately saline aqueous liquid, dark-colored solid, and vapor. Analysis of these materials by microscopy and by gas chromatography and mass spectrometry shows the presence of constituents of both low and high molecular weights. The former include CH_4, C_2H_6, C_3H_8 and possibly C_4H_{10} as well as CO, CO_2, H_2O, N_2 and H_2. High molecular weight components are dominantly n-alkanes and isoprenoid hydrocarbons. The n-alkanes range from at least n-C_{10} to n-C_{33}. Concentrations of n-alkanes larger than n-C_{17} decrease regularly with increasing carbon number. An homologous series of isoprenoid hydrocarbons ranging from at least C_{14} to C_{20} is present in unusually high concentrations. Pristane (C_{19}) is most abundant, and C_{17} isoprenoid is least abundant. The molecular composition and distribution of hydrocarbons suggest biological precursors for these components.

Consideration of data provided by freezing, crushing and heating experiments suggests that the pressures at the time these in part supercritical fluids were trapped probably exceeded 30-40 atm, and the minimum trapping temperature was about 120-160°C. Both primary and secondary inclusions apparently containing only organic materials were trapped by the growth of the host quartz from aqueous solution. The data obtained neither prove nor preclude Precambrian, Paleozoic or younger sources for the organic materials.

LAZKO, E. M., DOROSHENKO, Yu. P., KOLTUN, L. I., LYAKHOV, Yu. V., MYAZ, N. I., PIZNYUR, A. V., 1971, Processes of hydrothermal minerogenesis in the East Transbaikalian deposits / on gas-liquid inclusions in the minerals/ (abst.): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 1, p. 332-333 (in English) (Authors at Faculty of Geology, University of L'vov, USSR).

The majority of the postmagmatic deposits of East Transbaikalia, from different structural-facial zones of the region, are characterized by a mutual history and physico-chemical conditions of development, which may be represented as follows: I - the pneumatolytic-hydrothermal stage, which includes I/ the quartz-molybdenite sub-stage (t - 500-350°C, p - more than

1,000 atm), 2/ the quartz-tourmaline sub-stage (450-300°C, - more than 1,000 atm), 3/ the sub-stage of the early sulphides (400-270°C, 1,000-700 atm); II - hydrothermal stage proper, including 4/ the polymetallic sub-stage (300-200°C, 750-500 atm); 5/ the sub-stage of the quartz-carbonate with fluorite (200-50°C, 400-200° atm). Here and everywhere further thermobarometric data on inclusions in the minerals are used. The temperatures given are equal to the filling ones without corrections for pressure.

The predominant development of the first or second stages led to the formation of spatially separate genetic types of the deposits: pneumatolytic-hydrothermal (molybdenum, gold-molybdenum, gold of the quartz-tourmaline formation and tungsten), and hydrothermal proper (polymetals, fluorite and some gold).

The majority of the deposits, independent of the temperature peculiarity of the stages of minerogenesis as a whole, is characterized by a comparatively narrow temperature interval (20-80°C) of deposition: 20-50°C - for gold, 20-40°C - wolframite, 30-50°C - for molybdenite, 20-50°C - for base metals, 60-80°C - for fluorite.

An important role in the formation of the majority of the examined deposits belongs to carbon dioxide. This refers, primarily, to the gaseous solutions of the pneumatolytic-hydrothermal stage of the formation of molybdenum, gold and tungsten deposits.

The early period of development of the molybdenum and gold ore deposits were frequently characterized by the activity of high temperature sodium chloride solutions of high concentration. In the tungsten deposits solutions were of sodium bicarbonate. The solutions of middle temperature stages in all these and polymetallic deposits had a magnesium-calcium or calcium-magnesium bicarbonate composition. The low temperature stage (quartz-carbonate with fluorite), which is final in ore succession and probably corresponds to the main stage of formation of fluorite type of deposits, is characterized by calcium bicarbonate or fluorine-bearing solutions.

The concentration of hydrogen ions decreases to the end of the ore deposition. This decrease is unsteady, according to the steps of mineral formation. (Authors' abstract).

LEBEDEV, L.M., BARANOVA, N.N. and NIKITINA, I.B., 1971, On the forms of occurrence of lead and zinc in the Cheleken thermal brines: Geokhimiya, 1971, no. 7, p. 823-829, (in Russian, translated in Geochem. Internat., v.8, no. 4, p. 511-516, 1971).

Differential sorption on cation and anion exchanges has been utilized to demonstrate that most of th lead and zinc in the Cheleken thermal brines occurs as complex chloride anions. This is in agreement with thermochemically based calculations, which indicate that the dominant solution species are $PbCl_3^-$, $PbCl_4^-$, and $ZnCl_3^-$. Variation in de-sorption of lead from anion resins for samples from different horizons suggests the presence of Pb chloro-carbonate complexes at depth. (Authors' abstract) (Ed. note - of pertinence to the mode of transplant of ore elements in the chloride brines at ore deposit fluid inclusions).

LETNIKOV, A.M., 1969, On the sulphide mineralization of the Dzhus-Dzhursk anorthosite massif: V. Sb. "Petrol. Izverzh. i Metamorf. porod", Vladivostok, 1969. (Sic., as quoted in Bogoyavlenskaya, et al., 1971 in this volume).

LHAMSUREN, J. and TÜMENBAYAR, B., 1971, The inner defects and crystal structure of smoky quartz in the pegmatite vein of the Dzuun-Bayan deposit: Mongolian State Univ. Mineralogical Museum, Transactions, v. 1, p. 37-57 (in Russian with English abstract).

X-ray measurements of cell parameters indicating isomorphic substitutions are given for smoky quartz which was also studied by fluid inclusion thermometry. The inclusions are mainly complex, with liquid CO_2. The homogenization temperature of primary inclusions are 145-155-160-164-170-175-185-225°C, and the freezing temperature is -30°C. It is ascertained that the mineral formation temperature progressively decreased from the inner zones to the outer, and that the rate of growth changed greatly during its formation.

The decrepitation method shows a maximum at 360°-380°C. This is a rather low temperature in comparison with that of other crystals from Dzuun-Bayan deposits. (Authors' abstract, modified by E.R.)

LITVINOV, V.L., LYAKHOV, Yu, V., & POPIVNYAK, I.V., 1971, Physical chemical peculiarities of the formation of the Kariysk ore-bearing deposit (Eastern Transbaikal): L'vov Gos. Univ. Mineral. Sbornik, v. 25, no. 2, p. 152-163(in Russian). (Authors at Univ. L'vov.)

A four-stage table of ore formation has been worked out on the basis of mineralogical and mineral-thermobarometrical investigation of mineral generations of different age and their associations. The temperature (from 550 to 50°C) and pressure (760-300 atm.) regimes of the ore-forming solutions are characterized as well as their aggregate conditions and concentration (to 45%NaCl). The data received make it possible to look more throughly into the genetic peculiarities of the deposit and refer it to the high temperature pneumatolitic-hydrothermal formations of middle depth characteristic for Eastern Baikal. (Authors' abstract)

LIU, CHIA-TSUN and LINDSAY, W.T., JR., 1971, Thermodynamic properties of aqueous solutions at high temperatues: U.S. Office of Saline Water Research and Devel. Progress Rept. No. 722, 124pp.

Osmotic coefficients in aqueous salt soltuions have been determined by vapor-pressure lowering measurements at temperatures from 75° to 300°C. Measurements on sodium chloride solutions were carried out at concentrations from approximately 4 m up to saturation, thereby completing the thermodynamics of the $NaCl-H_2O$ system. Activity coefficients have been obtained for NaCl and many important thermodynamic functions have been calculated for water and salt for the complete concentration range. Uniquely precise solubility data of sodium chloride were obtained at emperatures up to 300°C. The system $MgCl_2-H_2O$ was studied at temperatures from 75° to 300°C at concentrations 1.6 m to 5.2 m. The system $MgSO_4-H_2O$ was studied at temperatures from 75° to 175°C at concentrations 0.4 m to 1.5 m. Measurements were obtained on the system $Na^+-Mg^{++}-Cl^--SO_4^{=}-H_2O$ for an ionic composition simulating sea water at concentration factors 1.5 to 10 times normal sea water at temperatures 75° to 300°C. Boiling point elevations calculated from these results are compared with previous estimates that were based on less extensive data. (Author's abstract)

LOFOLI, P., 1971a, Endoscopy of sand grains from the French coast of the English Channel (abstr.): Ass. Geol. Bassin Paris, Bull. Inform. No. 27, p. 16 (in French).

LOFOLI, P., 1971b, Endoscopy of sand grains from the French coast of the English Channel (abstr.): Ass. Geol. Bassin Paris, Bull. Inform. no. 27, p. 19-20, (Colloque sur la géologie de la Manche, Paris, 14-15, January, 1971), (in French).

LOFOLI, Paul, 1971c, Electron microscopy of sand grains: Comptes Rendus Acad. Sci., Paris, v. 273, Series D, p. 462-465 (in French).

The electron microscope provides excellent detail on the shape of minute fluid inclusions (∿ 1μm) and hence some indication of their source. (E.R.)

LOPATINA N. L., 1971, Halogenides in hypogene ore formation , in Investigations of mineral-forming solutions and melts in inclusions in minerals, N.P. Ermakov and L.N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 186-189, (in Russian),

The possibility of transporting Pb and Zn in the form of halides in water vapour at temperatures of 400 and 600°C at atmospheric and slightly higher pressures was demonstrated experimentally; the influence of certain impurities on this process was established. An increase of temperature and pressure raises the concentration of the indicated metals tens of times. Presumably, the absence of ore elements from the solutions explains the absence of the ore elements from the gas-liquid inclusions. (S. Theokritoff).

LUGOV, F.F., MAKEEV, B.V., NAUCHITEL', M.A., & POTAPOVA, T.M., 1969, Temperatures of formation of the tin deposits of the casserite-silicate formation, northeastern SSSR: v. Sb. "Rudoobrazovanie i ego svyaz' s magmatismom", Yakutsk, 1969, (sic., as quoted in Bogoyavlenskaya, et al., 1971, in this volume).

MADANYAN, O.G., 1969, Seminar on the thermodynamic geochemistry of mineral-forming media through inclusions in minerals: Izv. A.N., Arm. SSR., Naouki o Zemli, 1969, 3. (Sic., as quoted in Bogoyavlenskaya, et al., 1971, in this volume.)

MAKAGON, V.M., 1971, Formation temperature and postmagmatic alterations in the mica-bearing pegmatites of the Mama region (according to data of various geological thermometers): Geokhim. Pegmatitov Vost. Sib. 1971, p. 48-71, (in Russian). CA 76 (8) 36153k (1972).

Formation temps. and postmagmatic alterations in Mama mica-bearing pegmatites were studied with liq.-gas inclusions (homogenization and decrepitation), by using garnet-biotite, Sc, and paragonite-muscovite geol. thermometers, from the dependence of the Ba content in K feldspars on their formations temps., phase transitions in minerals, and ternary points and phase transitions in the Al_2SiO_5 system. The phase transformations in K feldspars and in the Al_2SiO_5 system indicate that the formation temp. of pegmatites is >600°. The temp. of metamorphic pegmatite formation, detd. from the garnet-biotite geol. thermometer coincides with the formation temp. of metamorphic country rocks in the Mama area and is 500-650°. The data obtained by the Sc geol. thermometer agreed with data of the garnet-biotite geol. thermometer. The granitic pegmatites of magmatic origin have a higher formation temp.: 650-700° detd. from garnet-biotite geol. thermometer. The lowest temps. were obtained during the study of liq. inclusions in minerals of pegmatites and from the 2-feldspar geol. thermometer. Both of these geol. thermometers are minimal which indicates that the postmagmatic replacement occurred at 370-530°.

MAKAGON, V. M., SHMAKIN, B. M., 1971, The physical-chemical conditions for formation processes of muscovite pegmatites (abst.): Internat. Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 2, p. 678-679. (Authors at Geochemistry Institute, Siberian Branch, Academy of Sciences, Irkutsk, USSR).

This investigation was to determine physico-chemical parameters of formation processes of muscovite pegmatites earlier oddly [sic] studied. Muscovite pegmatites of different districts of Eastern Siberia and India have been considered. For finding the best temperature for pegmatite formation we have used different methods of thermometry: geochemical and mineralogical geothermometers, and gas-liquid inclusions in minerals. The pressure was determined by liquid inclusions of carbon dioxide in pegmatite minerals.

Three phases of muscovite pegmatite formation have been distinguished: (1) metamorphic, (2) magmatic, (3), postmagmatic. The metamorphic phase is characterized by a temperature of 500°-650°C and a pressure in the liquid phase of 5-7.5 kbar. Pegmatites of this phase did form as a metamorphic segregation of enclosing rock materials in conditions of amphibolite facies metamorphism.

Pegmatites of the magmatic phase formed at a temperature of 650°-700°C and a pressure of 6-8 kbar from a melt of palingenic origin coming up along abyssal fracture zones.

The postmagmatic phase in the formation of pegmatite bodies is typified by wave-like acidity changes of the mineral forming solutions. As to mineral associations four stages were recognized: the early alkaline stage, that of increasing acidity, maximum acidity, and the late alkaline stage. The oxygen activity changes parallel to the alkalinity change of the mineral forming medium. The acidity increase of the postmagmatic solutions depends on temperature drop and a new alkalinity increase is caused by a sharp pressure drop in the late process stage and the related separation of volatile solution components.

The early alkaline stage is characterized by a temperature interval of 550°-530°C and a pressure of about 4 kbar. The increasing acidity stage and that of maximum acidity correspond to temperature intervals of 530°-420°C and a pressure of 4-3 kbar. The mineral formation of the late alkaline stage took place at a temperature of about 420°-370°C and a pressure of about 2 kbar.

[Estimates of?] the composition of gas-liquid inclusions in minerals indicates that carbon dioxide concentration in solutions of all process phases exceeded the concentration of other volatile components. (Authors' abstract).

MAKINE, I., 1971, Gas chromatographic analysis of bubbles in glass: Journ. Ceram. Soc. Japan, v. 79, p. 312-315, (in Japanese), 1971; British Ceram. Abstr., abstr. 72/1216, 1972.

Using a gas chromatograph, with a thermal conductivity cell as detector, it is possible in one operation to separate and analyse the gases in a bubble in the order CO_2, O_2, N_2, SO_2, H_2S, and CO within 25 minutes. The minimum diameter of the bubble that can be analysed ∿ 0.5 mm. (Prof. R.A. Howie).

MAKOGON, Yu., F., TREBIN, F.A., TROFIMUK, A.A., TSAREV, V.P., and CHERSKII, N.V., 1971, Detection of natural gas deposit in solid (gas-hydrated)state. Akad. Nauk SSSR, Dokl., v. 196, no. 1, p. 203-206, (in Russian).

Of interest as it indicates these clathrate compounds, formed in inclusions on freezing, may occur naturally also. (E.R.)

MALININ, S. D., 1971, Physical-chemical features of carbon dioxide-water-salt system in the magmatic process (abst.): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 1, p. 39-40 (in English) (Author at V.I. Vernadsky Institute of Geochemistry and Analytical Chemistry, Academy of Sciences, Moscow, USSR).

1. The H_2O-CO_2-system is fundamental importance as a model of the numerous natural equilibria corresponding to the wide range of conditions from those of low temperature gascontaining hydrotherms to the high temperature fluids coexisting with melts. The aim of the present report is to analyse the properties of this system applying to geochemical problems (firstly in connection with high temperature stages of volatiles evolution) and to estimate trends of future investigations of the system.

2. It is a special feature of this system that there is a considerable molecular interaction in it which is the reason of some anomalies in its properties. One of the consequences of this is that the calculation of CO_2-concentrations in solutions by the Henry's law equation must result in significant mistakes on account of this interaction if CO_2-concentrations in the vapour phase are small. This interaction in the liquid phase seems to be responsible for an anomalous dependance of carbonate solubility in homogeneous liquid mixtures of CO_2 and H_2O (maximum solubility).

3. The influence of electrolyts on the CO_2-solubility "out-salting effect" can be quantitatively described in first approximation by equations of the outsalting theories. Under the high temperature-pressure-electrolyte concentration conditions the equations of outsalting theories are wrong. This problem is unsatisfactorily investigated in spite of its importance for barometry by gas-liquid inclusions method.

4. At high temperature conditions near the critical transition region the electrolytic effect causes a sharp increase of homogenization temperature. It is possible to suggest that in highly concentrated solutions the change of the type of system may take place owing to inversion of the critical curve (from II to I type). It is essential for evaluation of phase relationships in fluid systems.

5. It is necessary for thermodynamic calculations of natural carbonate equilibria at high temperatures to know the fugacity values of H_2O and CO_2 in gas mixtures. The present data for gas mixture compressibility under supercritical conditions permit calculation of these values although with some approximations. The fugacity coefficient calculations in terms of divergence from the ideal mixtures law permitted establishing that in the temperature range of 600-650° the fugacity coefficient values when decreasing have a value equal unity as the result of inversion of the molecular interaction strengths in gas. The influence of electrolytes results in decrease of the compressibility of the system (preliminary data). This phenomena is analagous to the outsalting effect. (Author's abstract).

MALYSHEV, B.I., NAUMOV, V.B., and PANOV, G.I., 1964, Determination of the temperature of formation of minerals at the Ambarak deposit by the decrepitation method: Geokhimiya, no. 4, 1964, pp. 357-361 (in Russian); translated in Geokhimiya Translations 1964, Suppl. to Geochem. Internat., v. 1, issued in 1973. (Authors are at V.I. Vernadskii Institute of Geochemistry and Analytical Chemistry, Academy of Sciences USSR, Moscow).

Although this article is old, it is listed here since the translation has just been published (E.R.).

MARSHALL, William L., 1971, Predictions for geochemistry from aqueous electrolyte behavior to high temperatures and pressures (abst.): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 1, p. 259-260 (in English) (Author at Reactor Chemistry Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830).

Electrical conductances and solubilities of aqueous electrolytes over wide ranges of temperature (0-800°C) and pressure (1-4000 bars) have been determined at this laboratory over the past ten years. From these studies, correlations of aqueous electrolyte behavior have been observed. It is the purpose of this paper to present some new observations of electrolyte behavior that allow predictions over the above ranges of temperature and pressure and further correlate past results. The concepts derived from these observations should be useful to geochemistry for evaluating hydrothermal processes, and also useful for applications in oceanography.

Electrolyte ionization behavior and solubility are predicted through the use of a complete equilibrium constant (K°) that includes the solvent (water) as a reacting species of variable concentration. This constant is shown to originate from a detailed description of a conventional constant in terms of multi-step solvation equilibria. Predictions at high pressures are made from one value of K° and a knowledge of the average solvation equilibrium; this information is obtained either in water at low pressures or in dioxane-water solvents. In another application of K°, partial molar volumes of electrolyte species at infinite dilution are estimated at supercritical temperatures and high pressures from ionization constants obtained from conductance and solubility measurements at other pressures. The complete constant concept is applied also to vaporization processes to indicate quantitatively that the extent of bonding in liquid water decreases to "one extra-molecular bond per molecule" at the critical temperature of 374°C. This interpretation helps to explain why water can no longer exist as a condensed liquid at temperatures above 374°C.

Recent experimental results to high temperatures (350°C) on the solubility of calcium sulfate and its hydrates in mixed, aqueous electrolyte systems and on electrical conductances of sodium chloride in dioxane-water solvents, and also earlier related work, are presented briefly. These studies have been used in obtaining and confirming some of the above correlations. (Author's abstract).

MART'YANOVA, R.M., 1969, On the equilibrium of "negative crystals" and some questions of the thermodynamics of surface phenomena in inclusions: Vestn. A.N. Kaz. SSR, 1969, no. 1, (sic., as quoted in Bogoyavlenskaya, et al., 1971, in this volume).

MART'YANOVA, R.M., & EGEMBAEV, K.M., 1971, Temperature of crystallization of barites in the Kairaktinsk ore field: Izv. Akad. Nauk Kaz. SSR, Ser. Geol. 1971, v. 28, no. 5, p. 51-55, (in Russian). CA 76 (2) 5653u (1972). Authors at Inst. Geol. Nauk. im. Satpaeva, Alma-Ata, USSR.

The Kairaktinsk barite-complex ore deposits are localized in Devonian-Carboniferous formations including terrigenous and terrigenous-carbonate formations and liparite pyroclastic rocks. The amt. of gas bubble in barite crystals is 5-10% at high hydrostatic pressure. The homogenization temp. of barite with gas inclusions is calcd. to be 300-330° in the eastern part of the ore field, 200-50° in the Itazn field, and 70° in the Akshoky area. A relation is established between the barite homogenization temp. and the age of pre-mineralization. The temp. of crystn. of barite decreases from the lower to upper part of the ore field.

MASALOVICH, A. M. and OVCHINNIKOV, L. N., 1971, Approximate extimate of the pH of hydrothermal solutions in equilibrium with country rocks of acid composition, in Investigations of mineral-forming solutions and melts in inclusions in minerals, N. P. Ermakov and L. N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 109-113. (in Russian)

MATKOVSKY, O. I., 1971, Facial analysis and temperature of formation of metamorphic rocks in the Ukrainian Carpathians (abst.): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 2, p. 499-500 (in English) (Authors at L'vov State Ivan Franko University, L'vov, USSR)

Until recently thermodynamic conditions of formation of metamorphic rocks in the Ukrainian Carpathians were evaluated only qualitatively. This evaluation was based on the study of mineral paragenesis and peculiarities of the composition of minerals. Taking into account these data some scientists (Tkachuk and Danilovich, 1955) consider that progressive metamorphism took place under the conditions of amphibolitic facies, while others (Lavrenko, 1968) think it appeared under the conditions of green schist and epidote-amphibolitic facies.

To solve the problem we have used different mineralogical thermometers (Perchuk, 1967) and inclusions of solutions to take the temperature of mineral formations.

It was established that the temperature of plagioclase-amphibolitic equilibrium in epidote-chlorite-amphibolitic schists and zoisite amphibolites is 410-430°C and that of the garnet-amphibolitic equilibrium in garnet amphibolites equals to 450-510°C. These temperatures almost do not exceed the upper temperature limit of epidote-amphibolitic facies which has been accepted by many scientists (Turner and Verhoogen, 1961; Sobolev, 1964; Perchuk, 1967). The highest temperatures (590-620°C) were obtained for garnet-biotite equilibrium two-mica garnet and two-mica staurolite-garnet schist and in plagiogneisses which occupy the lowest parts of the stratigraphic section of the metamorphic complex or are found near the contact of granitoides. Investigating the vein- and lens-shaped quartz isolations from green schist rocks of the upper part of stratigraphic section of the metamorphic complex we have found two groups of gas-liquid inclusions: 1) inclusions having no connection with fractures and homogenizing into a liquid phase at 310-340°C, 2) numerous inclusions having connection with fractures (secondary) with the range of temperature of homogenization 180-210°C. The inclusions of the first group may be considered as primary or primary-secondary [i.e. pseudosecondary], and their temperature of homogenization is taken as the minimum one (without correction for pressure) of the formation of quartz, which appeared probably during the latest regressive (hydrothermal) stage of regional metamorphism.

These data testify to the fact that the lower temperature limit of green schist facies is higher than is supposed by some scientists (Bart, 1956; Sudovikov, 1964 and others) and the authors who have described analogous metamorphic rocks of the Romanian Eastern Carpathians (Savul and Pomîrleanu, 1960). (Author's abstract).

MATSUDA, Masuyoshi and KIZAKI, Koshiro, 1971, Experimental deformation of polvcrvstalline ice with special reference to internal deformation: Jour. Geol. Soc. Japan, v. 77, No. 12, p. 771-778 (in Japanese, English abstract).

Uniaxial compressional experiments on polycrystalline ice were carried out in the cold laboratory under the condition of temperature: -10°C and constant strain rate: 0.1 or $0.2h^{-1}$. The air bubbles occupying 2 per cent of total volume of the specimen exhibit quite interesting behavior, and their alignment produces three types of deformation planes as the deformation proceeds. It should be noted that three types of planes are those of extension fracture, shear fracture and flow plane identified by macroscopic as well as microscopic observations, and that the angle between the inclination of the planes and the axis of compression changes discontinuously in three steps.

The stress-strain curve revealed by the experiments is also divided into three steps. Therefore, it is obvious that there is a good agreement the between strain stage and plane formation in three steps. The relationship between stress and strain at each strain stage is as follows:

I $0.01 \leq \varepsilon < 0.03$

$\sigma(\varepsilon)=6.8\times10^{2}\cdot\sqrt[5]{\varepsilon^{4}}$ kg/cm^2

II $0.03 < \varepsilon < 0.18$

$\sigma(\varepsilon)=1.9\times10^{1}\,\sqrt[5]{\varepsilon}$ kg/cm^2

III $0.18 < \varepsilon < 0.80$

$\sigma(\varepsilon)=2.7\times10$ kg/cm^2

MEL'NIKOV, F.P., 1969, Third All-Union Conference on mineralogical thermobarometry and geochemistry of deep-seated mineral-forming solutions (9-14 Sept., 1968): Vestn. Mosk. Un. Geol., 1969, no. 3, (sic., as quoted in Bogoyavlenskaya, et al., 1971, in this volume).

MEL'NILOV, F. P., 1971, Experiments with a closed microsystem of natural geochemical medium in inclusions of minerals, in Investigations of mineral-forming solutions and melts in inclusions in minerals, N.P. Ermakov and L. N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 147-149 (in Russian)

On the basis of a study of inclusions as microsystems over the temperature range from +1600°C to -195°C, a conclusion is made on the possibilities of deducing the physical-chemical characteristics of hydrothermal systems in the process of endogenic ore and mineral formation. (S. Theokritoff).

MEL'NIKOV, F. P. and RYABOV, V. V., 1971, Kinetics of processes during the heating of ore minerals, in Investigations of mineral-forming solutions and melts in inclusions in minerals, N. P. Ermakov and L. N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 113-116. (in Russian)

MEYER, Charles, SHEA, E.P., GODDARD, C.C., and others, 1968, Ore deposits at Butte, Montana, p. 1373-1416 in Ore Deposits of the United States, 1933-1967, vol. II, J.D. Ridge, editor: New York, Amer. Inst. Min. Metal. & Petrol. Eng.

A very thorough summary of the district, with only a brief mention of homogenization data on inclusions in quartz (200-350°C), on p. 1410 and 1412. (E.R.)

MITCHELL, R.H., & CROCKET, J.H., 1971, Diamond genesis - a synthesis of opposing views: Mineral. Deposita (Berl.) v. 6, p. 392-403. First author at the Dept. of Geology, University of Alberta, Edmonton, Alberta, Canada.

A theory of genesis with synthesis of diamond seed nuclei in kimberlite magma at depth in the mantle and with continued metastable growth during ascent and in kimberlite magma pools at the base of the crust is proposed. (Authors abstract). The volatiles in fluid inclusions and diamonds and associated with xenoliths are discussed. (E.R.)

MIYAZAWA, T., TOKUNAGA, M., OKAMURA, S., and ENJOJI, M., 1971, Formation temperatures of veins in Japan: Soc. Mining Geol. Japan, Spec. Issue 3, p. 340-344, [Proc. IMA-IAGOD Meetings '70, IAGOD Vol.] (First author at Geological and Mineralogical Institute, Tokyo University of Education, Tokyo, Japan)

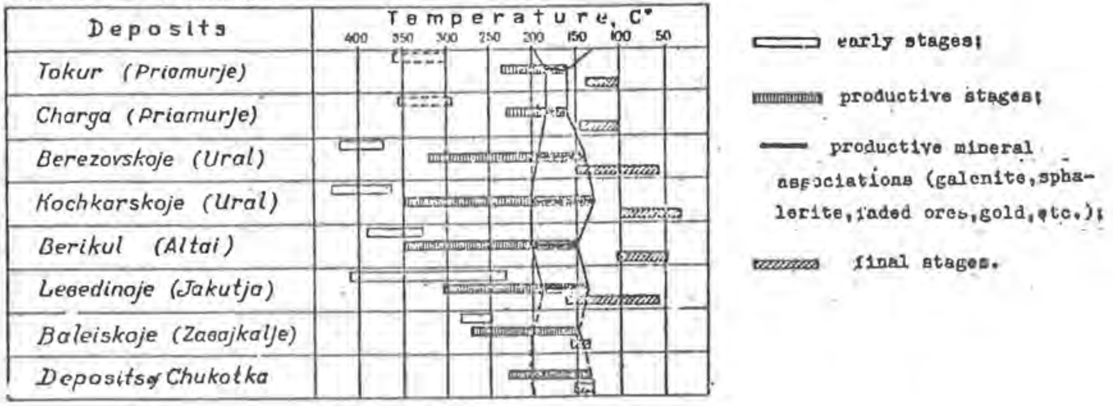
The authors' abstract is a somewhat different version of the abstract published in 1970 in the Abstract Volume (See Fluid Inclusion Research, v. 3, p. 45-46), but here the data are given. (ER)

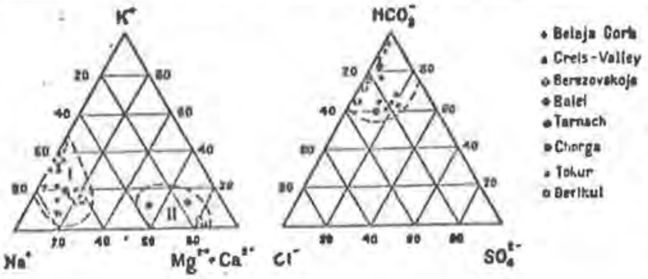
MOISEENKO, V. G., and FATYANOV, I. I., 1971, Physico-chemical conditions of the formation (of) hydrothermal gold-bearing deposits: International Geochemical Congress, Moscow, 1971. Abstracts of Reports, v. 1, p. 319-320 (in English) (Authors at Far-Eastern Geological Institute, Vladivostok, USSR).

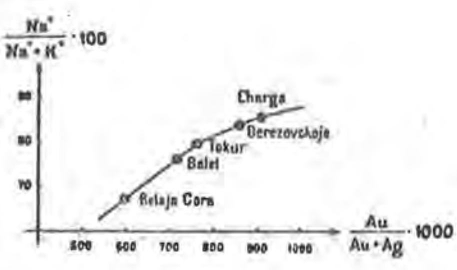
It is impossible to resolve the problem of the genesis of ore deposits when physico-chemical conditions of their formation are unknown. The authors have made detailed investigations which, with published data, permit establishment of several regularities in the forming of gold-quartz deposits.

Hydrothermal gold deposits formed at the temperature range from 430° to 30°C (Fig. 1). Within this interval the early barren or but feebly-auriferous stages are mainly composed at high temperatures (430-230°), productive stages - at middle temperatures (320-130°) and final stages, usually carbonate-rich, at low temperatures (165-30°). Moreover, the deposition of the productive mineral associations (galena, sphalerite, faded ores (sic), native gold, etc.) occurs in the narrow temperature interval from 200° to 130°.

According to data of water extractions from quartz of productive stages, the two types of hydrothermal solutions are found: alkaline-bicarbonate (I) and alkaline-earth-bicarbonate (II). In both types of hydrotherms sodium prevails over potassium. The percentage of gold in native gold ore of different deposits is first of all a function of the composition of hydrothermal solutions which formed productive stages but not a function of temperatures as it was considered earlier (Fig. 3). [The] established regularities are proved experimentally. (Authors' abstract).







MOORE, J. G. and CALK, Lewis, 1971, Sulfide spherules in vesicles of dredged pillow basalt: Amer. Min., v. 56, p. 476-488.

The walls of vesicles in glassy pillow basalt were found to be spotted with evenly-spaced minute spherules (0.2-2.5 μm). These spherules consist of Fe, S, Cu and Ni, presumably by reaction of sulfur in the vesicle with Fe, Cu, and Ni from the glass. A similar mechanism is proposed for some larger sulfide globules found in pillow basalts and surface lava flows (ER)

MOROZOV, S.A., 1969, On the possibility of applying the decrepitophonic method to prospecting for cavities with quartz crystals: Dokl. A.N., Tadzh. SSR., 1969, t. 12, n. 5, (as quoted in Bogoyavlenskaya, et al., 1971, in this volume).

MOROZOV, S.A., 1971, Relations of temperature of homogenization, decrepitation and crystal formation, with quartz as an example: Akad. Nauk Tadzh. SSR, Dokl., v. 14, no. 5, p. 35-38 (in Russian).

MOROZOV, S. A., DROZDOV, V. M., and ZAKHARCHUK, N. A., 1971, Physico-chemical conditions of formation of quartz veins of eastern Pamir, in Investigations of mineral-forming solutions and melts in inclusions in minerals, N. P. Ermakov and L. N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials, (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 48-52, (in Russian).

The quartz veins of Eastern Pamir were formed during three stages of mineral formation over a wide temperature interval ranging from 500 to 200°C. Quartz crystals formed in the last two stages; the first generation crystals form over the temperature range 400-320°C and pressures of the order of 1500-600 atm., whereas the second generation forms at 300-200°C and pressures not less than 1000-300 atm. A tendency to a gradual decrease in temperature and pressure is noted. (S. Theokritoff).

MORRISSEY, C.J., DAVIS, G.R., & STEED, G.M., 1971, Mineralization in the Lower Carboniferous of central Ireland: Inst. Min. & Met. Trans. v. 80, sect. B p. B-174-B-185.

The geological features of the metalliferous deposits discovered in central Ireland during the last decade are tabulated and compared in an attempt to discern genetic controls that could guide exploration for concealed orebodies (from authors' abstract). Fluid inclusion studies show temperatures of 175-250°C (p. B181). (E.R.)

MOSKALYUK, A. A., 1971, Application of the method of aqueous extraction to the study of the composition of inclusions in minerals, in Investigations of mineral-forming solutions and melts in inclusions in minerals, N. P. Ermakov and L. N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials, (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 102-106. (in Russian).

MUELLER, G., 1951, A geochemical and genetical survey of Derbyshire mineral deposits: PhD dissertation, Univ. of London, 316 pp.

A very detailed study, in particular of the various liquid and solid organic phases that occur with the Derbyshire fluorite deposits, and of the mineralogy, shape and orientation of the numerous solid inclusions within these crystals. Includes also occasional mention of liquid and gaseous inclusions (organic and aqueous), and interpretations of the mechanisims and environments of growth of the enclosing crystals. Only part of the many observations made are to be found in the author's later papers on this general subject. (ER)

MYAZ', N.I., PIZNYUR, A.V., & KOVALISHIN, Z.I., 1969, Third all-union conference on mineralogical thermobarometry and geochemistry of deep-seated mineral-forming solutions: (3-14 Sept. 1968): Vestn. L'vov Un., Ser. Geol., 1969, no. 3, (sic., as quoted in Bogoyavlenskaya, et al., 1971, in this volume.)

NAJDENOV, B. M., POLIWJANNIJ, E. J., SEMENOVA, T. V., BOGOLEPOV, V. G., 1971, The role of argon and lead isotopes in the determination of character of mineral-forming solution (abst.): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 1, p. 401-402 (in English) (Authors at Kazakh Scientific-Research Institute of Mineral Raw Materials, Alma-Ata, USSR).

The range of solvable problems of mineral formation can be considerably extended by combined studies of argon and lead isotopic compositions in gaseous-liquid inclusions of minerals.

1. It is known that [inclusions] can be regarded to a certain degree as relicts of the solutions forming these minerals. The identification of the aggregate state and material composition of the liquid phase with the initial mineral forming solutions arises well-reasoned objections. To a lesser degree the latter is referred to gases in general and particularly to the inert ones; thus it is probably accurate to say that the study of isotopic variations of argon composition or in other words the values of radiogenic (argon -40) and air argon - 36) components are informative factors for the origin determination of mineral-forming solutions. Thus, for example, the isotopic argon composition of gaseous-liquid inclusions in quartz of Karelia, Volynia and Kazakhstan pegmatites measured by us has shown that quartz of deep-seated platform formations contains practically [all] argon-40, while quartz gaseous-liquid inclusions have considerable additions (from 60 to 90%) of air argon in the regions with intensive tectonic-magmatic activity of plicate districts.

The isotopic argon composition of quartz gaseous-liquid inclusions in Karelia testify to there being juvenile solutions in its formation, while the formation of studied Volynia and Kazakhstan quartz occurred with the participation both of juvenile and vadose origin.

2. The study of lead in gaseous-liquid inclusions present special interest if approaching it as an example of ore forming element. The isotope content of lead in gaseous - liquid inclusions may be considered time factor [sic]. However the studies of lead isotopic composition in gaseous-liquid inclusions made in this paper revealed in most cases a discrepancy between the isotopic composition of prisoner-lead and the theoretically calculated isotopic composition of common (ore) lead of the same age. The possible reasons of the discovered discrepancy are discussed in the report. (Authors' abstract).

NASH, J.T., 1971a, [Composition of fluids in porphyry-type deposits] (abstr.): U.S. Geol. Survey Prof. Paper 750A, Geol. Survey Research, 1971, p. A-2 . Author at U.S. Geol. Survey, Menlo Park, California.

Microscopic study of fluid inclusions in samples from some 15 porphyry copper and porphyry molybdenum deposits in the Western United States has demonstrated a consistent relationship between fluid composition and wall-rock alteration assemblages. Each deposit displays a core zone of potash feldspar-biotite alteration surrounded by a zone of argillic alteration. Fluids associated with the potash feldspar-biotite assemblage were highly saline (up to 40 percent) brines which, when trapped by mineral growth and cooled to present temperatures, formed fluid inclusions containing halite, hematite, and sometimes other daughter minerals in addition to liquid and vapor phases. Fluids associated with the surrounding argillic zone were much more dilute and were trapped as fluid inclusions which at room temperature contain only liquid and vapor phases. "Relict" fluid inclusions of the high-salinity type are commonly found well beyond the present limits of the potash feldspar-biotite core zone indicating that it was once more extensive and has subsequently been argillized by the more dilute fluids. Although of broad scope, this investigation indicates that the study of fluid inclusions may be a valuable adjunct to wallrock alteration studies because it provides a means of recognition of the former presence of an early brine, even though the potash feldspar and biotite may have been completely destroyed by subsequent superimposed argillic alteration. The recognition of such early brines in samples from leached outcroppings may be of economic significance. (Author's abstract)

NASH, J. Thomas, 1971b, Fluid inclusions as a guide to porphyry-type mineralization (abst.): Econ. Geol. v. 66, p. 1268.

Fluid inclusion studies on more than 15 porphyry-type deposits show that copper and molybdenum are associated in time and space with hot, high salinity, high density fluids. The distribution of inclusions in and around three porphyry deposits shows distinctive patterns of favorable fluids. A dense brine, indicated by the presence of halite and other salt daughter minerals in fluid inclusions, is a possible exploration target. The brine has chemical as well as geological significance. Advantages of the fluid inclusion approach are that (1) fluid inclusions generally survive supergene effects which may destroy hypogene alteration, sulfides and other geochemical guides; (2) the abundance of fluid inclusions commonly reflects the intensity of fracturing, and thus also gives information on the deformation of the rocks; (3) fluid inclusions are the only means of determining fluid densities, which may suggest fluid zonation or direction of fluid movement; (4) zonation of fluid inclusion types in drill cores samples may foretell changes in mineralization. Inclusions in quartz are the most convenient to study. Quartz is brittle and heals easily, and commonly provides a sampling of fluids of many ages an advantage in its uses in exploration. Phenocrysts, **conglomerate pebbles, recrystallized chert, silicified limestone, as well as veinlets, have all been used in successful inclusion studies.** (Author's abstract)(Also in Mining Engineering, v. 23, no. 12, p. 80)

NASH, J.T., 1971c, Exploration aspects of the Copper Canyon porphyry copper deposit, Lander county, Nevada; part III, Fluid inclusion studies (abstr.): AIME Pacific Southwest Mineral Industry Conference, Program and Abstracts (p. 16), Am. Inst. Min., Metall. Pet. Eng., North Nev. Sect., Reno.

NASH, J.T., 1971d, Zonation of ore fluids in the Mayflower mine, Park City District, Utah (abstr.): Econ. Geology, v. 66, p. 980; also in Geol. Soc. Amer. Abstracts with Programs, v. 3, no. 7, p. 657-658. Author at the U.S. Geological Survey, Menlo Park, California 94025.

Vein and replacement Pb-Zn-Cu-Au-Ag mineralization in the Mayflower mine occurs along a normal fault zone in sedimentary and intrusive host rocks over a known vertical distance of at least 3,000 feet. Sphalerite, galena, chalcopyrite, and gold are accompanied by hematite and anhydrite. Fluid-inclusion studies outline three physically distinct fluid zones in time and space: (a) an early, deep brine of about 40 percent salinity neary 350°C and probably boiling, (b) an overlying contemporaneous and later zone, which coincides with the known ore zone, with liquids of 250° to 300°C temperature and 1 to 11 percent salinity, and (c) a near-surface zone of boiling. These fluid zones correspond to observed metal and alteration zones. Three types of anhydrite-bearing veins occur in the mine: an early deep stage deposited in the brine, and two stages deposited from solutions of relatively low salinity. The vertical zonation of fluid densities, temperature, boiling, and mineralogy appear to require mixing of fluids on the deeper levels of the mine. The fluid mixing, with consequent oxidation and dilution, appears to have led to sulfide deposition, but not all immediately at the site of mixing. (Author's abstract)

NASH, J.T., and THEODORE, T.G., 1971, Ore fluids in the porphyry copper deposit at Copper Canyon, Nevada: Econ. Geology, v. 66, p. 385-399. Authors at U.S. Geol. Survey, Menlo Park, Calif.

The large, low-grade copper and gold deposit at Copper Canyon, Lander County, Nevada, formed in the contact metasomatic enviroment adjacent to a shallow Tertiary intrusion. Vein and disseminated chalcopyrite-pyrite-pyrrhotite-arsenopyrite mineralization, with lesser amounts of gold, galena, sphalerite, marcasite, and siderite occur in the Upper Cambrian

Harmony and Middle Pennsylvanian Battle Formations. Studies of fluid inclusions in stages of vein quartz and in healed fractures through quartz phenocrysts and pebbles reveal the presence of very saline, sometimes CO_2-rich fluids in the early and middle stages of mineralization. Ore fluid salinities during the base metal mineralization were approximately 40 wt percent, and temperatures were near 375°C. Circulation of this hot brine was apparently restricted to an elongate highly fractured zone within 3,000 feet laterally of the intrusive. Later fluids in this central zone were somewhat cooler, near 300°C, and had significantly lower salinities in the range 12 to 1.2 wt percent. Smaller lode deposits approximately 1 to 5 miles from the intrusion appear to have formed from low to moderate salinity fluids at temperatures generally in the range 250 to 335°C. Geologic and fluid considerations suggest formation at approximately 6,000 feet in depth. (Authors abstract)

NASH, J.T., & WORL, R.G., 1971, [Inclusions in western fluorite deposits] (abstr.): U.S. Geol. Survey Prof. Paper, 750A, Geol. Survey Rresearch, p. A-5. (Authors at U.S. Geol. Survey, Menlo Park, Calif.)

Rare fluid inclusions in samples of fluorite from Northgate, Colo., gave homogenization temperatures clustering in 4 groups-near 113°, 144° 160°, and 177°C. Because of the small vapor fraction, metastable superheating was a problem in freezing runs, but several successful determinations indicate that salinities were near 0.2 wt percent NaCl equivalent. The fluids thus had the character of hot springs.

Features observed lend credence to a hypothesis that the fluorspar deposits are surface or halo indications of related metallic mineralization. Authors' abstract, shortened, (E.R.)

NAUMOV, G.B., and MIRONOVA, O.F., 1971, Influence of the regime of CO_2 and acid solutions in the formation of pitchblende-carbonate veins, in Geochemistry of hydrothermal ore formation, ed. by V.L. Barsukov: Moscow, Izdatel. "Nauka," p. 61-77, (in Russian).

A few data on CO_2 concentrations in inclusions (E.R.).

NAUMOV, G.B., MOTORINA, Z.M. and NAUMOV, V.B., 1971, Conditions of formation of carbonates in veins of the lead-cobalt-nickel-silver-uranium type: Geokhimiya, 1971, no. 8, p. 938-948, (in Russian; translated in Geochem. Internat., v. 8, no. 4, p. 590-598, 1971).

There is a single sequence of carbonates that replace one another: calcite, dolomite, ankerite, and siderite. These are deposited at a constant temperature as a result of increase in the CO_2 content of the mineralizing solutions. This has been deduced from the minerals in typical veins of this type and from gas-liquid inclusions. Thermodynamic calculations show that this can occur when CO_2 bearing solutions react with the country rocks and extract cations during metasomatism. Deposition of the iron carbonates requires not only elevated P_{CO_2} but also suitable lowering of the redox potential and low sulfur activity, a circumstance which is also reflected in the production of arsenide parageneses instead of sulfide ones. Authors' abstract.

NAUMOV, G.B., NIKITIN, A.A., and NAUMOV, V.B., 1971, The origin of hydrothermal whewellite from fluorite veins in Transbaykalia: Geokhimiya, 1971, no. 2, p. 180-186, (in Russian; translated in Geochem. Internat. v. 8, no. 1, p. 107-112, 1971).

Gas-liquid inclusions and thermodynamic analysis of mineral equilibria have been used to show that whewellite in quartz-calcite fluorite veins were deposited at about 150° and a partial pressure of CO_2 of 600 -860 atm from solutions containing 1-8 μmole of oxalic acid and 0.01-0.36 mmole fluorine per kg H_2O. The thermodynamic conditions of formation in the hydrothermal region are discussed. (Authors' abstract). The inclusions have liquid CO_2 and liquid H_2O, or just liquid CO_2; the fluid had 6-8% free CO_2. The CO_2 inclusions homogenize at 5-17°C (ER).

NAUMOV, V.B. and IVANOVA, G.F., 1971, The pressure and temperature conditions of formation of wolframite deposits: Geokhimiya, 1971, nò. 6, p. 627-641 (in Russian; translated in Geochem. Internat., v. 8, no.3, p. 381-394, 1971).

Fluid inclusions have been used to determine the temperature range for wolframite mineralization (250-450°C, usually 280-350°C) in deposits of various types. The corresponding pressures are 550-1650 atm. The mineralizing solutions sometimes contain up to 27 percent CO_2. (Authors' abstract).

NAUMOV, V.B., KOVALENKO, V.I., KUZMIN, M.I., VLADYKIN, N.V., & IVANOVA, G.F., 1971, Thermometric investigation of melting inclusions in topaz-bearing quartz keratophyres (ongonites): Doklqdy Akad. Nauk SSSR, v. 199, no. 3, p. 681-683 (in Russian).

Melt inclusions were homogenized; the glass softens at 520-600°C, and homogenization occurs at temperatures of 920-1030°C. A new bubble then formed when held at 750°. The ongonite melts were lower in viscosity than normal granitic melts, probably from Li and F. (E.R.)

NAUMOV, V.B. and POLYAKOV, A.I., 1971, A thermobarometric study of inclusions in volcanic rocks of the western fift zone in Africa: Geokhimiya, 1971, no. 4, p. 379-386 (in Russian): trans. in Geochemistry Internat., v. 8, no. 2, 1971, p. 234-240.

Homogenization is reported for primary inclusions in minerals from the potassic alkali rocks of Birunga (Uganda and Ruanda). Leucitites have high homogenization temperatures: leucite over 1400°C, pyroxene 1250-1320°C. Leucite basanites and trachybasalts give lower temperatures (1080 to 1160°C). Pyroxene and plagioclase phenocrysts have primary inclusions of high-density CO_2 (0.74 - 0.83 g/cm^3). These inclusions indicate pressures of 5000-6000 bar. (Authors' abstract)

NAUMOV, V.B., & POLYAKOV, A.I., 1971, Thermobarometric investigation of inclusions in minerals of volcanic rocks of the western rift zone of Africa: Geokhimiya, 1971, no. 4, p. 379-386 (in Russian); translated in Geochem. Internatl. v. 8, no. 2, p. 234-240. Authors at V.I. Vernadsky Institute of Geochemistry and Analytical Chemistry, USSR Academy of Sciences, Moscow.

Experiments on homogenization of primary inclusions of melt from minerals of potassic alkaline rocks of Birunga (Uganda and Ruanda) have been carried out. High homogenization temperatures are characteristic of leucitites: above 1400°C, pyroxene-1320-1250°C; for minerals from leucitic basanite and trachybasalts lower temperatures have been obtained: from 1160° to 1080°C. In phenocrysts of pyroxene and plagioclase primary inclusions of highly dense carbon dioxide-0.74-0.83 g/cm^3 have been revealed. Determination of pressures according to such inclusions gives values of an order of 5000-6000 bars.(Authors' abstract.)

NAUMOV, V. B., POLYAKOV, A. I., ROMANCHEV, B. P., 1971, Crystallization parameters of the basaltic melts according to thermobarometric investigations of inclusions in the minerals (abst.): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 1, p. 84-85 (in English) (Authors at V.I. Vernadsky Institute of Geochemistry and Analytical Chemistry, Academy of Sciences, Moscow, USSR).

1. Three strongly differentiated series of volcanic rocks are spread in rift zones of Eastern Africa: those of olivine basalts and those of potassium and sodium alkaline basaltoids.

2. The experiments on homogenization of primary inclusions in the phenocrysts of lavas give an idea about temperatures of their crystallization:

a) The series of olivine basalts crystallized at 1260-1100°C (temperature of homogenization of inclusions in pyroxenes and plagioclases). End products of these series differentiation are rhomb-porphyries and phonolites; they crystallized at 1050-950° (anorthoclase).

b) The series of potassium alkaline basaltoids crystallized at temperatures above 1400° (leucite) and 1320-1250° (pyroxene from ugandites and leucitites). The inclusions in the minerals of leucite basanites homogenized at temperatures from 1160 to 1080° (pyroxene and plagioclase).

c) The series of sodium alkaline basaltoids crystallized at temperatures from 1320-to 1120° (pyroxene and nepheline from nepheline pictures [sic] and nephelinites). End members of differentiation in these series are characterized by crystallization temperatures of 1080-860° (nepheline, anorthoclase, wollastonite from phonolites).

3. The crystallization temperatures obtained for these volcanic series suggest the independent character of each of these. It must be especially emphasized that potassium enriched alkaline melts are the most high-temperatures ones and therefore they cannot be the derivates of basaltic or sodium basaltoid magmas.

4. The pressures of crystallization have been determined by the investigation of high density CO_2 inclusions. They are 6000-5000 bars for minerals of potassium basaltoid series and 3000-2000 bars for minerals of basaltic series. These values indicate the depths of intermediate magmatic chambers where the phenocrysts began to grow and the processes of crystallization differentiation occured. (Authors' abstract).

NETREBA, A.V., FRIDMAN, A.I., PLOTNIKOV, I.A. and KHURIN, M.L., 1971, Large-scale mapping of closed ore-bearing areas in the north Caucasus by geochemical gas surveying: Geokhimiya, 1971, no. 8, p. 1016-1021 (in Russian).

The subsoil air over fault zones was found to have persistent CO_2 anomalies around Hg deposits in the N.W. Caucasus. Fault zones, indicated by gas surveys, were subsequently confirmed by geologival methods. Therefore such a survey can be used as a geochemical method in mapping Hg-bearing areas with extensive drift cover. (L.P. Greenland.) (Ed. note: of pertinence in view of the common occurrence of CO_2 in inclusions in mercury deposits).

NIKANOROV, A.S. and MIKHAILOV, I.I., 1964, Temperatures of formation of pegmatoidal structures in mica-bearing and ceramic pegmatites: Geokhimiya no.11, 1964, p. 1146-1151, (in Russian); translated in Geokhimiya Translations 1964, Suppl. to Geochem. Internat., v. 1, issued in 1973. (Authors are at All-Union Geological Research Institute, Leningrad.)

Although this article is old, it is listed here since the translation has just been published (E.R.).

OGANESYAN, L.V., & KOMOV, I.L., 1971, Dispersion haloes of mercury as prospecting indicators of hydrothermal rock crystal-bearing veins: Dokl. Akad. Nauk SSSR, v. 201, no. 1, p. 204-207 (in Russian); translation in Doklady Acad. Sci. USSR, Earth Sci. Sect., v. 201, p. 241-243 (1972). Authors at All-Union Research Institute for the Synthesis of Mineral Products, Aleksandrov (Vladimir Oblast).

Statistically significant haloes of mercury were found for some meters beyond the veins. These are the same productive quartz crystal veins of the Pamirs and Eastern Siberia that have been extensively studied by inclusion techniques. (E.R.)

OHMOTO, Hiroshi, 1971, Fluid inclusions and isotope study of the lead-zinc deposits at the Bluebell mine, British Columbia, Canada: Soc. Mining Geol. Japan, Spec. Issue 2, p. 93-99 (1971) (Proc. IMA-IAGOD Meetings '70, Joint Symp. Vol.)

This is the full paper covering the material abstracted in Fluid Inclusion Research, v. 3, 1970, p. 50-51 (E.R.)

ORLOVA (VASIL'CHIKOVA), L. M., 1971, Determination of alkalies in microinclusions in quartz by the method of aqueous extraction using small samples, in Investigations of mineral-forming solutions and melts in inclusions in minerals, N.P. Ermakov and L.N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials, (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 170-171 (See Translations Section), (in Russian).

PAGE, N.J., 1971, Comments of the role of oxygen fugacity in the formation of immiscible sulfide liquids in the H chromitite zone of the Stillwater Complex, Montana: Econ. Geol., v. 66, p. 607-610. Author at U.S. Geol.

Survey, Menlo Park, Calif.

Decreasing $Fe^{+3}/(Cr + Al + Fe^{+3})$ and $Fe^{+2}/(Mg + Fe^{+2})$ ratios in the cumulus chromites from the H chromite zone of the Stillwater Complex, Montana, correlate with an increasing volume percent of sulfide minerals. Apparently, the separation of sulfide material is not caused by increased oxygen fugacity in the magma or by temperature changes but by local depletion of Fe^{+2} in the magma. Author's abstract. (Pertinent to the trapping of sulfide inclusions in magmatic minerals. E.R.)

PAL'MOVA, L.G., and DIKOV, YU.P., 1970, The theoretical bases for decrepitation analysis: Vyssh. Ucheb. Zaved., Izv., Geol. Razved. no. 12, p. 64-69 (in Russian).

PARK, F.P., 1971, Interpretation of the fine topography of secondary glass inclusions in olivine crystals: Compte Rend. Acad. Sci., Paris v. 272, Ser. D, p. 1325-1327 (in French).

The author illustrates thin glass secondary inclusions that appear to define paired (and oppositely turning) spiral dislocations in the host olivine (approx. 40 μm center to center). (E.R., from author's translation).

PASHKOV, YU. N. and ELINSON, M. M., Method of experimental study of inclusions with barometric recording, in Investigations of mineral-forming solutions and melts in inclusions in minerals, N.P. Ermakov and L.N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 156-159, (in Russian)

PAWLOWSKA, Jadwiga, 1971, Homogenization and decrepitation in studies on crystallization temperatures of minerals and rocks: Kwart. Geol. v. 15, no. 4, p. 837-854 (in Polish).

Homogenization and decrepitation data on low temperature vein quartz and fluorite are found to be comparable. (E.R.)

PETERSIL'E, I. A.*, KARZHAVIN, V. K., 1971, Gases and organic compounds in the magmatic processes (abst.): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 1, p. 41-42 (in English) (Authors at Geological Institute, Kola Branch of the USSR Academy of Sciences, Apatity, USSR). * Note - transliterated "J.A. Petersilie" in original.

In the upper part of the mantle reversible chemical processes occur in which some gaseous substances are involved. During the long geological periods the chemical equilibrium of these processes is being set in their general orientation leading to the accumulation of gaseous components most stable at given pressure and temperature. After the completion of crystallization cycle the solid rock components acquire the most stable forms whereas gaseous substances appear to be "embedded" in the closed pores of rocks and minerals. The study of the gas phase composition of rocks and minerals renders significant assistance in decoding the rock genesis, in re-creation of thermodynamic conditions of rock formation, and in elucidation of the character and the intensity of post-magmatic processes (Petersil'e, 1964; Petersil'e, Andreeva, and Sweshnikova, 1965; Petersil'e, Yashina, 1970; Petersil'e, and Sorensen, 1970).

The gas component and the organic compounds found in minerals and rocks of agpaitic alkaline massifs (Kola Peninsula, Siberia, Greenland) are also of great interest. Methane is found to be the predominant component in the gas composition, amounting from 70 to 90%. The gas mixture contains He, H_2, and small quantities of hydrocarbons C_2-C_4. The amount of gases in rocks and minerals comes up to 200 cm^3/kg. Rocks and minerals are distinguished by quantity and composition of gases contained in them. δC^{13} of gases (standard PDB) varies from -0.32 to -1.46 and gets into ranges typical of CO_2 of magmatic origin. The alkaline rocks contain reduced dispersed bituminous substance. Its amount does not usually exceed 0.006 weight % of rock. The elementary composition of chloroform extract (%): C - 61.25-85.73, H - 7.94-12.35, S - 0.13-0.87. The amount of oils is 22-40% , in their composition prevail paraffin hydrocarbons; naphtene and aromatic hydrocarbons are present in relatively lesser quantities.

The occurence of hydrocarbons in alkaline rocks may be explained by the increased content of alkalis and the reduced partial pressure of oxygen ($P_{O_2} = 1.2 \cdot 10^{-24}$ atm) during the pre-crystalllization period (Korzhinskii, 1963; Kogarko, 1970). This deduction is confirmed by the conducted thermodynamic calculations. (Authors' abstract).

PETRITCHENKO, O. I., SLIVKO, E. P., 1971, Physico-chemical conditions of formation of halogene deposits of Ukraine according to the studies of inclusions in halite (abst.): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 2, p. 847-848 (in English) (Authors at Institute of Geology and Geochemistry of Fuel Minerals, Ukrainian Academy of Sciences, Lvov, USSR).

According to the investigation of the oil and gas content in salt plugs of some regions of the Ukraine, the physico-chemical conditions of forming of stocks [domes?] of rock salt in Dnieprovsko-Donietsk basin (Devonian-Permian) and in Transcarpathian trough (Neogene) were studied. When solving this problem some results from the study of inclusions in halite (liquid, gas and solid) were used. The chemical composition (K, Mg, Ca, SO_4, Cl, Fe^{+2}, Fe^{+3}) as well as pH-Eh of solutions of separate inclusions, the content of gases (N_2, H_2, CO_2, CH_4) and their internal pressure, were determined. The nature and the typomorphic peculiarities of solid inclusions (authigenic minerals) in halite were also studied.

It was stated that the solutions of primary inclusions in the sedimentary halite from the Devonian rock salt belong to a chloride type Cl-Na-Ca of the structure having (in gr/l): K-0.5-2.5, Mg-8-32, Ca-40-90, pH = 5.4-5.8, Eh - +110-160 mv; the temperature of homogenization of monophase inclusions being 45-80°C. During the formation of stocks the rock salt was undergoing processes of metamorphism at elevated temperature (90-120°C) and pressure (150-300 atm). This was testified by the composition of solution of the individual inclusions in the recrystallized halite (in gr/l): K-0.5-10, Mg-7-17, Ca-30-110 and by some other physico-chemical parameters: pH - 3.7-6.1, Eh = -10-160 mv, P = 60-350 atm. The content of gases in the essential-gas and gas-liquid inclusions is as follows: (in percent) N_2 = 10-50, CO_2 = 26-51, H_2 = 5-15, CH_4 = 10-52.

The solutions of inclusions in the sedimentary halite from the Permian rock salt belong to a sulphate type of the structure having (in gr/l): K - 10-30, Mg - 8-44, Ca 0.5, pH = 4.7-6.3, Eh = +130-260 mv. During the metamorphism of the Permian salts the processes of desulphatization of the solutions took place, as well as lowering of pH (up to 4.3-5.6) and Eh (up to -10-120 mv) of the medium, increasing of temperature up to 80-110°C and pressure up to 15-35 atm. The Permian salt underwent the greatest metamorphism in the contact zone with the Devonian salt stocks.

The presence of only monophase liquid inclusions in the halite of the Neogene rock salt confirms the fact that the halite was not affected by the high temperatures and pressure during the period of the stock formation. The composition of the solutions of the liquid inclusions in the recrystallized halite is very similar to that of the original brine of the evaporites, (in gr/l): K- 4-42, Mg - 15-25, SO_4 - 20-43, Ca - below 0.5. The paramters of pH-Eh of the recrystallization medium corresponded to the subacid (pH = 5.3-5.5) recovery (Eh = 160-260 mv) conditions (sic). By these investigations it was determined that the formation of the salt sediments in the old evaporites in the Ukraine area took place as a result of the evaporation of the chloride (in Devonian) and sulphate (in Permian and Neogene) type solutions. During the formation of the salt stocks the rock salt underwent the influence of dynamic metamorphism processes, hydrothermal activity, and contact metamorphism, as well as the influence of the mobile phases of the enclosing rock. (Authors' abstract).

PETROVIC, Radomir and SKINNER, B.J., 1971, Alkali ion exchange reaction between alkali feldspars and hydrothermal solutions: replacement vs. cation exchange (abstr.): Geol. Soc. Amer. Abstracts with Programs, v. 3 no. 7, p. 669. (Authors at the Department of Geology and Geophysics, Yale

University, New Haven, Connecticut 06520).

Alkali ion exchange reaction between alkali feldspars and hydrothermal solutions has been observed only in experiments in which essentially pure albite was converted into essentially pure K-feldspar and vice versa. The reaction proceeds by a replacement mechanism involving dissolution and reprecipitation. This is in contrast with the true cation exchange observed when alkali feldspars are exposed to molten salts. Assuming a purely elastic behaviour, a microcline layer produced by cation exchange on a low albite crystal has a coherency strain energy of 1.8 kcal/mole at 25°C and 1.0 kcal/mole at 800°C. As a consequence, the solubility product of microcline in such a layer is increased over that of unconstrained microcline by a factor of 22 at 25°C and 1.6 at 800°C. Thus replacement by dissolution and reprecipitation is due to coherency stress. True cation exchange will therefore be the reaction mechanism when the difference between the equilibrium value and the initial value of the K/(Na+K) ratio of the feldspar is small.

Optically clear adularia crystals of composition $Or_{86}Ab_{14}$ and originating from the same druse were exposed to (a) 2M KCl aqueous solution and (b) dry KCl, in platinum capsules placed in the same cold seal bomb, at 750°C and 1 kb. A typical diffusion profile is obtained in case (a), confirming the hypothesis. Diffusion profiles in cases (a) and (b) are virtually identical, indicating that H_2O has little or no effect on the interdiffusion coefficient and cannot be involved in the diffusion mechanism. (Authors' abstract) (Ed's. note: the replacement process described here opens up many possibilities for fluid inclusion formation during replacement.)

PETROVSKAYA, N. V., ELINSON, M. M., NIKOLAEVA, L. A., 1971, Composition and formation conditions of gas inclusions in native gold (abst.): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 1, p. 326-327 (in English) (Authors at Institute of Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry; Mining-Prospecting Institute of Non-ferrous and Precious Metals, Moscow, USSR).

Gas inclusions in native gold have been long disregarded by researchers. They were detected for the first time through swells on the surface of gold particles from placers of the Lena area, the uncovering of cavities having shown absence of a liquid phase in them (Nikolaeva, 1954). New data testify to their abundance. Despite of the importance of gas inclusions, as indicators of genesis of natural concentrations of gold, they remained poorly studied owing mostly to imperfect research methods.

In the laboratory of IGODPMG was designed a hermetic microdegasser that made it possible to extract a gas constituent from gold samples without heating them up. As result it has been found that 90% of the constituent was presented by CO_2; among other gases there was determined nitrogen. Pressure in capsules was estimated as 5-20 atm.

Carbon dioxide and nitrogen are present in gaseous-liquid inclusions in gold-containing quartz of the same deposits. The authors believe that presence of capsulated gases only in native gold, precipitated from aqueous solutions, is the result of adherence of bubbles CO_2 to the surface of growing gold grains that are hydrophobic to a certain extent. Experiments have been carried in the Institute that confirmed these phenomena. It is necessary to take into account, when one interprets the results of mineralothermometry. In the process of crystallization of gold gaseous cavities in it change(d)forms, partially or completely lost their spherical contours, and became angular. In gold precipitated under conditions of small depths cavities acquired the forms of negative crystals.

The data obtained testify to significant role of carbon dioxide in crystallization of gold from hydrothermal solutions and frequent boiling up of the latter under local conditions of considerably decreasing pressure. Similar phenomena were observed when studying gold precipitated at various depths. (Authors' abstract).

PHAIR, George & HICKLING, N.L., 1971, [Formation temperatures of carbonatites, Wet Mountains, Colo.](abstr.): U.S. Geol. Survey Prof. Paper 750A, Geological Survey Research, p. A-120.

The authors have estimated the temperatures of formation of eight calcite-dolomite pairs from carbonatites of the Wet Mountains, Fremont and Custer Counties, Colo. The MgO content of the calcite was determined on three splits of each sample by precise, repetitive X-ray diffractometer measurement of the position of the $(\bar{2}11)$ line. The formation temperatures estimated from the solvus curve of Harker and Tuttle average 350° ± 25°C, several hundred degrees below the minimum temperatures determined in laboratory studies of carbonatite melts. The low temperatures are consistent with structural, textural, and paragenetic evidence that these carbonatite bodies are hydrothermal replacements of mafic and ultramafic rocks. The results further substantiate qualitative temperature estimates on genetically related bodies of nearly pure potash feldspar which in turn have been interpreted as being genetically related to the formation of thorium deposits formed by outward secretion of thorium during potash metasomatism of CaO-poor granites. (Authors' abstract). Note- pertinent also in view of the relatively low temperatures of homogenization of inclusions from some (other) carbonates. (E.R.)

PHUKAN, Sudha, 1971, Inclusions in the Panna diamonds of India: J. Gemmol. v. 12, no. 5, p. 157-166.

The study of 200 diamonds from Panna shows that they are essentially characterized by primary solid and gaseous inclusions, viz. (1) chromite, magnetite, ilmenite, (2) graphite, (3) olivine, (4) diamond, (5) garnet, (6) diopside and (7) gaseous CO_2, arranged in order of their abundance. Secondary inclusions included hematite and limonite. These inclusions mainly occur as discrete individual crystals; only spinel minerals and olivine-chromite occur at places in aggregates. The physical characteristics and nature of inclusions show that diamonds of primary pipe rock and secondary conglomerate are markedly homogeneous and have a common source. Graphite-CO_2-diamond perhaps maintained a critical P-T condition to form together, but the significance of other inclusions found in Panna diamond is yet to be worked out. (Author's abstract)

POIROT, Jean-Paul, 1971, Some notes on growth-disturbances found in Colombian emeralds: Jour. Gemmology, vol. 12, no. 7, p. 271-274.

Brief discussion of liquid water solution, NaCl, and CO_2 found in inclusions, and their mechanism of trapping. (ER)

POLYKOVSKII, V. S., 1971, The problem of the possibility of applying decrepitation for showing aureoles of hydrothermal steaming (?) in bismuth showings of Uzbekistan, in Investigations of mineral-forming solutions and melts in inclusions in minerals, N. P. Ermakov and L. N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 139-143, (in Russian)

POLYKOVSKII, V. S. and MORGENSHTERN, L. E., 1971, Empirical formula for calculating probable temperature of homogenization of inclusions in fluorite, in Investigations of mineral-forming solutions and melts in inclusions in minerals, N.P. Ermakov and L.N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 182-183, (in Russian).

POMÂRLEANU, VASILE, V., 1971a, Homogenization temperature of the fluid inclusions from the minerals and its application to the thermogeochemistry of the hydrothermal processes (abst): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 1, p. 323 (in English) (Author at Geochemistry Section, Jassy branch of Romanian Academy, Romania).

More than 4000 data on the homogenization temperature of the fluid inclusions of quartz, sphalerite, scheelite, barite, fluorite, calcite, etc., from polymetal and gold hydrothermal deposits from Baia Mare (Romania) have been obtained.

By statistical interpretation of these data (histograms, frequency curves and diagrams) and their correlation with the subterranean and microscopic observations on the ores, the following aspects about the thermogeochemistry of the hydrothermal processes were pointed out:

- the establishment of the polyascendent and pulsatory character of the mineralizing solutions;
- the determination of the thermal state of the mineralizing solutions in the longitudinal and cross section of the veins;
- the determination of the geothermal gradient of the hydrothermal solutions;
- the delimitation of the dispersion aureole of the mineralizing fluids in the host rocks from the neighbourhood of the veins;
- the determination of the relations of the mineral associations and the establishment of the limits of the deposition temperature of the whole mineral succession in a given lode. (Author's abstract).

POMÂRLEANU, V. V., 1971b, Geothermometry and its applications to some minerals from Romania. Bucharest, Editura Academiei RSR, 158 pp. (in Romanian whith 3-p. English summary).

Ed's note: This rather rare book is a summary of Dr. Pomârleanu's extensive studies of inclusions in Romanian ore deposits, most of which are published only in Romanian, in journals that are difficult to obtain. Hence the entire English summary (edited rather extensively) is given here, as it provides insight into the status of various inclusion studies, and particularly decrepitation, in the RSR.

The knowledge of the formation temperature of minerals and rocks is important for their genesis, elucidation, and especially in view of synthesizing some minerals which, through their properties are useful in different branches of modern technology. The knowledge of this factor is also an additional criterion for the orientation of prospecting and delimitation of new ore bodies. This paper was elaborated starting from these considerations and from the lack of a systematic research in this field in Romania.

In the first part a synthesis is presented of the principal methods utilized in geothermometry, including methods based on solid solutions: ZnS-FeS, FeS-FeS_2, muscovite-paragonite etc., and based also on the method of element partition coefficients in minerals.

The second part deals with the study of the fluid inclusions in minerals. After a short history, the classification and the homogenization types of fluid inclusions are presented with examples from minerals in the Romanian territory. In the same part the theory of homogenization and decrepitation of inclusions in minerals is presented as well as their suitability for geothermometry.

The third part deals with the presentation and description of the technique utilized in geothermometric research (homogenization and decrepitation methods).

The geothermometrical data were directly obtained on a number of samples of over 16 minerals, from different genetic types of rocks (sedimentary, metamorphic, pegmatitic and magmatic), as well as ore deposits from Romania (hydrothermal, pyrometasomatic, pegmatitic and metamorphic). Other geothermometric research methods were also used, e.g.: the systems ZnS-FeS, FeS-FeS_2, muscovite-paragonite, etc.

The data obtained through the homogenization and decrepitation methods were statistically processed after the model (histograms, frequency curves, diagrams) first elaborated in geothermometry by M. Savul and V. Pomârleanu (1957) and admitted and extended then in other countries (N.P. Ermakov, 1963; Siui Go-Tin, 1965 etc).

From the comparative study of the diagrams obtained through both methods, it was concluded that in the evaluation of the crystallization temperature of hydrothermal minerals, in the decrepitation method it is necessary to take into account the temperature interval determined by the first maximum of frequency of the decrepitation in a body of inclusions and not just one temperature. Some facts obtained by the author over many years are in support of this finding, and they are presented in the paper (p. 90-91).

The geothermometric data resulting from the study of the fluid inclusions, and statistical processing, correlated with the terrain and microscopic observations, led to the elucidation of some problems of local interest and of some crystallogenesis, mineralogenesis, petrogenesis and metallogenesis problems.

From the crystallogenetic point of view there were established new correlations bearing on the distribution of fluid inclusions in growth zones of some crystals and the homogenization temperature of the phases from inclusions. In the case of quartz crystals (Herja, Baia Sprie, Băiuț, etc.) with different growth zones, higher temperatures were defined in the central part and lower ones in the periphery. A correlation was also found between the habit of crystals and the negative crystal form of fluid inclusions (dodecahedon in garnets, rhombohedron in calcite, cube in fluorite, hexagonal prism in beryl, etc), confirming the syngenetic character of the inclusions from crystals.

The morphological peculiarities of the fluid inclusions as well as the experimentally determined temperatures show that the hypothesis according to which some mineral species can serve as temperature indicators is not confirmed. Thus, in scheelite of hydrothermal deposits (Baia Sprie) associated with quartz and chalcopyrite there are two-phase inclusions (the liquid phase being predominant), indicating a temperature interval of homogenization between 255° and 320°C, while the scheelite from skarn (Tincova) associated with garnet and magnetite contains preponderantly gas phase inclusions and triphasic (aqueous solution + liquid CO_2 + gas), showing a temperature interval between 339° and 450°C. Another example is found in wolframite, which, in the hydrothermal deposits, indicates a temperature interval of decrepitation (for the frequency maximum) between 275° and 330°C, while in the skarn deposits (Ocna de Fier) it indicates a frequency maximum between 405° and 455°C.

The histograms and frequency curves of the obtained temperatures through the study of the fluid inclusions facilitate the determination of the association relations between minerals, and at the same time the prediction of their paragenetic character. In the case of the association fluorite + calcite (Herja) the slight discrepancy of the temperature frequency maxima from one mineral to another shows that in an appreciable interval (195°-235°C) the respective minerals have crystallized in identical thermodynamic conditions. Hence, in this interval both minerals exist in a paragenetic association (Fig. 60).

In petrogenesis the study of inclusions may serve as indicators in establishing the origin and nature of the rocks. In the minerals of magmatic rocks solid inclusions (glass + gas) predominate while in pegmatitic rocks complex inclusions (aqueous solution + liquid CO_2 + gas) are prominent. It is also possible through inclusion study to distinguish granite bodies of magmatic origin from the metasomatic ones.

In metamorphism fluid inclusions may serve as indicators in the separation of metamorphic zones. The minerals from rocks with a low metamorphic grade are characterized by the presence of two-phase inclusions (liquid + gas) and those in rocks with a medium metamorphic grade are characterized three-phase inclusions (aqueous solution + liquid CO_2 + vapor) or by gaseous and preponderantly gas phase inclusions.

Also, through the study of fluid inclusions the genesis of some minerals preexisting in sedimentary rocks may be established.

In metallogenesis, the geothermometric data and their statistical representations, completed with underground and microscopic observations on the ores, led to the elucidation of many problems, such as: the establishment of the polyascendent (or descendent) and pulsatory character of the mineralizing solutions, the establishment of the thermal regime of the solutions in vertical and horizontal sections, the determination of the geothermal gradient of the mineralizing solutions, the determination of the sequential deposition of minerals and the establishment of the temperature limits of this deposition.

The polyascendent and pulsatory character of the solutions may be deduced from the analysis of the histograms and geothermometric diagrams obtained on transverse profiles of ore bodies. These histograms and diagrams show a sequence and a variation of the deposition temperature from the marginal parts of the vein to the axial part (Fig. 67).

The variation of the thermal regime of the mineralizing solutions in the vertical and horizontal planes of the vein is indicated in the diagrams with the sequence of the limiting values of the frequency maxima and of the arithmetic averages of the temperatures from one level to another (the Sofia vein, the Nistru deposit (Fig. 52) and the main vein Baia Sprie (Fig. 63)). From the analysis of these diagrams it results that at a certain level, a given mineral had the possibility of formation in a large interval of temperature and that the same temperature existed over many levels. The limits and the frequency maxima of the temperature varied regularly with the depth. Great variations in the same level show that the isotherms in the plane of the vein are inclined.

The geothermometric data have led to the establishment of the geothermal gradient of the mineralizing solutions with respect to the depth (Table 25). If the generating source of the mineralizing solutions is at great depth, the geothermal gradient is low (Herja deposit). If the magmatic source is near the surface, the value of the geothermal gradient is great (Baia Sprie deposit). (Author's abstract).

POMÂRLEANU, V. and MOVILEANU, A., 1971, Geothermometry of some pegmatites in Romania: Soc. Mining Geol. Japan, Spec. Issue 2, p. 171-177 (Proc. IMA-IAGOD Meetings '70, Joint Symp. Vol.)

With a view to determine the formation temperature of some pegmatites of the Carpathian Arc of Romania, the fluid inclusions occurring in quartz, apatite, tourmaline, spodumene, beryl and muscovite were studied.

Most minerals (muscovite excepted) formed from fluid CO_2-saturated solutions and from salt-saturated solutions (aqueous solutions + crystals).

The formation temperatures of the minerals (pressure correction omitted) varies within limits between 530°C and 300°C. The proper pegmatitic process developed from 530°C to 300°C. Lower temperatures, obtained by studying secondary fluid inclusions (320°C to 100°C), are related to hydrothermal replacement processes as confirmed by macro- and microscopic findings in minerals.

The formation temperature of pegmatitic muscovites differs from that of muscovite in the enclosing rock (paragneisses, micaschists, etc.). (Authors' abstract)

(A similar abstract but with some other data was published in 1970-see Fluid Inclusion Research, v. 3, p. 55 (1970); many of the data dealing with tourmaline were given in German in a previous publication (Pomârleanu and Murariu, 1970, Summary of studies of tourmaline from pegmatites in Romania) abstracted briefly in Fluid Inclusion Research, v. 3, p. 56 (1970) (Ed.))

PURTOV, V.K., 1971, On the method of determination of mineral crystallization temperature and pressure by gaseous-liquid inclusions: Geokhimiya, 1971, no. 4, p. 387-391 (in Russian). Translated in Geochem. Internat'l., v. 8, no. 2, p. 241-247. Author at Institute of Geology and Geochemistry, Ural Branch of the USSR Academy of Sciences, Sverdlovsk.

On the basis of a calculation of quantitative H_2O/CO_2 ratios in syngenetic liquid and gaseous inclusions and of experimental data on H_2O and CO_2 mutual solubility at high temperatures and pressures a determination of P-T conditions of quartz crystallization has been carried out. A good coincidence of the calculated temperature with the temperature of homogenization of the inclusions is shown for inclusions formed in the range 300°C and 400 atm. pressure; crystals formed at high pressure have much larger errors. A qualitative estimation of the influence of the concentration of salts dissolved in the aqueous phase of inclusions upon the results of determinations has been made. Control determinations of the pressure by the method of calculating the specific CO_2 volume under conditions of mineral formation have been carried out. (Author's abstract, modified.)

PUZANOV, L.S. and KUDAKOVA, L.P., 1964, On the determination of relative and absolute temperatures of formation of rocks: Geokhimiya, no. 12, 1964 p. 1319-1324; translated in Geokhimiya Translations 1964, Suppl. to Geochem. Internat., v. 1, issued in 1973. (Authors are at All-Union Institute of Raw Mineral Materials, Moscow.)

Although this article is old, it is listed here since the translation has just been published (E.R.).

RADKEVICH, E.A., KOKORIN, A.M., & KOROSTELEV, P.G., 1971, The temperature and geochemical zonality in the Komsomolsk region, (abstr.): Internat. Geochem. Congress, Moscow, 1971, Abstracts of Reports, v. 1, p. 306-307 (in English). Authors at the Far-East Geological Institute, Vladivostok, USSR.

In the Komsomolsk region data on the horizontal and vertical geochemical zonality caused by the temperature of ore-formation are obtained.

A. In the south-west of the region in the great Chalbinsky granite massif and in surrounding contact - metamorphosed Jurassic terrigenous rocks, high-temperature greisens and quartz-tourmaline veins are observed. According to the thermometrical determination (Kokorin) quartz was formed at 500-450°; tourmaline contains more magnesium than elsewhere in the region; cassiterite is Be-rich but contains little other trace-elements; trace-elements in arsenopyrite are scarce. Other sulphides are not widely developed.

B. In the central part of the region the metasomatic quartz-tourmaline zones have developed in Jurassic alevrolites and in Lower Cretacous tuffs and sandstones, sometimes associated with small diorite stocks.

The following stages of mineralization are established here: 1 - quartz-tourmaline; 2 - quartz-cassiterite (400°-/350°); 3 - quartz-sulphide with pyrrhotite, chalcopyrite (370°-270°); 4 - quartz-carbonate (up to 150°).

The W-content in cassiterite increases, but other trace-elements (Fe, Zn, Sc, Nb) decrease with depth and toward the diorite stocks. In arsenopyrite the content of Sb increases, but Bi decreases with the depth.

C. The west-east part of region is characterized by relatively low-temperature mineralization (up to 150°), especially in the upper parts of zones crossing the Upper Cretaceous propylitized andesites, where Pb-Zn ores are known. At depth tin-bearing tourmaline zones appear. Tourmaline contains more Fe^{3+} than Fe^{2+} here.

The abundances of trace elements (especially Bi and Sb in arsenopyrites and galena) and their correlations (Ag-Bi-Sb in galena) may be used as the indicators of the depth and temperature of ore formation. (Authors' abstract.)

RADKEVICH, E.A., and 13 others, 1971, Chapt. 3, pp.211-268, Temperature conditions of formation of the mineralized zones, in Geology, mineralogy, and geochemistry of the [ore deposits of the] Komsomol'skii region: Moscow, "Nauka" Publishing House, for Acad. Sci. USSR, Siberian Division and Ministry of Geology RSFSR, 334 pp (in Russian).

These 54 pages present an extremely detailed study of the many stages of quartz deposition associated with the tungsten, tin and base metal mineralization in this region. Large numbers of homogenization temperatures are given, in 14 tables, for primary and secondary inclusions in each stage of quartz from many sampling points in various mines. Thirty-one decrepigrams are given for quartz and tourmaline. Most homogenization temperatures of primary inclusions in quartz show first a rise with paragenetic stage, from 300° up to a maximum around 380°C, and then a gradual decrease with stage to less than 100° for very late stage material. Numerous multiphase inclusions containing fibrous radial daughter crystals identified as tourmaline and cassiterite, cubes of halite, and other unknown phases are described. One very large included crystal was identified as galena (Fig. 66; presumably this is a solid inclusion and not a daughter mineral? Ed.) (E.R.).

RADKEVICH, R.O., 1971, Temperature conditions of hydrothermal ore formation for the example of the principal polymetallic deposits of the northern Caucasus, in Geochemistry of hydrothermal ore formation, ed. by V.L. Barsukov: Moscow, Izdatel. "Nauka," p. 78-90, (in Russian).

Temperatures of formation of 400° to 100°C are reported, mainly by decrepitation (many decrepigrams are illustrated) (E.R.).

REEVE, E.J., & ANDERSON, G.M., 1971, Geochemistry of a nepheline pegmatite and adjacent gneisses near Bancroft, Ontario (abstr.): Geol. Soc. Amer. Abstracts with Programs, v. 3, no. 7, p. 679. Authors at the Department of Geology, University of Toronto, Toronto 5, Ontario.

The Golding-Keene pegmatite is a large, unzoned, very coarse-grained nepheline-albite pegmatite enclosed within the York River belt of heterogenous nepheline-plagioclase-hastingsite-biotite-calcite gneisses. The purpose of this study was to test the hypothesis that the pegmatite represents a low melting fraction on the gneisses. Chemical analyses have been performed on samples from over 800 feet of diamond drill core.

The normative composition of the pegmatite lies at ne 62, ks 9, qz 29. This is on the line joining the compositions of the co-existing nepheline solid solutions and albite near the cotectic line in the "nepheline syenite system." Using a modified CIPW norm containing biotite and hastingsite, the gneiss compositions plot around ne 67, ks 11 qz 22. These compositions of the gneiss and pegmatite are compatible with a partial melting interpretation for the origin of the pegmatite but not with an origin by differentiation from most nepheline syenite magmas. Experimental studies indicate that minimum temperatures of 750°C at 2 kb or 700°C at 4 kb are required for beginning of melting of the gneiss. Addition of 50 mole per cent CO_2 to the fluid phase increases the solidus temperatures at 2 and 4 kb by about 35°C. The composition of co-existing nepheline and albite in the pegmatite indicate that these phases were in equilibrium at temperatures of 400° to 500°C. (Authors' abstract.)

REMESHILO, B.G., 1971, On liquid inclusions in accessory beryl of the Zanorysh pegmatites of the Ukraine: L'vov Gos. Univ. Mineral. Sbornik, v. 25, no. 3, p. 262-264 (in Russian). Author at Inst. Geol. Geokhim. Goryuch. Iskop, L'vov.

A description is given of multiphase primary and secondary inclusions in beryl crystals from Zanorysh pegmatites of the Ukraine. They contain alkali chlorides and CO_2. The homogenization temperatures of these inclusions are 350°-415°C (in the gaseous phase), pH=8.0-8.5. Author's abstract, modified (ER)

RIFE, D.L., 1971, Barite fluid inclusion geothermometry, Cartersville mining district, northwest Georgia: Econ. Geol. v. 66, p. 1164-1167.

The residual barite deposits in the Cartersville, Georgia district, were formed by secondary concentration of primary barite veins and barite-filled breccias. The deposits are found in deep, 200 feet thick, residual clays. Primary barite was formed by precipitation of barium-bearing solutions in shattered Lower Cambrian dolomite. The mineralization is thought to be associated with magmatic activity during Appalachian deformation in late Carboniferous time. Primary fluid inclusions in the barite homogenize in the temperature range of 126° to 297°C (uncorrected for pressure). This is compatible with hydrothermal derivation of the solutions. A 5,000 feet depth of emplacement requires a +20° to 30°C pressure correction for these temperatures. Boiling seems not to have occurred during the time of inclusion entrapment. Lack of daughter salts in the inclusions is indicative of salinities below about 26 weight percent. (Author's abstract) Note: a discussion of this paper was published in Econ. Geology, v. 67, p. 821-827, 1972.(ER)

RODZYANKO, N.G., 1969, Distribution of chemical elements in the Turnyauzsk ore field and some questions of its formation: Avtoref. Dokt. Diss., Baku, 1969. (A dissertation) (sic., as quoted in Bogoyavlenskaya, et al., 1971, in this volume).

RODZYANKO, N. G., 1971, Thermal evolution for the processes of formation of skarn rare metal (W, Mo) deposits (abst.): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 1, p. 385-386 (in English) (Author at Rostov State University, Rostov-on-Don, USSR).

On the basis of the vast factual material of the mineralthermal study of inclusions in minerals the thermal conditions of evolution of the formation processes of the well-known Tyrnyaus skarn - ore (W, Mo) field is considered. According to 2,000 records of the aggregate state of inclusions there have been singled out their morphogenetic types. There is also given an interpretation of 3,000 temperature measurements of decrepitation and homogenization of the inclusions, in the translucent (pyroxenes, garnets, vesuvianite) and ore (molybdenite, sphalerite, pyrite) minerals, in particular.

The formation of hornfels close to skarn and skarns correlating to the early alkaline stage (according to D.S. Khosdsinoky) [sic] and concluding by the deposition of iron pyroxene and garnets together with molybdoscheelite, scheelite and magnetite (wollastonite → diopside → grossularite → vesuvianite → salite → hedenbergite → molybdoscheelite + scheelite → magnetite + andradite) originates in the range of average temperatures 750-400-350°C. Iron pyroxenes and garnets of the late stages of skarns, hedenbergite, and andradite crystallize at temperatures not higher than 600°C (for pyroxene) and 550-500°C (for garnets). In the late pyroxene and garnet inclusions there are usually present ore "prisoner - minerals [i.e., daughter minerals, Ed.]

The next acid stage, manifested in the deposition of the quartz-feldspathic metasomatite formation (pyroxene + garnet + molybdenite quartz quartz + molybdenite) [sic] is characterised by the range of average temperatures 600-250°C. Barren quartz, isolated in the maximum acid conditions, contains a lesser number of "prisoner" [daughter] - minerals than quartz of the up - and - down - going branches (according to pH value). [sic].

The products of the late alkaline stage (propylites of sulphide zones) are represented by successive associations of pyrite, copper-polymetallic and antimony (pyrite + arseno-pyrite + chalcopyrite + pyrrhotite → chalcopyrite + pyrite + sphalerite + galenite → antimony minerals). Their formation takes place under gradually lowering solution temperatures - 450-350-250°C → 220-80°C.

The study of mineral-forming solution temperature was carried out with the help of some original apparatus and methods, for example, in the homodecrepitation chamber at long-wave infrared for molybdenite and antimonite.

Taking into account the distribution features of the admixture - elements there have been pointed out their characteristic associations in the skarns of the early and late stages, in mineral associations of the quartz-feldpathic metasomatites and the late sulphide ores.

The determined succession in the change of the thermal regimes of the ore - mineral paragenses proves that their formation bases on the common flow of solutions, which develops in time on the background of ever changing acid-alkaline and thermal conditions. (Author's abstract).

ROEDDER, Edwin, 1971a, Fluid-inclusion evidence on the environment of formation of mineral deposits of the Southern Appalachian Valley: Economic Geology, v. 66, p. 777-791. Note: This is the full text of a paper given previously only as an abstract (Roedder, 1969, Fluid Inclusion Research - Proceedings of COFFI 1969, p. 65) with minor changes and updating. (E.R.)

ROEDDER, E., 1971b, Discussion of "Chloride-rich brines from sabkha sediments and their possible role in ore formation", by P. R. Bush: Inst. Mining and Metallurgy Trans., Sect. B., v. 80, Bull. 771, p. B61.

Certain of the mechanisms proposed by Bush do not agree with evidence from fluid inclusion studies. (E.R.)

ROEDDER, E., 1971c, Fluid Inclusions (abst.): Upper Mantle Project, U.S. Program Final Report, p. 207-208, Natl. Acad. Sci., July, 1971.

A brief review of five published papers on fluid inclusions that are pertinent to the Upper Mantle Project. (E.R.)

ROEDDER, E., 1971d, Fluid inclusion studies on the porphyry-type ore deposits at Bingham, Utah; Butte, Montana; and Climax, Colorado: Econ. Geology, vol. 66, p. 98-120.

Data are given on the composition, temperature, pressure, and density of the hydrothermal fluids present in the central Cu-Mo core of the deposit at Bingham, Utah, and in its related but not necessarily coeval peripheral Pb-Zn deposits. These data are based on a study of primary and secondary fluid inclusions in transparent ore and gangue minerals that included the use of freezing, heating, and crushing microscope stages.

The composition of the hydrothermal fluids at various stages in the mineralization and repeated later fracturing and rehealing ranged from nearly fresh water to water containing more than 60 weight percent salts in solution -- virtually a hydrous saline melt -- in some quartz-molybdenite-chaclopyrite veins from the core. Most of these salts have crystallized out as daughter minerals on cooling, forming major amounts of halite and sylvite and minor amounts of anhydrite (?), hematite (?) and several unidentified phases. These highly saline fluids occur only in the core. Some of them have apparently boiled, forming bubbles of a relatively low density CO_2-rich "steam" containing only a few percent NaCl. These low-density fluids have also been trapped as inclusions. The fluids that formed the peripheral deposits had low salinities, and some of these also have apparently boiled. A few were very high in hydrogen sulfide.

Inclusions from a quartz pod and in the quartz-molybdenite-chalcopyrite veins from the core yield the highest temperatures, 640°-725°C; most inclusions from the core homogenize at temperatures above 400°C. Samples from the peripheral deposits were uniformly lower, in the range 294°-330°C.

The abundant evidence of intermittent boiling of these solutions is important because it places limits on the pressure at the time of trapping, it results in there being little or no need for a pressure correction to the homogenization temperatures, and it indicates that the pressure has varied with time. Although some of the homogenization temperatures are very high, the high salinity causes the vapor pressures at homogenization to be relatively low, from about 80 to a maximum of about 1,100 atmospheres.

The density of the hydrothermal fluids is of great concern in any consideration of flow patterns, and particularly in the inevitable mixing with possibly heated ground waters. Steam inclusions from the core had gross densities of 0.3 to 0.1 $g \cdot cm^{-3}$, but many of the highly saline inclusions in the core contain fluids whose density at trapping was as high as 1.3 $g \cdot cm^{-3}$. The fluids trapped in inclusions in the peripheral deposits had densities of 0.75-0.95 $g \cdot cm^{-3}$, well below that of the surrounding cold ground water. Hydraulic pressure gradients from these density differences, and the vapor pressures involved, must also have varied with time in any given location, particularly when boiling occurred, and thus the circulation patterns could have been very complex. The more highly saline fluids are believed to be of truly magmatic origin, and not merely heated ground water from the area at the time of the intrusion.

The great abundance throughout the core of planes of secondary inclusions in which individual planes are uniform but adjacent planes have widely varying composition, density, and homogenization temperature, is evidence of thorough and repeated fracturing of these rocks under hydrothermal conditions.

Inclusions were also examined in some samples from Butte, Montana, Climax, Colorado, and several Arizona porphyry copper deposits. The ranges of temperature, composition, and density found were similar but smaller than at Bingham. This might be simply a result of insufficient sampling.

ROEDDER, Edwin, 1971e, Metastability in fluid inclusions: Soc. Mining Geol. Japan, Spec. Issue 3, p. 327-334 (Proc. IMA-IAGOD Meetings '70, IAGOD Vol.)

Fluid inclusions in minerals are exceedingly small chemical systems, very effectively isolated from their surroundings. As a result, they frequently exhibit metastable equilibria, generally from lack of nucleation of those stable phases that should form after some change in conditions. Metastability may persist over extensive ranges of temperature, pressure, and geologic time. Metastability in natural fluid inclusions as found, provides several types of otherwise unobtainable data (such as on cooling rates), and metastability induced by laboratory conditions can also provide useful information. If not recognized, both varieties of metastability can, and frequently do lead to erroneous conclusions.

The most common and potentially useful types of metastability result from the failure to necleate: (1) a vapor bubble or daughter crystals on cooling, (both in melt and aqueous inclusions); (2) ice or other crystal phases on cooling aqueous inclusions below room temperature; and (3) a vapor bubble on heating frozen aqueous inclusions.

Other, laboratory-induced nonequilibrium conditions, particularly from sluggish mixing in frozen aqueous inclusions that became stratified during melting, or sluggish solution of daughter minerals at high temperatures, can cause experimental difficulties but have no known compensating usefulness.

As long as an assemblage remains static, there is no valid criterion for determining if it is stable or metastable. If, however, there are differences in behavior of otherwise similar inclusions, or a given inclusion behaves differently in sequential but apparently duplicate experiments, metastability may be involved. Any sudden or irreversible phase change other than from leadage in an inclusion under constant temperature conditions signifies that the former assemblage was metastable. (Author's abstract)

The abstract for this paper was first published in 1970 - see Fluid Inclusion Research, 1970, vol. 3, p. 60 (Ed.)

ROEDDER, Edwin, 1971f, Natural and laboratory crystallization of lunar glasses from Apollo 11: Mineral. Soc. Japan. Spec. Pap. 1, p. 5-12 (Proc. IMA-IAGOD Meeting, '70, IMA Vol.)

Note: this is the full text of a paper given previously only as an abstract (Roedder 1970b Fluid Inclusion Research, v. 3, p. 60-61, 1970.)

ROEDDER, Edwin, 1971g, [Fluid inclusions] (abstr.): U.S. Geological Survey Prof. Paper, 750A, Geol. Survey Research, p. A113.

A partial abstract of material on the crushing stage, presented in full in Roedder, 1970c, Fluid Inclusion Research, v. 3, 1970, p. 61. (E.R.)

ROEDDER, Edwin, 1971h, [Fluid inclusions from Ascension Island] (abstr.): U.S. Geol. Survey Prof. Paper [Geological Survey Research] 750A], p. A119.

An abstract of material presented in full in a 1970 Russian volume (see Roedder, 1970d, Fluid Inclusion Research, v. 3, 1970, p. 61-62). (E.R.)

ROEDDER, Edwin, & KVENVOLDEN, K.A., 1971, [Nature of organic matter in fluid inclusions] (abstr.): U.S. Geol. Survey Prof. Paper 750A, Geol. Survey Research, p. A123.

An abstract of material given in full in Kvenvolden and Roedder, 1971 (this issue). (E.R.)

ROEDDER, Edwin, and P.W. WEIBLEN, 1971a, Petrology of silicate melt inclusions, Apollo 11 and Apollo 12 and terrestrial equivalents, In Lunar Science Conf., 2d, 1971, Proc., v. 1, Geochimica et Cosmochimica Acta Supp. 2, Cambridge, Mass., MIT Press, p. 507-528.

Early (high temperature) 5-50 μm inclusions occur in lunar olivine, from the trapping of originally homogeneous silicate melt. The smaller ones now consist of glass plus a shrinkage bubble, but the larger ones have crystallized in part on cooling to form ilmenite, plagioclase, and pyroxene as "daughter minerals." Reheating such olivine grains in vacuum at progressively higher temperatures, with repeated quenching and examination, established a sequence of phase changes for these olivine-saturated assemblages: first recognizable liquid < 1065°C; plagioclase out, 1103 ± 3°C; pyroxene out, 1130 ± 5°C; ilmenite out, 1210 ± 5°C. The ilmenite and plagioclase daughter crystals occur as flat plates, "epitaxially" oriented parallel to (100) of the enclosing olivine. These were thought to be unique until apparently identical epitaxial daughter crystals were found in melt inclusions in olivine from Hawaii. Experiments on such inclusions provide rough estimates of lunar and terrestrial lava temperatures and cooling rates. After homogenization, these inclusions provide excellent samples for probe analyses of the melt that was trapped.

Late (low temperature) melt inclusions in lunar rocks show that when these magmas were 90%-98% solid, the residual liquid split into two immiscible melts which, in part, were quenched to glasses of grossly different color, index, and composition. Probe analyses show normative compositions similar to ferropyroxenite and potassic granite. The latter differs from granitic melts formed by crystal fractionation, e.g., in distribution of phosphorous. The discovery of immiscibility was also thought to be unique to lunar rocks until similar evidence of immiscibility was found in samples of Hawaiian, Modoc, Disko, and upper Precambrian basalts. In these rapidly cooled rocks, the immiscible liquids are retained as isolated globules. Under conditions of slower cooling, as in the early history of the earth or moon, significant separation of liquids might have occurred.

ROEDDER, Edwin, & WEIBLEN, P.W., 1971b, [Petrology of lunar rocks] (abstr.) U.S. Geol. Survey Prof. Paper 750A, Geological Survey Research, p. A190.

An abstract dealing with the material presented in full in Geochim. Cosmo. Acta Suppl. 2, 1971 (see above). (E.R.)

ROEDDER, Edwin. and WEIBLEN, Paul W., 1971c, Silicate melt inclusions and glasses in lunar soil fragments from the Luna 16 core sample: Earth and Planetary Science Letters, v.13, pp. 272-285.

More than 2000 fragments were studied microscopically, and electron microprobe analyses were made of 39 selected areas, from a few square mm of polished surface, through 75- to 425-μm fragments of lunar soil from two samples of the Luna 16 core. The silicate melt inclusions and glasses differ in important details from those observed earlier in the Apollo samples. Melt inclusions in olivine contain epitaxially oriented daughter crystals, but also show a similar epitaxy around the outside of the crystals not observed in previous lunar samples. Melt inclusions in ilmenite suggest trapping at successive stages in a differentiation sequence. There is abundant evidence for late-stage silicate liquid immiscibility, with melt compositions similar but not identical to those from Apollo 11 and 12. A comparison of the alkali ratio of any given bulk rock analysis with that of its late-stage, high-silica melt shows gross differences for different rocks. This is pertinent to understanding late-stage differentiation processes. Glass fragments and spherules exhibit a wide range of crystallization textures, reflecting their wide range of compositions and cooling histories. No significant differences were found between the two portions of core examined (Zones A and D). (Authors' abstract)

ROGOVA, V. P., NIKITIN, A. A. & NAUMOV, G. B., 1971, Mineralogic-geochemical conditions of the localization of uranium-molybdenum deposits in volcanogenic sedimentary formations (abst.): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 1, p. 374-375 (in English) (Authors at Ministry of Geology of the USSR, V.I. Vernadsky Institute of Geochemistry and Analytical Chemistry, USSR Academy of Sciences, Moscow).

1. [The] uranium-molybdenum ores [are] localized in various stratigraphic levels of volcanogenic sedimentary formations consisting of nappes of basic, intermediate and acid effusive rock alternating with the layers of sedimentary-pyroclastic rocks, and in the granites also.

The first stages of hydrothermal alteration considerably level mineralogic-geochemical differences of primary volcanogenic sedimentary formations. The chemical and physico-mechanical properties of the altered rocks govern the distribution of ore and vein minerals.

2. Pitchblende is found to form several generations in various paragenetic associations.

Metasomatic pitchblende in the enclosing rocks is associated with hydromica and chlorite accompanied by hematitization of the first. It forms mainly the molybdenum-free uranium ore bodies. In veins and breccias the pitchblende is associated with drusy quartz, ankerite, fluorite and ore mineral-molybdenite, galena, native copper and chalcopyrite. There are coarse and fine spherulites of this pitchblende.

Pitchblende generations differ in cell lattice parameters and the oxygen coefficient.

Generation	Cell parameter, A°	Oxygen coefficient
Metasomatic	5.38-5.40	2.49-2.59
Coarse spherulite	5.40-5.41	2.43-2.46
Fine spherulite	5.43	2.32

3. In the course of the hydrothermal process the temperature changes from 300-250°C to 50°C. Ores were formed at a temperature of 200-150°C. Hydrothermal solutions were characterized by a high content of carbon dioxide-up to 100 g CO_2/kg H_2O.

Three-phase inclusions with liquid carbon dioxide found in some minerals (quartz and others) suggest a minimal partial pressure of carbon dioxide in the solutions of the moment of mineral formation which is equal to 800-1000 bars.

Thus, the pressure in the hydrothermal solutions reached values of hundreds of bars, the latter considerably exceeds the value of lithostatic pressure. The deposition might be caused by the variation of pressure, by the loss of carbon dioxide and by reaction with the wall-rocks. (Authors' abstract).

RUB, M. G., 1971, The role of gaseous phase during the formation of ore-bearing magmatic complexes (abst.): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 1, p. 47-49 (in English) (Author at Institute for Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry, Moscow, USSR).

1. The content of volatiles and in particular that of fluorine in the rocks of rare-metal, tin-bearing, and tungsten-bearing complexes are usually 2-3 that of fluorine in acid rocks. The abrupt increase in the fluorine content is usually observed in the most acid differentiates of these complexes. The variance of fluorine content grows in the same direction. E.g., the coefficient of variation in the rocks of early phases does not exceed 60, while in the late differentiates it amounts to 100-120.

2. The direct correlation is observed in ore-bearing magmatic complexes between the abundances of ore elements (Sn, Ta, Be, etc) and

volatile components in rocks and rock-forming minerals. In the ore-bearing and rare-metal granites of Near-Khankay district the correlation coefficient between the tin and fluorine contents in rocks is equal to 0.82, while that for the concentrations of these elements in biotites of these granites is 0.88.

3. The volatile components in ore-bearing complexes are present not only in the accessory and coloured rock-forming minerals, but also in quartz (in fluid inclusions). The concentrations of fluorine in biotites and quartzes increase from the granites of early phases to the latter ones, which testifies to the magmatic and not assimilation genesis of this element and its accumulation in the residual magmatic melt. Fluorite-bearing lavas with peculiar spherical structures investigated by the author in Maritime Territory provide an excellent example of the extreme enrichment of magmatic melt in volatile components.

4. It is demonstrated on an example of certain ore regions of the Pacific belt that the investigation of the composition of fluid inclusions in the rock-forming minerals of granites and accompanying postmagmatic formations along with the other facts permits solution of the problem concerning the specialized magmatic complexes, the character of their connection with ore-mineralization, and the composition of ore-forming solutions. Thus, elevated fluorine contents were established in the quartz of ore-bearing granites and in quartz from the associated postmagmatic formations. The fluorine content in gaseous-liquid inclusions from the quartz of these granites (from the data on aqueous leachates) is equal to 0.50-0.54 per cent which is 12-15 times as large as the average fluorine content in the quartz of these granites.

5. Protolithionate granites found at the East Territories which are markedly enriched in fluorine point to the great importance of volatile components during the formation of rare-metal magmatic complexes.

6. The investigation of the behaviour of volatile elements in magmatic and associated postmagmatic formations of Near-Khankay district suggests that fluorine was present in magmatic melt from the very beginning of the formation of palyngenetic granitic magma and it is related to some deep-seated source, while boron was incorporated in magma during the advancement of the front of magma formation due to the involvement of arenaceous-pelitic sediments rich in boron in this process. In accord with this assumption the ore-bearing granites of certain regions and associated post-magmatic formations are enriched in both fluorine and boron. In other regions boron is related to the deep-seated source as well. (Author's abstract).

RUCHKIN, G.V., & DEMIN, Yu. I., 1969, Some questions about the genesis of chalcopyrite ore deposits in the Blyavinsk ore field: "Sovetskaya Geologiya", 1969, no. 1, (as quoted in Bogoyavlenskaya, et al., 1971, in this volume.)

RYABCHIKOV, I.D., & KHAMILTON, D.L., 1971, Possible separation of concentrated chloride solutions during crystallization of felsic magmas: Akad. Nauk SSSR, Doklady, v. 197, no. 4, p. 933-935 (in Russian); trans. in Doklady Acad. Sci. USSR, Earth Sci. Sect. v. 197, p. 219-220, 1971.

A brief experimental study of part of the system "sodagranite" - water-NaCl, at 1 kb and an unstated range of temperatures, indicating the coexistence of two fluid phases (a dense gas and a NaCl-rich melt) with the silicate melt at "various temperatures" above the solides. These two fluids are trapped as inclusions in the silicate melt. (E.R.)

RYABOV, V.V., 1969, Petrography of the Makansk ore field and the conditions of formation of chalcopyrite ore: Avtoref. Kand. Diss., M., 1969. (Sic., as quoted in Bogoyavlenskaya, et al., 1971, in this volume).

RYE, Robert O., and HALL, Wayne E., 1971, Carbon, hydrogen, oxygen, and sulfur isotope study of the Darwin silver-lead-zinc deposits, Southern California (abst.): Econ. Geol., v. 66, p. 1269

The isotopic compositions of carbon and oxygen in calcite, sulfur in ore minerals, and hydrogen in water in fluid inclusions were determined to help clarify the origin and history of the ore-forming fluids. The similarity of the results from the Darwin deposits to those previously obtained from the Providencia and Casapalca ore deposits suggests fundamental controls for certain types of post-magmatic ore deposits.

The δC^{13} values of the hydrothermal calcites range from -3.6 to -5.8‰ (PDB). These values indicate that most of the hydrothermal CO_2 was not from the limestone host rocks but from deeper seated sources rocks.

The δO^{18} values of the calcite, when combined with probable depositional temperatures, suggest an average δO^{18} of 5±3‰ (SMOW) for the hydrothermal fluids in areas of pyrite-rich sulfide assemblages and + 7‰ for the fluids in areas of pyrrhotite-rich sulfide assemblages. These variations are consistent with geologic observations regarding the probable channelways for the ore fluids at Darwin.

The δD values of water in fluid inclusions in sphalerite range from -62 to -70 ‰ (SMOW) and are compatible with a magmatic origin for the hydrothermal fluids.

The δS^{34} values of all sulfides range from + 4.4 to - 5.7‰. The differences in δS^{34} values for galena and sphalerite from a given assemblage are very consistent and indicate that these minerals were almost always deposited in equilibrium at temperatures averaging 330°C. The data indicate that the δS^{34} of the hydrothermal sulfur was close to +1‰ and that the range of δS^{34} values reflects variations of P_{O_2} and pH in the hydrothermal fluids, which resulted in the deposition of pyrrhotite instead of pyrite in certain areas of the mine. (Authors' abstract, corrected for typographical errors by R.O.R.)

SAMOILOVICH, L. A. & KHETCHIKOV, L. N., 1971a, Experimental data on the correlations between pressure, temperature, density and composition of the mineral-forming solutions (abst.): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 1, p. 297-299 (in English) (Authors at All-Union Institute of Mineral Synthesis, Alexandrov, USSR).

1. Salt components of hydrothermal solutions often consist of chlorides, sulphates and carbonates of the alkaline and of the alkali earth elements. Carbon dioxide, hydrogen sulphide and ammonia prevail as active gases of hydrothermal processes. The basic parameters of the mineral-forming solutions - pressure (P), temperature (T), density (F) and composition (X) are codependent.

We have accomplished an experimental study of the P-T-F-X correlations in a number of solutions (more than 700 experiments) including solutions of chlorides of sodium, potassium, lithium, calcium, that of carbonates and sulphates of sodium, potassium and of their mixtures. A natural solution of low concentration taken from a deep well was studied as well as an artificial chloride-carbonate-sodium-potassium solution whose composition was equal to that of the fluid inclusions in quartz. Furthermore, studies were made to investigate chloride, carbonate, and sulphate sodium solutions, containing carbon dioxide (up to 3% by weight), ammonia (up to 18% by weight) and hydrogen. The measurement limits were as follows: T-from 160-500°C, P-from 10 to 1500 kg/cm^2, salt component concentration - not more than 20% by weight:

The above parameters embrace heterogeneous (liq. + gas) and homogeneous (liquid) regions and correspond to the parameters of the hydrothermal processes. All the experiments were conducted in isochoric conditions after the specially elaborated technique.

2. Tables and diagrams were drawn to show the correlations between pressure, temperature, density and composition of the mentioned solutions.

3. The continuous rise of the temperature of transition the heterogeneous systems (T hom.) into the homogeneous liquid state with an increase in salt concentration is demonstrated. Volatiles, on the contrary, reduce the T hom. This temperature is lower for aqueous solutions of sodium and potassium chlorides (max. 3-4°C) than that for their sulphates, other conditions being equal. And it is higher for the solution having potassium cation than that for the solution with sodium and lithium cations, if

one takes a 1-1 valent electrolyte [sic] with the same Cl anion.

The "lifting" effect of the potassium cation is equally proved for the 1-2 valent electrolytes (sulphates and carbonates). Calculations made for the salt partial molar volumes (V) in the aqueous chloride solutions showed that the higher V is that of a potassium chloride.

4. A presence of volatiles in the homogenous liquid region shifts the isochors to the lower temperature side, while the salt components produce a reverse effect. The value of the shift depends on the nature of the dissolved substance. The volatiles in heterogenous as well as in homogenous conditions lift considerably the pressure in the system, other conditions being equal.

5. Questions of practical application of the results obtained are now being discussed. Particularly it would be important in the synthesis of minerals, in the estimation of possible use of the mineral fluid inclusions as geological thermometers and barometers and in studies of the thermobaric environments during the evolution of hydrothermal solutions. (Authors' abstract).

SAMOILOVICH. L. A. and KHETCHIKOV, L. N., 1971b, Dependence of temperatures of disappearance of gas phase in closed volumes on the concentration of non-volatile components in solutions of some electrolytes, in Investigations of mineral-forming solutions and melts in inclusions in minerals, N.P. Ermakov and L. N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 149-153 (in Russian).

The relationship between the temperature of disappearance of the gaseous phase (homogenization temperature) and the concentration of the salt and the degree of fill of the sealed system by the liquid phase at temperatures up to 400°C was investigated experimentally for the following salt-water systems: sodium, potassium, calcium, and lithium; chlorides, sodium and potassium; carbonates and sodium hydroxide.

The homogenization temperature increased continuously with an increase in the concentration of the non-volatile component of the solutions; moreover, the lower the degree of fill of the system by the liquid phase, the greater the increase in the homogenization temperature. A change in the composition of the solutions had a much less noticeable effect on the homogenization temperature. (S. Theokritoff)

SANIN, B. P., 1971, Geochemical particularities of polymetal deposits depending on the ore-matter sources (abst.): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 1, p. 257-258 (in English) (Author at Geochemistry Institute, Siberian Branch, Academy of Sciences, Irkutsk, USSR).

On the territory of Eastern Transbaikalia [covered] by Mesozoic [deposits] two groups of polymetallic deposits with different [origins] are distinguished.

The deposits of the first group are of the skarn-polymetallic type and genetically related to the granitoids of the Kukulbeisky complex. Pb-Zn deposits of the second group are connected with acid intrusive differentiates of alkaline gabbroids completing the Upper-Jurassic magmatism in Priargun.

These groups of polymetal deposits differ in many mineral-geochemical features.

The analysis of the chemical composition of gas-liquid inclusions shows that the hydrothermal solutions forming the deposits of the second group are enriched in Na and Cl ($\frac{Na^+}{K^+} = 2$; $\frac{Cl^-}{F^-} = 20$) compared with the solutions forming the deposits of the first group ($\frac{Na^+}{K^+} = 1$; $\frac{Cl^-}{F^-} = 5$). In the highest-temperature deposits of the skarn-polymetallic type the hydrothermal changes of enclosing rocks are expressed by greisens, skarns, the high-temperature propylization and silicification. At the deposits of the second group the enclosing rock changes are characterized by dolomitization, serpentinization, silicification, beresitization, argillization and kaolinization.

These groups of polymetallic deposits differ sharply in rare-element composition. The geochemical particularities of the skarn-polymetallic type are expressed in the element spectrum which is characterized by Li, Be, Nb, Ta, Sn, low quantities of In, Ga, Tl, Hg and the sharp differentiation of Pb and Zn in the vertical profile.

The second-group deposits have high contents of As, Sb, Ag, Cu, Hg, Tl, In, Cd along the whole ore-forming interval. The relation with the derivatives of the basic magma is stressed by high concentrations of Ni, Co, V, Cr, Bi, Sn in pyrites and arsenopyrites of the early mineral formation stage.

Peculiarly different is the element content in sphalerites. In sphalerites from the second-group deposits the concentration of Hg and Sn is nearly 1000 times, and Sb and As 100 times higher than those of the skarn-polymetallic type. (Author's abstract).

SANTOS, A., 1968, La Esmeralda: Madrid, Instituto Gemologico Espanol, 121 pp (in Spanish).

Includes one chapter (IX) on inclusions in emerald, with 40 color photographs of various solid and liquid inclusions and 4 pages with text. (E.R.)

SATO, Motoaki, 1971, Electrochemical measurements and control of oxygen fugacity and other gaseous fugacitites with solid electrolyte sensors, Chapter 3 in Research Techniques for High Pressure and High Temperature, ed. G.C. Ulmer: New York, Springer Verlag, p. 43-99.

A thorough review of the literature (58 references) and of the author's own work on theory and practice of such measurements; of pertinence to all investigations of magmatic inclusions and the fo_2 and fs_2 under which they were trapped. (E.R.)

SAWKINS, Frederick J. and RYE, Robert O., 1971, Fluid inclusion and stable isotope studies of the Casapalca silver-lead-zinc-copper deposit, Central-Andes, Peru: Soc. Mining Geol. Japan, Spec. Issue 2, p. 163 (Proc. IMA-IAGOD Meetings '70, Joint Symp. Vol)

The extensive Casapolca vein system occurs in Tertiary redbeds and volcanics and has produced about 10 million tons of ore. The deposits contain primarily pyrite, sphalerite, galena and tetrahedrite, accompanied by quartz and minor calcite gangue; vugs are common in many parts of the vein system. Quartz was precipitated throughout the period of sulfide deposition, but calcite deposition was restricted to the late and final stages of hydrothermal activity.

Studies of fluid inclusions in quartz, sphaleite, and calcite crystals indicate that ore deposition took place over the temperature range 370-280°C, by hydrothermal solutions whose salinity varied erratically from 4-40 equivalent weight percent NaCl. The distribution of vapor phase inclusions in main stage minerals indicates sporadic "boiling" of the hydrothermal fluids. The temperature data suggest a progressive drop in temperature with time, but preclude the existence of sharp temperature gradients within the vein system during mineralization.

Stable isotope measurements on vein minerals indicate a deep source of sulfur (δS^{34} values of sphalerite range from -0.4 to +1.2%) and for hydrothermal carbon in earliest calcite (δC^{13} values range from -9.9 to -7.2% (PDB)), and a very uniform high temperature silicate source (δO^{18} of hydrothermal solutions range from +7 to +8% SMOW).

δD values from inclusions in sphalerite range from -51 to -65%, distinctly different from the -118 and -144% average values obtained respectively from present day local meteoric waters and from inclusions in post-sulfide calcites. The stable isotope data imply a deepseated origin for the main stage inclusion fluids, and that mixing with ambient meteoric waters was restricted to the final stages of hydrothermal activity. (Authors' abstract)

The abstract for this paper was first published in 1970 - see Fluid Inclusion Research, 1970, vol. 3, p. 66 (Ed.)

SCHUBNEL, Henri-Jean, and ZARKA, Albert, 1971, X-ray topography of a natural emerald and a synthetic emerald: Jour. Gemmology, v. 12, no. 7, p. 300-304.

X-ray topographs show details of growth irregularities (which probably are also related to fluid inclusion trapping - Ed.)

SCOTT, S.D., & O'CONNOR, T.P., 1971, Fluid inclusions in vein quartz, Silverfields mine, Cobalt, Ontario: Can. Miner. v. 11, part 1, p. 263-271. Authors at Department of Geology, University of Toronto, Toronto 5, Ontario.

A reconnaissance study of primary (?) fluid inclusions in quartz from the principal ore veins of the Silverfields mine near Cobalt, Ontario has revealed four types of inclusions containing various combinations of vapour, liquid, and a halite crystal as follows: I (liquid only), II (liquid + halite crystal), III (liquid + vapor), and IV (liquid + vapor + halite crystal). Repeated chilling and thawing induced nucleation of the vapor phase in types I and II, but did not precipitate a halite crystal in types I and III. The anomalous behaviour of types I, II and III is thought to be due to metastability caused by the very small size of the inclusions (< 10 microns).

Heating experiments show that the included brines contain >30 wt % NaCl. There are two distinct populations of filling temperatures with median values of 165°C and 250°C, but only one population is found in a sample. Depositional temperatures of the two quartz populations, corrected for confining pressures of 400 to 1200 atm as estimated from geological evidence, range from 195° to 260°C and 285° to 360°C. (Authors' abstract)

SERGEEVA, E.I., NAUMOV, V.B., and KHODAKOVSKIĬ I.L., 1971, Conditions of formation of arsenic sulfides in hydrothermal deposits, in Geochemistry of hydrothermal ore formation, ed. by V.L. Barsukov: Moscow, Izdatel. "Nauka", p. 210-222, (in Russian).

Some inclusions with liquid CO_2 are reported in natural realgar and orpiment with homogenization of the CO_2 at 23.9-30.0°C, indicating a low pH and high CO_2 pressures. (E.R.)

SHEPPARD, S.M.F., NIELSEN, R.L., & TAYLOR, H.P., Jr., 1971, Hydrogen and oxygen isotope ratios in minerals from porphyry copper deposits: Econ. Geol., v. 66, p. 515-542. Authors at Div. Geol. Sciences, Calif. Inst. Tech., Pasadena, Calif., 91109.

The O^{18}/O^{16}, D/H and C^{13}/C^{12} values, where applicable, were measured on quartz (40 samples), K-feldspar (12), biotite (16), sericite (23), and calcite (7) from potassic, sericitic and argillic alteration assemblages and from fresh igneous rocks and veins in 9 North American porphyry copper and molybdenum deposits, and in 4 other hydrothermal mineral deposits. The porphyry copper deposit at Santa Rita, New Mexico was sampled in detail.

Both sericites and biotites appear to preserve their O^{18}/O^{16} and D/H values, as these isotope ratios are not affected by later low-temperature exchange with local ground waters. A systematic correlation is, however, observed between the D/H ratios of sericites (and clays) from most Tertiary porphyry deposits and those of meteoric ground waters; this requires the presence of a significant meteoric water component in the hydrothermal fluids involved in sericitization (and argillization). In contrast to the sericites, the very restricted range of D/H ratios of biotites from Bingham, Ely and Santa Rita (-74 ± 10‰) indicates the probable dominance of magmatic waters in the fluids associated with biotite alteration. The oxygen isotope data for the quartz-K-feldspar-biotite-chalcopyrite assemblages also support a high temperature of formation in the presence of waters with δO^{18}-values in the magmatic water range. However, at the Butte deposit meteoric waters were apparently associated with the early biotitization.

Many problems are associated with the application of isotopic geothermometers to the alteration assemblages because of the general presence of: (1) retrograde exchange, especially of the K-feldspars, (2) isotopically heterogeneous minerals, such as quartz of different origins, that are intimately intergrown and thus difficult to separate physically, and (3) the common lack of independent criteria for recognizing isotopic equilibrium. In the quartz-sericite assemblage the δO^{18} of the igneous quartz is preserved and is different from that of quartz precipitated during the sericitization processes.

The Santa Rita isotopic data are discussed in terms of two simplified end-member models to evaluate the importance of temperature variations relative to variations in the O^{18}/O^{16} ratio of the hydrothermal fluids; both types of variations are probable. Calculated temperature ranges for the combined models are 580° to 390°C for potassic alteration (note that these orthoclases are very K-rich, Or_{90-96}), and 390° to 285°C for sericite alteration, with δO^{18}-water ranging from 7.3 to 3.9 per mil. Similar "temperatures" for sericite formation were obtained independently by direct isotopic analysis of some quartz-sericite assemblages, utilizing the quartz-muscovite O^{18}/O^{16} geothermometer.

C^{13}/C^{12} values of hydrothermal vein carbonates in the porphyry copper deposits (δ= -2.6 to -5.9) tend to be a little heavier than primary igneous calcites from carbonatites (which typically have δ= -5 to -8‰).

The similarities between the isotopic variations in the calculated hydrothermal waters associated with sericitization and argillization and those of saline formation waters of North America suggest that heated Na-Ca-Cl brines originally present in the neighboring sedimentary and volcanic sections may be an important component of the hydrothermal fluids. The quantities of meteoric ground water that have interacted with the hot igneous stocks of the porphyry ore deposits, though very signigicant, are much smaller than the amounts involved in the vein systems at Butte and in many epizonal Tertiary igneous intrusions emplaced into permeable volcanic country rocks. (Authors' abstract)

SHILO, N.A., et al., 1971, Temperature conditions and the depths of formation of gold-ore deposits: Soc. Mining Geol. Japan, Spec. Issue 3, p. 356-359 (Proc. IMA-IAGOD Meetings '70, IAGOD vol.)

This is the full paper covering the material abstracted under a somewhat different title in Fluid Inclusion Research, v. 3, 1970, p. 67-68. (E.R.)

SHUGUROVA, N. A., 1971, Gas phase composition of individual inclusions in minerals (abst.): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 1, p. 295-296 (in English) (Author at Institute of Geology and Geophysics, Siberian Branch of the USSR Ac. Sci., Novosibirsk, USSR).

Improvements achieved in the methods of ultramicrochemical analysis of the gas phase composition of individual inclusions in minerals with separate determination of the seven gas components (H_2S, SO_2, NH_3, HCl, HF), CO_2; hydrocarbon, O_2, CO, N_2 + rare gases based on their selective absorption combined with cryometric and thermometric methods enabled one to estimate conditions of mineral formation and the dynamics of variations in the gas composition in time.

Checking of the methods performed on artificial crystals has proved its high reliability and sufficient accuracy thus permitting their practical use. The studies carried out be the author on the gas phase composition of inclusions in natural minerals of different genesis with varying conditions of formation indicated their universality (also the possibility of application of these methods to the study of inclusions in all varieties of most common minerals).

It seems possible to characterize the composition of the most important gases typical of magmatic, pneumatolytic and hydrothermal processes as follows:

1. Carbon dioxide and nitrogen + rare gases, with predominance of one of the components are most typical for the magmatic mineral formation.

2. Variations in the composition of the gas phase is typical for the processes of pegmatitic and pneumatolytic mineral formation. The leading

role in the composition of volatiles also belongs to carbon dioxide.

A direct correlation has been established between the carbon dioxide content in the gas phase of inclusions and the temperature of mineral formation.

3. CO_2 is also typical for the inclusions in minerals of hydrothermal genesis formed at lower temperatures. However, the predominant role in the gas composition is played by nitrogen and oxygen (like in the atmospheric air). (Author's abstract).

SIDOROV, A.A., 1969, Thermobaric geochemistry of endogenic mineral formation and perspectives for its development in northeastern SSSR: Kolyma, 1969, no. 12. (Sic., as quoted in Bogoyavlenskaya, et al., 1971, in this volume).

SIDOROV, A. A., GONTCHAROV, V. I., NAIBORODIN, V. I., 1971, Thermobarogeochemistry of the deposits of gold-silver formation (abst.): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 1, p. 382-383 (in English) (Authors at North-Eastern Complex Scientific-Research Institute, Magadan).

Deposits of the gold-silver type are most typical of the volcanogenic class of hydrothermal deposits. They are associated with the metasomatites of carbonate-chlorite and adularia-quartz composition. The formation of the deposits took place near the surface, the conditions being characterized by abrupt pulsating changes of physico-chemical parameters. The rapid separation of the gas-steam phase, the supersaturation of the solutions, their transition to the colloidal state and the formation of the ores with specific structural-textural peculiarites are common phenomena for these deposits. It was found that the mineral-forming process was characterized by a wide temperature interval and relatively low pressure. Three types of deposits were distinguished from studying inclusions in the minerals.

Types of deposits	Temperature C°	Pressure atm.	Max. depth of formation
High-temperature	450-230	280-25	1400
Middle-temperature	360-50	190-25	900
Low-temperature	270-80	85-5	500

The middle temperature conditions of the mineral formation (300-200°) are the most typical for all deposits. The relatively high temperatures of the solutions at small depths are caused by their conjugation with volcanic and matasomatic processes (high gradient of temperatures, exothermal reactions). Interstadial inversions of temperatures, exothermal reactions). sic Interstadial inversions of temperatures up to -150° and pressures - to 180 atm are common. The rapid change of pressure as the result of joint formation is the cause of ore deposition from the superheated hydrothermal solutions. The mode of formation resulted in the mineralogical and geochemical pecularities of the deposits studied: the deposition of sulphides was scarce in the high-temperature deposits, and intensive in the middle-temperature and low-temperature ones.

The analyses of water leachates from the inclusions showed that during all the formation of the deposits the solutions had the following composition: Na-K-HCO_3-Cl-F-CO_2 with some SO_4 and Mg. The higher concentration of alkaline metals and predominance of K were found to be typical for high-temperature deposits, while for middle- and low-temperature deposits the predominance of Na over K has been determined for all the stages of the process. The concentration of K increases to the moment of crystallization of main productive associations. The Cl/F ratio varies but the concentration of F is usually more than of chloride ion. The ore-forming elements have been discovered in the dried residues of the water leachates. Gaseous phase of inclusions has been found to consist of CO_2, O_2, N + rare gases. The O_2/N_2 ratio is close to atmospheric. (Authors' abstract).

SILLITOE, R.H., & SAWKINS, F.J., 1971, Geologic, mineralogic and fluid inclusion studies relating to the origin of copper-bearing tourmaline breccia pipes, Chile: Econ. Geol., v. 66, p. 1028-1041.

In north and central Chile, groups containing from two to over one hundred breccia pipes are located in a 2,000 km-long, north-south-trending belt. In the large majority of cases the pipes cut small, granitic, epizonal plutons of early Tertiary age, but some were emplaced in adjacent andesitic volcanics. Individual pipes, which are circular to elliptical in plan, range from as little as 3 m to 1,200 m in diameter. The steeply dipping to vertical pipes contain angular to sub-rounded, and in some cases tabular, fragments of host rock, and are bounded along their margins by zones of well-developed vertical sheeting. The pipes appear to pass upwards into bodies of hydrothermally altered rock surrounded by sheeted contacts. Small bodies of fine-grained porphyritic felsic rock were intruded with close spatial and temporal relation to the brecciation.

The hydrothermal mineralization of the pipes may be divided into an early replacement stage, followed by open-space filling. Fragment replacement produced aggregates of quartz-sericite, together with intense silicification and tourmalinization. The filling stage resulted in tourmaline, accompanied by specularite, and followed principally by quartz, scheelite, chalcopyrite, pyrite, molybdenite, galena, and finally rare anhydrite, barite and carbonates.

Studies of primary and pseudo-secondary fluid inclusions in quartz crystals indicate that quartz deposition occurred over the temperature range of approximately 440-350°C. Certain inclusions also indicate that both high and low density fluids were present at times during quartz precipitation, and that strong salinity variations occurred (2.9 to 36 equiv. wt % NaCl). Some of the inclusions studied contain complex daughter mineral assemblages including cubes of sodium chloride and several birefringent mineral phases. Fluid inclusion, mineralogic and stratigraphic evidence indicate that pipe genesis occurred at depths of approximately 2-3 km below the then-existing surface.

The pipes are interpreted as post-magmatic hydrothermal collapse breccias, formed as a result of the removal of rock by the corrosive action of hydrothermal fluids, in a manner analogous to the "mineralization stoping" mechanism of Locke (1926). The continuing upward passage of such fluids through these uncemented columns of breccia resulted in the development of the relacement and open-space filling stages of mineralization. In some instances, further fragmentation appears to have occurred in situ at this stage due to the action of chemical brecciation (Sawkins 1969).

The geologic, mineralogic and fluid inclusion data support a close genetic relationship between the breccia pipes and the latter stages of the earliest Tertiary magmatic cycle in Chile. (Authors' abstract)

SINYAKOV, V.I., & FEDOSEEVA, M.M., 1971, Two types of pyroxenes from the magnesian skarns of Temir-Tau (Gornaya Shoriya): Geol. Geofiz. v. 7, p. 57-69, (in Russian). CA 76 (20) 115937x (1972). Authors at the Inst. Geol. Geofiz., Novosibirsk, USSR.

Two types of pyroxenes from spinel-pyroxene skarns of the magmatic stage and from early-postmagmatic pyroxene skarns are described. The skarn-ore deposits are localized in dolomitic xenoliths at the contact with Telbessk granodiorites. The post-skarn metasomatic diopside rocks are formed in the magmatic stage. The 2 types of pyroxenes are: (1) pyroxenes of the fassaite-type occurring in magnesian skarns of the magmatic stage, and (2) pyroxenes of diopisde compn. in early-postmagmatic magnesian skarns. Fassaites show a strong optical dispersion and are characterized by a high Al_2O_3 content (< 11.77 wt. %) and low ferruginosity. Diopsides of spinel-free paragenesis do not show opitcal dispersion and are characterized by low (< 0.56 wt. %) Al_2O_3 content. Geothermometric studies of gas-liq. inclusions suggest the temp. of formation of fassaites (800-860°) to be higher than that of diopsides (660-700°).

SKURIDIN, V. A., PROSKURJAKOV, A. A., 1971, The role of acid components in the process of subvolcanic hydrothermal minerogenesis (abst.): International

Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 1, p. 289-290 (in English) (Authors at The Institute of Geology and Geophysics Novosibirsk, USSR).

The character of the minerogenesis process, along with thermodynamic parameters of the system, is defined in many respects by the anion composition of the solutions.

The role of anions in the processes of minerogenesis differing from subvolcanic magmatism and explosive brecciation to hydrothermal minerogenesis was studied on the materials of subvolcanic copper and molybdenum deposits of Siberia and Middle Asia. The data of the analysis of rocks and individual minerals (including electron microprobe data), gas analysis of individual gas and liquid inclusions, analysis of water extracts and the experimental data were used.

The general scheme of the endogenic process in the multistage deposits being considered appears as: explosive breccias-magmatic formations - hydrothermal mineralization.

Explosive brecciation represented in the leading front of the development of magmatic process to a considerable extent, was due to the effervescence of high-temperature fluids on sharp reduction of the outside pressure and also to the vaporization of vadose waters having penetrated into the hot area. The process proceeded with extensive participation of Cl, F and CO_2. Chlorine is typical for explosive breccias fixing the most active effluent channels and being closely connected with large magmatic masses. The longer the distance between the place of the process and canal, the less is the role of chlorine and the stronger is the activity of fluorine. Under the late brecciation the leading role belongs to CO_2 with noticeable participation of nitrogen and inert gases. Minerogenesis in the process of explosive brecciation is weak because of the rapidity of the process.

The content of chlorine and fluorine in the magmatic formations is not high, with the main concentration in late minerals, which is caused by subvolcanic magmatism in relatively open systems, when the separation of solutions from [melts] is possible in two stages: before the crystallization of [melts] under the high temperatures (period of explosive brecciation) and under the comparatively low temperatures when eutectic crystallization had taken place (period of hydrothermal minerogenesis).

The role of fluorine and carbon dioxide in the products of metasomatis noticeably increases, expecially in the deposits where later hydrothermal fluorite and carbonate mineralization is intensive. The specialization of mineral-forming solutions on certain anions is reflected in the character of metasomatic process and in the special features of minerals formed. Fluorine's participation in the metasomatic process promotes the broad albitization, and carbon dioxide [promotes] argillization and carbonization, which have been confirmed by the experimental investigation of the anion's influence on the hydrothermal changing of orthoclase.

Chlorine is not typical for metasomatic and ore formations. Its evacuation from the sphere of the postmagmatic process is observed. (Authors' abstract).

SMIRNOV, V. I., 1971a, Temperature conditions of the origin of strata-bound pyritic volcanogenic ore deposits: Soc. Mining Geol. Japan, Spec. Issue 3, p. 221-225 [Proc. IMA-IAGOD Meetings '70, IAGOD Vol.].

Decreptometric investigation of sulphides from stratabound sulphide deposits from the Urals, Caucasus, Tuva, and Japan allowed to distinguish three types of ores. The first group does not display decrepitation effect and belong to cold water precipitates. The second group reveals decrepitation at low temperatures which testifies to the precipitation of sulphides from weakly heated solutions. The third group is characterized by multi-crystallization of sulphides from hot hydrothermal solutions. High temperature sulphides of the third group build up the central parts of lodes and their lower walls. Low temperature ores of the first and second groups form thin layers at the flanks and the intercalations near the hanging walls of ore bodies.

The possibility of the formation of stratabound sulphide ore bodies by a complex hydrothermal-sedimentary mechanism is proposed. It is plausible, therefore, that near the center of the source of mineral substances from deeply formed hydrothermal solutions the formation of ores occurred at comparatively high temperatures, while in the outer parts the temperature became gradually lower, and the ores were precipitated as a sediment on the sea bottom. (Author's abstract).

SMIRNOV, V. I., 1971b, On the conditions of pyrite deposits formation from the data on decrepitation and sulphur isotopes variations in ore-forming sulphide minerals (abst.): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 1, p. 213 (in English) (Author at Moscow State University, Moscow, USSR).

On the basis of decrepitation and sulphur isotope variations in ore-forming sulphides, two groups of pyrite deposits may be distinguished. One of them is characterized by multiphase decrepitation of sulphides in the range from 200 to 450°C, which, even allowing for the deviations of the results of decrepitation to the higher values, indicates that their formation proceeded from sufficiently hot hydrothermal solutions. The isotope ratios for sulphide sulphur of the ores belonging to this group are fairly uniform and approach the meteoritic standard. It is consistent with the concept of the direct sulphide accumulation from primary deep sources related to basaltic magma.

The second group does not reveal decrepitation effect of ore-forming minerals, or it is characterized by decrepitation at low temperatures which after correction for too high results give values below 100°C. The ores of this group are characterized by the extensive variations of the isotopic composition of sulphur giving significant deviations to the both sides of the meteoritic standard. These data testify to the formation of the second group from either cool or slightly heated aqueous solutions with the participation of bacterial processes accompanied by the marked fractionation of sulphur isotopes. (Author's abstract).

SOLOMON, M., RAFTER, T.A., & DUNHAM, K.C., 1971, Sulphur and oxygen isotope studies in the northern Pennines in relation to ore genesis: Inst. Min. & Metal. Trans. v. 80, Sect. B, p. B259-B275.

Sulphur isotope ratios have been determined for 81 sulphides and sulphur and oxygen isotope ratios for 26 barites from the Alston Block in the northern Pennine ore field. In addition, both isotope ratios have been determined for 29 evaporitic anhydrites of various ages from European and Australian localities. The consistency of the sulphate isotope ratios over a wide area of the northern Pennines, and their similarity to values for Lower Carboniferous evaporites, suggests that the sulphate originated from Lower Carboniferous connate waters. It is suggested that these mingled with warm brines rising through granitic plutons beneath Tynehead and Upper Weardale, the aqueous sulphide ion in these brines having a $\delta^{34}S$ value of approximately +10 per mille. The $\delta^{34}S$ values for the sulphides range from +15.0 to 5.0 per mille and show an outward zonation with higher values in the central fluorite zones and mainly negative values in the outer barite zones. The wide range of $\delta^{34}S$ values for the sulphide sulphur is not characteristic of magmatic sulphur and there is no adequate local source in the Carboniferous sediments. It is suggested that formation waters, probably mainly of connate origin, sank down sufficiently deep to become heated above 200°C before rising through Caledonian granite plutons into the Carboniferous sediments, where they spread laterally to mingle with cooler sulphatic connate water. The rising fluids were hypersaline brines carrying F, Ba, Pb, Zn, Cu and S. Temperatures of deposition calculated from galena-sphalerite isotope fractionation are similar to temperatures previously determined from fluid inclusion studies. (Authors' abstract)

SØRENSEN, Henning, DANØ, Marianne, & PETERSEN, O.V., 1971, On the mineralogy and paragenesis of tugtupite $Na_8Al_2Be_2Si_8O_{24}(Cl,S)_2$ from the Ilímaussaq alkaline intrusion, South Greenland: Medd. om Grønland, v. 181

no. 13, p. 1-38, plus 9 plates, (in English). Authors at Institute of Petrology, Østervoldgade 5, 1350 Copenhagen; and the Mineralogical Museum, Østervoldgade 5, 1350 Copenhagen.

Tugtupite, $Na_8Al_2Be_2Si_8O_{24}(Cl,S)_2$, is colourless to red, tetragonal, pseudocubic and forms triplet twins. It occurs in hydrothermal veins in the Ilímaussaq alkaline intrusion, South Greenland, and in the Lovozero alkaline intrusion, Kola Peninsula (beryllosodalite). A number of occurences of tugtupite in Ilímaussaq are described.

Tugtupite is most commonly associated with albite, analcime and Li-mica and is generally secondary after chkalovite. The paragenesis and origin of the mineral and a number of associated beryllium silicates are discussed. The authors believe that tugtupite has been formed from alkaline aqueous fluids at temperatures around 400°C and at a fairly high volatile pressure since S and Cl take part in the crystallization of the mineral, and since the replaced anhedra of chkalovite often are shattered. There may have been several injections of hydrothermal fluids into vein systems. Residual fluids were squeezed out from successive injections of lujavrite magma at different stages of crystallization. As they have travelled different distances through the rocks, it is reasonable to assume that the various residual fluid phases have differed from one another with respect to chemical composition, temperature and vapour pressure. Authors' abstract, extended. Note: in a previous paper, Sobolev et al., 1970 (Fluid Inclusion Research v. 3, 1970 , p. 70-71), show high homogenization temperatures for some Ilímaussaq minerals (up to 1040°C) and 440-460° for those in tugtupite. (E.R.)

STEVENS, R.E., SAINSBURY, C.L., & BETTIGA, A.C., 1962, Dissolving fluorite with solutions of aluminum salts: U.S. Geol. Survey Prof. Paper 450C, Geol. Survey Research 1962, p. C98-C99.

Hot strong water solutions of $AlCl_3$, $Al(NO_3)_3$, or $Al_2(SO_4)_3$ are good solvents for CaF_2. Although this is an old reference, it is brought up because it is pertinent to fluid inclusion studies of the numerous fluoride daughter crystals in aluminum-rich fluid inclusions in some pegmatitic minerals. (E.R.)

ŠTOCHL, Václav, 1971, On the geochemistry of gas inclusions in rocks of the Karlovy Vary granite massif: Geochemical Methods and Data 1: Prague, Ústřední ústav geologiký, pp. 89-132 (in English with Czech summary).

Gases were released from 32 rock and separated mineral samples by heating to various temperatures, in vacuum, and analyzed by gas chromatography methods (given) for H_2, O_2, N_2, CH_4, CO, CO_2, CnHm, and total volume. Variations with mineralogy temperature and grainsize are used to help elucidate the problems of chronological and spatial differentiation of the various granites associated with late Variscan orogogeny in the region. (E.R.)

STOLLERY, G., BORCSIK, M. & HOLLAND, H.D., 1971, Chlorine in intrusives: a possible prospecting tool: Econ. Geol. v. 66, p. 361-367.

Nearly all biotites in a 2 km section across the Providencia stock, Zacatecas, Mexico contain between 0.25 and 0.50% chlorine. Their average chlorine content is twice to three times the mean chlorine content of biotites in granitic rocks; the bulk chlorine content of the stock exceeds the average chlorine content of granitic rocks by approximately the same amount. Quartz throughout the stock contains highly saline postmagmatic fluid inclusions. Since ore metals are strongly concentrated from silicate melts into highly saline aqueous fluids, we suggest that the development of the lead-zinc-silver ore deposits of the Providencia area was due in part to the abnormally large chlorine content of the stock. A relatively large chlorine content in intrusives may well be a necessary, though hardly a sufficient, prerequisite for the formation of associated magmatic-hydrothermal ore deposits. The chlorine content of intrusive rocks may therefore develop into a useful diagnostic prospecting tool. (Authors' abstract.)

STUPAKOV, G.P., & ANUFRIYEV, Yu.N., 1971, Genesis of crystal quartz at Kochkar gold deposit: Akad. Nauk SSSR, Izvestia, Ser. Geol., 1971, no. 6, p. 79-87 (in Russian). Translated in Internat. Geol. Rev., v. 14, no. 6, p. 559-565 (1972).

The crystal-filled pocket described here resembles the metamorphogenic Uralian type of such accumulations. Comprehensive analysis of this crystal quartz, vein quartz, and others, including the absolute age of the paragenesis, do not sustain the once assumed genetic connection of ores with the Late Hercynian microcline granites. (I.G.R. abstract)

The fluid inclusions homogenize at 230-356°C and contain up to 10 volume % CO_2. Decrepigrams are also given. H_2O/CO_2 ratios (method of Vertushkov et al., 1969) range from 8.9 - 13.5. Water extracts were analyzed, from 3 samples, for K, Na, Mg, Ca, Li, NH_4, Cl, F, SO_4, HCO_3, and SiO_2. The thermoluminescence relative to distance from druse and gamma-ray irradiation coloring within individual crystal zones were also examined. (E.R.)

SUCHKOV, P.N., KALUGIN, E.N., BUSHEV, A.G., & GROMOV, A.V., 1969, Determination of the temperature of formation of graphic and apographic parts of mica-bearing pegmatites: Izv. Vyssh. Zaved. Geologiya i Razvedka, 1969, no. 5, (in Russian).

In addition to description of graphic and apographic biotite-microcline pegmatites of the Berezov region, the authors describe 4 groups of inclusions in quartz crystals:

1- Polyphase gaseous inclusions - primary inclusions found only in graphic pegmatite. Rare (1%), with negative crystal shape, small (< 10 microns), volume ratio vapor/solid/liquid (V/S/L) ∿ 3/3/4. They homogenize in the liquid phase between 420 and 450°C.

2- Essentially gaseous inclusions. Secondary, more common (5 % of the total), round, 2 to 100 μm, with V/L ∿ 9/1, and contain small anisotropic particles. They homogenize in the gas phase at 340-360°C.

3- Gas-liquid inclusions. Secondary, abundant (40% of the total), vapor/total volume ∿ 1/4, 5 to 200 μm, various shapes. Found in both graphic and apographic pegmatites; homogenize at 250-280°C in the liquid phase.

4- Essentially liquid inclusions. Always secondary and especially characteristic of apographic pegmaties. They homogenize in the liquid phase between 90 and 120°C.

Decrepitation measurements agree fairly well with these data; the peaks begin some 70° below homogenization temperature. Barth's geothermometer applied on two samples (graphic and apographic structure) gave good agreement with fluid inclusion data (500°C) but the scandium content of biotites gave a higher temperature (570°C). In conclusion the minimum temperature of formation for graphic pegmatites of Berezov is 420-450°. Both graphic and apographic structures suffered a late hydrothermal alteration which has been much more intense for the apographic ones. These pegmatites are more complex than previously thought and further work is needed. (B. Poty)

SUGISAKI, Ryuichi, and JENSEN, M.L., 1971, Oxygen isotopic studies of silicate minerals with special reference to hydrothermal mineral deposits: Geochem. Journ., (Japan) v. 5, p. 7-21. Authors at Department of Earth Sciences, Nagoya University, Nagoya, Japan; and Laboratory of Isotope Geology, University of Utah, Salt Lake City, Utah, U.S.A.

Oxygen isotopic compositions of various silicate minerals of sedimentary and igneous origins have been investigated. The determined $\delta^{18}O$ values of these hydrothermal silicates vary between -3 and +30‰; most of them correlate well with the crystallization temperature. The δ values of hydrothermal solutions (δ_w) from which quartz had been deposited have been calculated. The values thus calculated for samples which crystallized at temperatures above 300°C * show a small variation about a mean value of +8‰ and decrease systematically with temperature below 300°C. An ore fluid that existed above 300°C is interpreted as having equilibrated with a large reservoir of silicate rocks at high temperatures on the basis of ^{18}O content. The variations of δw with temperature for samples which crystallized below 300°C are attributed to the mixing of the ore fluid with ^{18}O-poor meteoric water. This view supports the cooling mechanism of hydrothermal ore fluids, which was proposed by Barton and Toulmin (1961). Hydrothermal solutions of ore deposits of shallow, so-called "subvolcanic" origin, however, contain large proportions of meteoric water. The isotopic composition of the initial hydrothermal solution can be measured directly only in fluid inclusions in minerals deposited above 300°C and with no oxygen atoms. When ore deposits are classified, the separation of the group of deposits as "volcanic" or "subvolcanic" is helpful. Authors' abstract. (* Editor's note - almost all temperatures used were decrepitation temperatures from the literature.)

SUSHCHEVSKAYA, T.M., 1969a, Geochemical characteristics of tin-bearing hydrothermal solutions from data based on inclusion research: V sb. "Rudoobr. i ego svyaz' s magmat." Yakutsk, 1969, (sic., as quoted in Bogoyavlenskaya, et al., 1971, in this volume).

SUSHCHEVSKAYA, T.M., 1969b, Geochemical characteristics of tin-bearing hydrothermal solutions: Avtoref. Kand. Diss., M., 1969. (A dissertation) (sic., as quoted in Bogoyavlenskaya, et al., 1971, in this volume).

SUSHCHEVSKAYA, T.M., 1971, Comparative characteristics of the chemical composition of tin-bearing hydrothermal solutions (from analyses of gas-liquid inclusions), in Geochemistry of hydrothermal ore formation, ed. by V.L. Barsukov: Moscow, Izdatel. "Nauka," p. 35-60 (in Russian). CA 76 (20) 115975h (1972).

The chem. compn. of Sn-bearing hydrothermal solns. is controlled by the relative amts. of the main ions: Na-K-Ca, Cl-HCO_3-F, and to lesser degree Mg and Li. Two groups of solns. (chloride Na and complex) are sepd. according to the predominance of definite ions. The 1st group is typical of Sn deposits with strong sulfide mineralization. The 2nd group includes low-sulfide Sn-bearing veins, some veins of sulfide-cassiterite deposits, and deposits of the quartz-cassiterite type. The Sn-bearing hydrothermal solns. have a high Li concn. and 1-9 mole/l. CO_2. The av. total mineral content of Sn-bearing hydrothermal solns. is 30-70 g/l., which is also typical of most hydrothermal deposits. The complex Sn compds. with F and OH are the most probable and stable Sn compds. in the hydrothermal medium. The transfer of Sn in the form of $[Sn(OH,F)_6]^{2-}$ ion is probably typical of both sulfide-cassiterite and quartz-cassiterite deposits.

SWINZOW, G. K., 1971, Anomalous water: nucleation, growth, and properties: U.S. Army Cold Regions Research and Engineering Lab. Spec. Rept. 156, 36 pp.

Summary of literature (24 references) plus new experimental work, indicating that although there is a lack of convincing evidence for the existence of a water polymer, the data obtained cannot be explained by impurities in solution. (ER)

TAKENOUCHI, Sukune, 1971, Study of CO_2-bearing fluid inclusions by means of the freezing stage microscope: Mining Geology (Japan) (Kozan Chishitsu) v. 21, no. 108, p. 28-42 (1971) and 286-300 (second pagination) (in Japanese with English abstract). Author at Dept. Mineral. Development Engineering Univ. Tokyo, Tokyo 113, Japan.

CO_2-rich fluid inclusions in minerals were studied by means of the freezing method. When CO_2-rich inclusions were cooled, liquid CO_2 or CO_2 gas hydrate appeared in them, and the volume of these phases was various according to the content of carbon dioxide. As the change of the CO_2 hydrate which was formed in inclusions was comparable to the phase diagram of the H^2O-CO_2 system at low temperature, it was possible to infer the inside pressure of fluid inclusions and to calculate the approximate concentration of carbon dioxide from the data on the solubility of carbon dioxide in water and the pressure-temperature-density relation of carbon dioxide. The CO_2-rich inclusions were found in quartz from the Ohtani and Kaneuchi mines, Kyoto Pref., Takatori mine, Ibaragi Pref., and Taishu mine, Nagasaki Pref. It is interesting that these ore deposits except that of the Taishu mine belong to the hypothermal tungsten quartz veins. In any case, however, CO_2-rich inclusions were found as secondary inclusions, or as primary inclusions in rock crystals from druses. This fact will imply that CO_2 has been concentrated in the late stage of mineralization of these ore deposits. (Author's abstract)

TAKENOUCHI, Sukune, and IMAI, H., 1968, Magmatic emanations and ore-forming fluid; on the salinity of liquid inclusions in quartz crystals (abstr.): Chikyukagaku (Geochem.), v. 2, no. 1, p. 41-42 (in Japanese).

TAKENOUCHI, S. and IMAI, H., 1971, Fluid inclusion study of some tungsten-quartz veins in Japan: Soc. Mining Geol. Japan, Spec. Issue 3, 345-350 (Proc. IMA-IAGOD Meetings '70, IAGOD Vol.)

Fluid inclusions from the Takatori, Ohtani and Kaneuchi mines in Japan were studied by means of the heating stage and freezing stage microscope. The ore deposits belong to hypothermal tungsten-quartz veins in sedimentary rocks and granitic rocks. The filling temperatures and freezing temperatures of fluid inclsions in quartz, cassiterite, scheelite, topaz and fluorite from these ore deposits were studied. The filling temperature and the NaCl equivalent concentration of inclusions in cassiterite were the highest, but those of quartz varied. CO_2-bearing inclusions were found in quartz as primary and secondary inclusions, especially in rock crystals from druses. It is concluded from the results of the investigation, that the temperature and the concentration of the ore-forming solutions which have formed these ore deposits were almost the same in spite of the different geological setting, and that CO_2 have concentrated in the late stage of mineralization. (Authors' abstract)

A more extensive abstract for this same paper was first published in 1970 - see Fluid inclusion Research, 1970, v. 3, p. 74-75 (Ed.)

TAYLOR, H.P., JR., 1971, Oxygen isotope evidence for large-scale interaction between meteoric ground waters and Tertiary granodiorite intrusions, Western Cascade range, Oregon: Jour. Geophys. Research, v. 76, p. 7855-7874.

^{18}O data are similar to those previously discovered in the Tertiary intrusive centers of western Scotland and the San Juan Mountains, Colorado. They are typically associated with (1) pervasive epidote and chlorite alteration; (2) "turbid" feldspars; (3) granophyric textures and miarolitic cavities; and (4) young, jointed, flat-lying, volcanic country rocks that are known to be highly permable to ground-water flow. Convective circulation of heated ground waters in the vicinity of the stocks must have occurred throughout a large part of their crystallization and cooling history. The amounts of H_2O involved are estimated to be about equal in volume to that of the exchanged rock. Hence, much so-called "deuteric" alteration of igneous rocks is probably caused by such meteoric-hydrothermal waters rather than by H_2O released during magmatic crystallization. (Author's abstract, abbreviated).

TAYLOR, H.P.,Jr., & FORESTER, R.W., 1971, Low-O^{18} igneous rocks from the intrusive complexes of Skye, Mull, and Ardnamurchan, Western Scotland: Journ. Petrology, v. 12, no. 3, p. 465-497. Authors at Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, Calif. 91109.

Oxygen isotope analyses have been obtained on rocks and coexisting minerals from the Tertiary stocks, ring-dikes, and cone-sheets in Ardnamurchan (18 samples), Skye (41 samples), and Mull (18 samples); these include a few samples of the plateau basalt country rocks. Almost all of the rocks in the vicinity of the central ring complexes (within 2 mi. of an intrusive contact) are strongly depleted in O^{18} relative to "normal" igneous rocks from other areas. The rocks in Skye (∿150 sq. mi.) and Mull (∿ 150 sq. mi.) have suffered an overall O^{18} depletion of about 6 to 7 per mil, and those in Ardnamurchan (∿30 sq. mi.) about 3 to 6 per mil.

These data indicate that very large hydrothermal convection systems involving heated low-O^{18} meteoric ground waters were established in these areas at the time of igneous intrusion. The heated ground waters exchanged with the gabbros, granites, and basaltic lavas, locally lowering their O^{18}/O^{16} ratios by at least 12 per mil. Much, if not all, of this exchange occurred after crystallization of a given igneous rock was essentially complete, inasmuch as feldspars invariably have undergone much more depletion in O^{18} than has coexisting quartz or pyrozene. The meteoric-hydrothermal processes and the presence of an aqueous gas phase may possibly be responsible for the widespread epidote-chlorite alteration, the turbid or cloudy feldspars, the abundant feldspathic veins, the felsitic and granophyric textures, the miarolitic cavities and much of the explosive volcanic activity and brecciation that are found in these areas. (Authors' abstract)

TAYLOR, P.S., & STOIBER, R.E., 1971, Soluble material on ash from Central American volcanoes (abstr.): Amer. Geophys. Union Trans., EOS, v. 52, no. 4, p. 382. Authors at Dept. of Earth Sciences, Dartmouth College, Hanover, N.H. 03755.

Water soluble materials were leached from volcanic ash which had not been rained on. The 60 samples of ash came from recent eruptions of Central American volcanoes. The Cerro Negro eruption of 1968 produced 17 million tons of ash. It was calculated from the chemistry of the leachate that the eruption contributed to the ground water circulation 21 thousand tons of chemicals for which analyses were made: Na, K, Mg, Ca, SO_4, Cl, F, Mn, Zn, and Cu. Based on our Central American leachate data and published estimates of annual tephra production in the world, the soluble Cl and S on volcanic ejecta is more than enough to supply the excess of Cl and S in the oceans. The water soluble chemicals are deposited on the ash from volcanic gas during eruption. This is shown by the large amount of Cl and S, both of which are common to volcanic gas and condensates and fume, by sublimate minerals on some ash particle surfaces, and by the fact that concentrations in the leachate are related to the surface area of the ash size fraction leached. (Authors' abstract) Note-pertinent to a variety of aspects of fluid inclusion study (ER)

TOLSTIKHIN, I. N. and PRASOLOV, E. M., 1971, Method of study of isotopes of noble gases from microinclusions in rocks and minerals, in Investigations of mineral-forming solutions and melts in inclusions in minerals, N. P. Ermakov and L. N.Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials, (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 86-98, (in Russian).

The apparatus for studying the isotopes of argon and helium as impurities in the crystal lattice and in microinclusions in minerals is described. Rocks of deep-seated origin were analysed. The argon contained a microinclusions can have a considerable effect on the results of absolute age determinations by the K/Ar method. The characteristics of the isotopic composition of argon and helium in risschorite from the Khibiny massif are presented. (S. Theokritoff).

TOURAY, Jean-Claude, 1971, Deep-origin CO_2 trapped by healed cracks in epigenetic tunisian fluorites: Soc. Mining Geol. Japan, Spec. Issue 3, p. 351-354 (Proc. IMA-IAGOD Meetings '70, IAGOD vol.)

The samples discussed in this paper contain water primary inclusions and sometimes three-phase petroleum bearing ones. Besides, both contain heterogeneous groups of CO_2 bearing and water inclusions, testifying the existence of two immiscible fluids before the healing of the cracks.

The results of the mineralothermometric investigation of those inclusions are presented. The existence of secondary CO_2 rich inclusions in association with water rich ones in a same healed crack may be interpreted as the result of the trapping at shallow depth of an immiscible fluid proceeding from the mixing of a deep-origin hot CO2 (temperature -200°C) and supergene solutions. (Author's abstract)

A different, more extensive abstract for this same paper was first published in 1970 - see Fluid Inclusion Research, 1970, vol. 3, p. 77-78 (Ed.)

TOURET, JACQUES, 1971a, Migmatization of the Selås banded gneisses (Southern Norway) (abst.): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 2, p. 614-615 (in English) (Author at Départment des Sciences de la Terre, Nancy, France).

In the Precambrian shield of Southern Norway (Bamble province), ancient sediments have still retained some essential features of the initial chemical composition and structure, in spite of a high grade metamorphism (granulite/ high amphibolite facies). The Selås banded gneisses are thus rythmic metagreywackes with traces of graded bedding and the following mineralogical composition: quartz-oligoclase-microcline-biotite-garnet-graphite-sulfide. They contain numerous patches and dikes of granodiorite (quartz, oligoclase, microcline, biotite, iron oxides) which intersect the sedimentary structures and appear to be of a late, non-sedimentary origin. The chemical composition of the granodiorite is very close to the average composition of banded gneisses; from geochemical and structural arguments, it is believed that it has been created "in situ" by local anatexis and migmatization during metamorphism (Dalslandian episode, about 1 billion years ago). But [in] this hypothesis, the small amount of "mobilisat" (less than 20% of the banded gneisses) is a major problem which can only been explained by the behavior of fluid phase during metamorphism. Investigations of fluid inclusions in quartz crystals from banded gneisses and granodiorite reveal striking differences: banded gneisses contain only water-bearing inclusions with a variable salt content, while in granodiorite CO_2-rich fluids occur predominantly. Their [homogenization] temperatures (about 75°C) indicate that CO_2 is mixed with other compounds, probably hydrocarbons. These fluids are interpreted as reaction products of water with graphite, the amount of water in the fluid phase controlling the extent of migmatization under P-T metamorphic conditions. (Author's abstract).

TOURET, Jacques, 1971b, The granulite facies in Southern Norway. I: The mineral associations; II: The fluid inclusions: Lithos, v. 4, p. 239-249 and 423-436 (in French with English abstract). Author at Laboratoire de Géologie Structurale, Universite de Nancy I, B.P. 452, 54-Nancy-France.

I-The basement of Southern Norway is a genetically homogeneous migmatite complex in which old supracrustals produced granitic and granodioritic "neosome" during a late Precambrian (10^9 years ago) regional metamorphism. Observed isograds of critical minerals: muscovite, cordierite, orthopyroxene indicate that the Telemark amphibolite facies in the North passes into the coastal Bamble granulite facies in the South. The data of experimental petrology suggest that the transition, which took place at temperatures of 700-800°C, is essentially due to a decrease of the partial water pressure. P_{H_2O} was equal to total pressure Ps in the amphibolite facies and lower than 2 kb in the granulite facies.

II-Liquid inclusions in quartz found in rocks of amphibolite and of granulite facies were studied. In the former water is predominant, in the latter CO_2 (probably juvenile). Estimates of PT conditions during metamorphism based on the study of inclusions gave values (800°C, 8 kb) comparable to those obtained by the petrological study (7-800°C, 6-8 kb) presented in part I. (Author's abstract).

TOURET, Jacques, 1971c, Control of the granulite facies in the Bamble by the CO_2 in the fluid phase: Comptes Rendus Sommaire des Seances de la Soc. Géologique de France, 1971, p. 143-145 (in French).

A brief discussion covering essentially the material presented in the previous abstracts. (E.R.)

TRUESDELL, A.H., 1971, Nonideality of oxygen isotope fugacity in salt solutions at elevated temperatures--geochemical implications (Abst.): Geol. Soc. Amer. Abstracts with Programs, v. 3, no. 7, p. 735. Author at U.S. Geological Survey, Menlo Park, Calif. 94025.

The isotopic differences between CO_2 equilibrated with pure water and that equilibrated with one molal salt solutions (that is, (δCO_2, water)-(δCO_2, solution)) at the extreme temperatures studied (25° and 275°C) are in per mil δO^{18}: NaCl 0.0, -1.0; KCl -0.2, -2.8; LiCl +0.3, +0.1; $MgCl_2$ +1.1, +0.2; $CaCl_2$ +0.4, -1.4; NaF (0.8m) 0.0, +0.8; NH_4Cl (0.55m) +0.1, +0.8.

These fractionations should be considered in the isotope study of geothermal brines and saline fluid inclusions, and may require modifications in the quartz-water and calcite-water geothermometers. (Author's abstract, abbreviated.)

TRUFANOV, V.N., 1969, Mineralogy and thermodynamics of crystal-bearing cavities in granite pegmatites: Izd. Rostov. Un. 1969. (Sic., as quoted in Bogoyavlenskaya, et al., 1971, in this volume).

TRUFANOV, V. N. and KURSHEY, S. A., 1971, Electron microscopy of fluid inclusions in minerals, in Investigations of mineral-forming solutions and melts in inclusions in minerals, N.P. Ermakov and L.N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials (Tr. vsesouz. nauchno-issled inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 171-174, (in Russian).

TRUFANOV, V. N., KURSHEV, S.A., MAISKY, U.G.,+ USHAK, A.T., 1971, Experimental investigations of phase equilibria in the persilicic differentiates of granite magma at extreme conditions (abst.): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 2, p. 688-689 (in English) (Authors at Rostov State University, Rostov-on-Don, USSR).

The problem of phase equilibriums in the persilicic differentiates of the granite magma at the terminal stages of its evolution is one of the most debatable in geochemistry of endogeneous processes of mineral formation. It was showed theoreticaly (Vogt, 1924, Niggli, 1919-1937, Fersman, 1931-1940, Zavaritzsky, 1944, Nikolaev, 1953) and was settled experimentally (Khitarov, 1957-1969, Kennedy, 1962) that two kinds of phase equilibrium are possible in granite magma, corresponding to the "P" and "P-Q" physical-chemical systems.

At the same time the realization of this possibility and the degree of importance of the above-mentioned kinds of the phase equilibria is not quite evident for genesis of the pegmatites, silexites, quartzolites and the other granite magma products.

Experimental investigations of the phase equilibria in the different kinds of the "natural microautoclaves" - crystal-fluid inclusions preserved in quartz from granitoids, pegmatites and silixites of Central Kazakhstan and North Caucasus - have been fulfilled.

As the result of the phase transformation observation in these inclusions, existence of "gas-melt", "liquid-liquid" and "fluid-fluid" heterogeneous equlibria were found at temperatures of 1000°C and under pressures of 2000 atm. It was found also that due to the geochemical specialization of initial granitic melt, relative quantity of volatiles+ rate of cooling, a continuous transition from homogeneous silica melt to laminated residual brine and further to the ordinary hydrothermal solution without critical effects takes place, or repeated division of the residual persilicic magmatic "pinches" with separation of critical superdense gas-fluid differentiates is observed. The latter ones are distinguished by strong reactional ability as regard to quartz and other rock-forming granite minerals [sic.]. (Author's abstract).

TRUFANOV, V. N., KURSHEV, S. A., and USHAK, A. T., 1971, Thermal metamorphism of fluid inclusions in minerals, in Investigations of mineral-forming solutions and melts in inclusions in minerals, N.P. Ermakov and L.N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 177-182, (in Russian).

Fluid inclusions in quartz and fluorite from the chambered pegmatites of Central Kazakhstan were investigated by the method of isothermal or isobaric heating in autoclaves calculated for a pressure up to 2000 atm. and temperature up to 800°C. It was established that on overheating multiphase inclusions 250-300°C above the homogenization temperature, the high density fluid formed dissolves the walls of the vacuoles energetically. For smaller degrees of overheating, or a lower concentration of dissolved salts, systems of satellite inclusions are formed.

As a result of overheating carbon dioxide-water inclusions and gas-liquid vacuoles, the phenomenon of a metastable state of the supercritical fluids formed is observed, which persists for several months under the conditions of isothermal storage of the preparations, cooled to 20°C. Natural and artificially changed inclusions are compared. (S. Theokritoff).

TUGARINOV, A.I., & NAUMOV, V.B., 1971, Physico-chemical parameters of hydrothermal mineral- forming process (abst.): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 1, p. 302-303 (in English) (Authors at V.I. Vernadsky Institute of Geochemistry and Analytical Chemistry, Moscow, USSR).

Natural minerals are not perfectly homogeneous. During their growth crystals often entrap and conserve the medium in inclusions. Investigation of the mineral-forming medium in inclusions permits determination of the physico-chemical parameters of crystallization: temperature, pressure, state of medium, density, viscosity, composition and salinity, acidity, etc.

Examination of more than 3000 available data on gaseous-liquid inclusions in minerals from about 1000 deposits throughout the world suggests, that: 1. Homogenization of inclusions in liquid or gas phase characterizes the aggregation of hydrothermal solutions. The inclusions homogenize into liquid phase: in quartz- in 94% of 980 determinations, in topaz, beryl and tourmaline- in 95% of 110 determinations, and in such minerals as cassiterite, hubnerite, realgar, orpiment, fluorite, calcite, dolomite, magnesite, siderite, barite, celestite, and gypsum- in 100% of 1300 determinations. 2. Hydrothermal solutions are characterized by high density: more than 0.5 (more often 0.7-1.0 g/cm^3/). In the cases when inclusions homogenize into the gaseous phase it is found that the latter is not water vapour of low density (less than 0.2 g/cm^3, but CO_2 of high density (0.35-0.90 g/cm^3). So we conclude, that the field of pneumatolitic processes, i.e. the field of high temperatures and low pressures, is absent. 3. Hydrothermal mineral-forming processes occur in a large temperature range from the lowest temperatures up to 850°C, however different minerals crystallize at different temperatures. For some minerals a large interval of possible crystallization temperatures has been established: quartz- to 850°, calcite to 600°, fluorite to 500°; for other minerals - more narrow intervals: topaz - above 300°, beryl - from 650° to 250°, cassiterite - from 500° to 250°, wolframite - from 450° to 250°, tourmaline - from 400° to 200°, arsenopyrite - from 400° to 200°, sphalerite - below 400° galena - below 300°, barite, cinnabar, stibnite, realgar, orpiment - below 250°, gypsum - below 50°. 4. Hydrothermal mineral-forming processes occur at high pressures: from several hundreds to 1500-2000 bars (150 determinations) In many cases those pressures appear to be much more than the lithostatic one. Frequently enough the essential fluctuations of pressures (i.e. from 900 to 200 bars) are noticed that result in boiling up of CO_2 - containing hydrothermal solutions. (Authors' abstract).

TURI, Bruno, & TAYLOR, H.P., Jr., 1971a, O^{18}/O^{16} ratios of the Johnny Lyon Granodiorite and Texas Canyon quartz monzonite plutons, Arizona, and their contact aureoles: Contr. Mineral. and Petrol. v. 32, p. 138-146. Authors at Division of Geological and Planetary Sciences, California Inst. of Technology , Pasadena, California 91109.

There is no isotopic evidence for significant influx of "external" H_2O into either of the plutons during their crystallization and cooling. However, in roof-zones where metasedimentary rocks overlie the plutons there is a strong δO^{18} lowering in the contact metamorphic aureoles, indicating upward expulsion of low-O^{18}"magmatic" H_2O into these rocks. (Authors' abstract, abbreviated)

TURI, Bruno, & TAYLOR, H.P., Jr., 1971b, An oxygen and hydrogen isotope study of a granodiorite pluton from the Southern California batholith: Geo. Cosmo. Acta, v. 35, p. 383-406. Authors at Division of Geological Sciences, California Institute of Technology, Pasadena, California.

The isotope effects must in large part be brought about by exchange between the granodiorite and the surrounding metasedimentary rocks, probably by means of upward and inward migration of high-O^{18} aqueous fluids through the marginal zones of the pluton. Locally, sub-solidus exchange occurred at temperatures as low as 550°-600°C, based on the quartz-biotite O^{18}/O^{16} geothermometer. (Authors' abstract, abbreviated)

TURNEAURE, F. S., 1971, The Bolivian tin-silver province: Econ. Geol., v. 66, p. 215-225.

The tin-silver province of Bolivia includes the Cordillera Real with tin and tungsten ores associated with granitic batholiths, and the region to the south where tin, tin-silver, tin-zinc and other subvolcanic deposits are associated with porphyritic stocks and dikes.

The batholiths and related plutonic ores of the north have been variously dated as Late Paleozoic, Late Triassic and Early or Middle Tertiary. In the southern region, the record points to two periods of igneous activity and mineralization: Miocene and Pliocene. Most of the subvolcanic deposits probably date from the Pliocene. Hydrothermal regeneration has been emphasized to account for the subvolcanic deposits, but from a review of the evidence it is concluded that this process did not play a major role in ore deposition.

The tin and tungsten ores show four stages of vein growth: quartz-cassiterite (-wolframite), base-metal sulfides, alteration of pyrrhotite, and late veinlets and crusts. Fluid-inclusion studies indicate an increase in temperature from 300° to 530°C, followed by a drop in temperature to 70°C or less. Periodic boiling of the saline ore fluid took place during the quartz-cassiterite stage. The ore deposits of the province are believed to be of hydrothermal origin although the decrease in temperature and salinity of the ore fluid points to dilution with ground water during late stages of deposition.

The differences in mineralization between the tin-silver province of Bolivia, the copper province of Chile and the belt of polymetallic ores of central Peru are not readily explained but may be related to differences in tectonic environment and stratigraphy of the three regions. (Author's abstract).

UCHAMEISHVILI, N. E., MALININ, S. D. + KHITAROV, N. I., 1971, Physical and chemical principles of hydrothermal barite forming and some typical barite-containing associations (abst.): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 1, p. 276-277 (in English) (Authors at V.I. Vernadsky Institute of Geochemistry and Analytical Chemistry, Moscow, USSR).

1. Until now the quantitative theory of hydrothermal mineral formation does not yet exist. The absence of different ways for studying the deposition processes, particularly, the absence of close connection between experimental and geology-mineralogical investigations is one of the reasons.

The attempt to investigate the formation of one of the most widely distributed vein minerals - barite - and some of its natural associations, has been made by the authors of this paper.

2. As the result of geological and mineralogical study of barite in the Caucasus and Middle Asia, and investigations via gas-liquid inclusions, the ideas of chemical contamination (sic) of barite-forming solutions, their evolution during deposition processes, and the sequences of mineral formation

have been received.

It was decided that barite formation in all studied deposits took place at relatively low temperature (<150°C) from chloride and chloride-carbonate solutions of alkali and earth-alkali metals. One distinctive feature of these solutions is their high concentration of Ca^{2+}.

3. The experimental determination of barite solubility in solutions comparable with hypothetical barite-forming ones at temperatures from 100° to 350°C has shown that temperature curves of barite solubility are complicated. It is affected at one hand, by the effect of electrolytic background and, at the other hand, by the solid state phase forming of sulfate and complex sulfate combination, which are formed with chloride cations.

4. Testing of experimental data of barite solubility with the theory of strong electrolytes has allowed us to calculate the products of $BaSO_4$ activity in the range of room temperature and 350°C and independently - the steadyless [sic] constants of already known complexes $CaSO_4$ and $MgSO_4$.

5. Possibility of forming high-temperature anhydrite, which had been formed before barite and then had been dissolved during the following evolution of barite-forming solution, has been theoretically predicted. This supposition has been confirmed with the find of anhydrite relicts as mineral inclusions, formed before barite.

6. The results of this work, in comparison with the anhydrite, calcite, and witherite solution data, tested on the basis of strong electrolyte theory, allowed us to determine stability conditions of general minerals of sulfate-carbonate associations and to consider the possible causes of their formation. (Authors' abstract).

UCHAMEISHVILI, N. E., RYZHENKO, B. N., and SAVEL'EVA, N. I., 1971, Method of determination of pH of hydrothermal solutions, in Investigations of mineral-forming solutions and melts in inclusions in minerals, N. P. Ermakov and L. N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials, (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 106-109. (in Russian)

ULRICHOVA, Daria, & BRADAC, Ladislav, 1971, Decrepitation and optical methods applied to inclusions in minerals: Vestn. Ustred. Ustavu Geol. 1971 v. 46, no. 4, p. 193-208 (in Czech). CA 75 (26) 153693b (1971). Authors at Ustred. Ustav. Geol., Prague, Czech.

A fully automatic app. is described which records the decrepitation effects of minerals upon heating from 20 to 1000°. Decrepitation is most intense within the frequency range 1000-4000 Hz. The frequency analyzer makes it possible to use the frequency range with max. acoustic phenomena and to eliminate the background sounds of low frequency. The input potentiometer in the recorder enables one to note even very slight decrepitations. Results of decrepitation analyses of quartz, fluorite, wolframite, cordierite, cassiterite, topaz, beryl, and apatite from various Czechoslovakian localities are given. Temps. of decrepitation are compared with the homogenization temps. for some minerals as measured optically on 2-phase inclusions.

UNKSOVA, M. V., 1971, Conditions of formation of the principal minerals of quartz-and fluorite-bearing "cellars"(?) in granitic pegmatites, Kazakhstan, in Investigations of mineral-forming solutions and melts in inclusions in minerals, N. P. Ermakov and L. N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 52-56 (in Russian)

URUSOVA, M.A., & RAVICH, M.I., 1971, Vapour pressure and solubility in the sodium chloride-water system at 350° and 400°C: Russian Journal of Inorganic Chemistry, (English translation), v. 16, no. 10, p. 1534-1535.

The authors determined the vapour pressure of aqueous solutions of sodium chloride over the entire range of concentrations up to saturation and also the solubility of the salt at 350° and 400°C:

NaCl mass %	ρ, kgf cm^{-2}	NaCl mass %	ρ, kgf cm^{-2}	NaCl mass %	ρ,kgf cm^{-2}
350°C				400°C	
10.0*	155.5	3.0*	290.5	29.8*	228
11.0	153	4.0	288	30.1*	227
20.0*	141.5	5.0*	285.5	32.3	221
21.3	139	5.0	285.5	39.1*	201.5
21.6	138.5	6.5	282	41.3	192
30.0*	126	8.6	276	43.1*	187.5
31.3	125	10.0*	275	45.6	179.5
31.4	123.5	13.9*	264	48.3**	176
37.6	113.5	20.0*	253	49.5**	176
40.7	109.5	25.1	239		
43.9**	107.5				
45.4**	107.5				

*Results obtained from the break in the ρ-V curves (in other instances, in the presence of vapour phase, with a correction for the concentration of the solution).

** Saturated solutions in the presence of solid phase. (E.R.)

VASIL'EV, V. I., DOLOMANOVA, E. I., KOSTYLEVA, E. E., and PETROVSKAYA, N. V., 1971, Some morphological features of gas-liquid inclusions in ore-bearing quartz (from electron microscope data), in Investigations of mineral-forming solutions and melts in inclusions in minerals, N. P. Ermakov and L. N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 116-129. (in Russian)

The shapes and distribution characteristics of numerous gas-liquid inclusions in chips of ore-bearing quartz were examined under the electron microscope. A considerable variety in the shapes of cavities in different types of quartz was noted. A tendency was noted for an increase in the complexity of the form of inclusions in quartz on going from pegmatitic and deep-seated hydrothermal occurrences to shallow occurrences. Simultaneously there was an increase in the quantitative role of inclusions of irregular shape related to intergranular spaces. Certain additional criteria for differentiating between primary and secondary inclusions were examined in electron microscope images. The differences between primary intragranular and intergranular cavities were noted. The morphologies of inclusions in quartz crystals from several occurrences were compared. (S. Theokritoff).

VERDIER, J., & DEICHA, G., 1971, The distribution of epigenetic fluid inclusions as evidence of rock microfissuration: Symposium Soc. Internat. Mécanique des Roches, Nancy, 1971, paper 1-10 (11 unnumbered pages).

A new method of studying microfissuration is described, based on special microscopy of alignments of secondary inclusions that is pertinent to engineering geological problems.

In particular, the most recent physical effects to which the rocks have been subjected, which alter their mechanical properties, may be shown by burst primary or secondary inclusions. Examination of intergranular pores (especially with a scanning electron microscope) reveals new factors affecting intercrystalline adherence.

The absence of fluid inclusions in microfissures means that they have been opened and allowed to communicate with the surface. This is a possible additional means of checking the quality of the rock in excavations. (Authors' abstract, revised.)

VERES, G.I., 1971, Apparatus and ampul for the thermobarographic study of geochemical samples: Vop. Prikl. Geokhim. 1971, no. 2, p. 186-188, (in Russian). CA 77 (6) 77736s (1972).

The highly effective app. for thermobarog. study of geochem. samples for the detn. of the relative vol. of gas-liq. inclusions in minerals consists of a tubular resistance furnace, reaction vessel, vacuum device, and electronic potentiometer for registering thermobarographs. The thermobarometric ampul is devised for measuring the decrepitation temp. of gas-liq. inclusions and cols. of gas and liq. in inclusions in minerals for interpretation of geochem. anomalies.

VERGNOUX, A.M., RIERA, M., RIBET, J.L., & RIBET, M., 1971, Étude par la méthode de Lang, de l'évolution des défauts dans la croissance en solution de cristaux ioniques et moléculaires: Jour. Crystal Growth, v. 10, p. 202-204 (in French).

Lang topography shows bundles of dislocations traversing the crystals from the seed to the external faces. (Of pertinence to origin and leakage of fluid inclusions, E.R.)

VERTUSHKOV, G.N., 1970, "The closed pipe" and its use for determining the quantity and composition of fluid inclusions in vein quzrtz: Mineraly izverzhennykh i metamorficheskikh gornyky porod Urala, Adad. Nauk SSSR, Ural. Filial, Inst. Geol. Geokh., Tr., no. 86, p. 44-52, (in Russian).

VLASOV, K.A., KUZ'MENKO, M.Z., & ES'KOVA, E.M., 1959, The Lovozero Alkali Massif: Moscow, Acad. Sci. USSR Press, (in Russian). Translated, Hafner Pub. Co., N.Y., 1966, 627 pp.

This is an old reference, but included here since Lovozero is one of the alkalic intrusives on which considerable inclusion work has been done, and the editor was unaware of this English translation. Unfortunately, although the book covers much geological and mineralogical detail, inclusions and thermometry are not listed in the index and seemingly not mentioned in the text. (E.R.)

VOLYNETS, V. F., ZADOROZHNY, I. K.,+ FLORENSKY, K. P., 1971, Isotopic composition and geochemical behaviour of gaseous components in the hydrothermal process (abst.): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 1, p. 230-231 (in English) (Authors at V.I. Vernadsky Institute of Geochemistry and Analytical Chemistry, Institute of Cosmic Exploration, USSR Academy of Sciences, Moscow)

1. The geochemical behaviour of microcomponents and, especially, of gaseous components in the hydrothermal process has been studied very little.

2. This investigation established the concentration limits of chemically bound nitrogen (ammonium) in solutions of inclusions in quartz (0.10-0.84g/l). A higher level of ammonium concentration characterizes the solution of inclusions in fluorites (0.84-3.60 g/l). Quartz and the nearly synchronous fluorite may differ ten times in their ammonium content. This difference is still greater for the antimonites studied. Here the difference in ammonium concentration already reaches two orders of magnitude.

3. As the geochemically molecular nitrogen is usually considered together with argon and helium, the distribution and the isotopic composition of N_2, He, Ar, Kr and Xe in thermal waters have been studied. Against the background of "usual" Ar/N_2 and He/N_2 ratios, the ratio of Kr and Xe concentrations proved to differ strongly from the aerial one. The isotopic compositions of ammonium and molecular nitrogen, argon and xenon were found to be changed in comparison with their aerial ratios. Of special interest is xenon, the isotopic composition of which differs from the isotopic variation of Xe of the Earth crust, and approaches primary xenon. The chemical and isotopic composition of gaseous components may serve as a criterion of the depth at which the process occurs.

4. The thermodynamical calculations and the data obtained permit estimates of the stability of different chemical nitrogen compounds in the solution at elevated pressures and temperatures. (Authors' abstract).

VOZNYAK, D.K., KALYUZHNYI, V.A., & SOROKIN, Yu. G., 1969, Accessory bertrandite from the Volynian residual pegmatites: Mineral. Sborn., L'vov. Geol. ob., v. 23, no.1, p. 81-84, (in Russian).

Bertrandite is an accessory mineral found in the Volynian pegmatites.

It grows with muscovite from the alteration of beryl by potash-bearing solutions. The crystals are up to 4 mm in size, tabular, with (001), (011) and (100) as major faces. Primary fluid inclusions (negative crystals) in bertrandite give homogenization temperatures of 150°C; secondary inclusions give 140-150°C, in the liquid phase. (B.Poty)

VYNAR, O.N., PIVOVAR, I.G., & RAZUMEEVA, N.N., 1971, Inclusions in genthelvite: L'vov. Gos. Univ. Mineral. Sbornik, v. 25, no. 1, p. 59-63 (in Russian).

Decrepitation occurred at 360-525°C (primary) and about 160° (secondary). (E.R.)

WENGERT, P.R., & BAYARD, Michael, 1971, Analysis of crystals in bubbles in glass: Amer. Ceramic Soc. Bull, v. 50, no. 12, p. 976-981. Authors at Owens-Illinois, Inc., Toledo; and Walter C. McCrone Assoc., Inc., Chicago.

Analysis of gases in bubbles neglects the important possibility that a gaseous species causing the bubble at molten glass temperatures may be solid at room temperature. Analysis is not complete unless the bubble is examined for solid deposits. In the method developed, the crystals are removed from the bubble in a fluid plastic and transported to a suitable substrate. Optical microscopy, electron probe microanalysis, X-ray diffraction and electron diffraction have been used to analyze particles of diameters as small as 0.05μm. Bubbles of diameters down to 20μm have been examined. Advantages of the technique are (1) avoidance of the optics associated with the curved bubble surface; and (2) the crystals are protected from hydration. Crystals in bubbles in three types of commercial glass have been analyzed. (Authors' abstract)

WHITE, D.E., MUFFLER, L.J.P., & TRUESDELL, A.H., 1971, Vapor-dominated hydrothermal systems compared with hot-water systems: Econ. Geol. v. 66 p. 75-97.

Vapor-dominated ("dry steam") geothermal systems are uncommon and poorly understood compared with hot-water systems. Critical physical data on both types were obtained from U.S. Geological Survey research in Yellowstone Park.

The main vapor-dominated reservoir actually is a two-phase heat-transfer system. Vapor boiled from the deep (brine?) water table flows upward; most liquid condensate flows down to the water table, but some may be swept out with steam in channels of principal upflow.

We suggest that vapor-dominated systems provide a good mechanism for separating volatile mercury from all other metals of lower volatility.

A more speculative suggestion is that porphyry copper deposits form below the deep water tables hypothesized for the vapor-dominated systems. Some enigmatic characteristics of these copper deposits are consistent with such a relationship, and warrant consideration and testing. (Authors' abstract, abbreviated)

WILCOX, W.R., & LEON, Alberto, 1971, Twinning of potassium bromide: Journ. of Crystal Growth, v. 8, p. 230-234. Authors at University of Southern California, Los Angeles, California 90007, U.S.A.

Large numbers of [211] penetration twins were formed when KBr reagent from one supplier was crystallized from water by evaporation. Most of these were butterfly twins while a few were interpenetrating cubes. Some lots of reagent from another supplier also produced twins while other lots did not. The non-twinning KBr was of an overall higher purity than that which produced twins. Twin formation appeared to be stimulated by Na^+, Cl^-, and Thiazine Red R. Trace amounts of $PbCl_2$ prevented twinning. The maximum yield of twins was obtained at intermediate growth rates. The interface surface was not a twin plane but varied widely in orientation. A model showed that the twin intersection forms a step much like that of a screw dislocation at the tip of the butterflies. Experimentally it was found that growth layers originated from this tip and later coalesced to form large waves which trapped tubular inclusions. (Authors' abstract)

WILCOX, W.R., & SHLICHTA, P.J., 1971, Movement of Crystal inclusions in a centrifugal field: Jour. of Applied Physics, v. 42, no. 5, p. 1823-1827. Authors at University of Southern California, Los Angles, California 90007, and McDonnell Douglas Corporation, Huntington Beach, California 92647.

A centrifugal field can cause migration of solvent inclusions in crystals, both by the preferential sedimentation of the denser solute ions and by diffusion across the concentration gradient caused by the variation of solubility with pressure. The two mechanisms can act either in the same or in opposite directions so that both centripetal and centrifugal migration are possible. Aqueous inclusions in KI were observed to move centripetally at about 0.05 mm/h at room temperature in centrifugal fields of 210,000 G; at higher temperatures the direction of migration was reversed. Inclusion movement was also observed in KCl and $Pb(NO_3)_2$. Plastic deformation, cracking, and changes in inclusion shape were also encountered. (Authors' abstract)

YAJIMA, J. and KOMATSU, M., 1971, Studies on solid inclusions in the phenocrysts of some volcanic rocks: Soc. Mining Geol. Japan, Spec. Issue 3, p. 369 (Proc. IMA-IAGOD Meetings '70, IAGOD vol.)

Microscopic observations, thermometry and chemical analyses of two-or three-phase solid inclusions in the phenocrysts such as olivines, pyroxenes, feldspars and quartz which occur in various volcanic rocks are presented.

Three types of solid inclusions are observed. e.g., (1) silicate crystal + glass + bubble(s), (2) glass + bubble(s), and (3) devitrified glass + bubble. Type (1) is common in olivines and pyroxenes, meanwhile type (2) is abundant in feldspars and quartz. In olivines, spinel is often observed as a solid inclusion or as a crystal phase in a glass inclusion. Thus, the spinel may be considered as a crystal which had been formed before crystallization of olivine. Solid inclusions are always primary and secondary inclusions are hardly seen.

Table 1. Chemical Compositions of Glass Inclusions

	1	2	3	4	5	6
SiO_2	59.45	48.66	51.65	57.02	78.27	75.10
TiO_2	0.19	1.37	2.72	2.43	-	-
Al_2O_3	24.42	19.26	19.25	16.85	13.51	12.78
FeO*	1.40	7.31	7.61	6.09	0.93	0.86
MgO	0.14	4.94	6.11	2.88	0.07	0.16
CaO	7.77	11.37	10.58	11.58	1.46	0.53
Na_2O	2.9	2.3	1.9	2.5	5.0	2.9
K_2O	1.4	2.2	0.3	0.4	0.2	5.5
Total	97.67	97.41	100.08	99.75	99.44	97.83

Samples 1 Olivine in picrite (Sado, Japan)
2 Olivine in olivine basalt (Oshima-oshima, Japan)
3 Olivine in olivine basalt (Kilauea, Hawaii)
4 Olivine in olivine basalt (Mauna Loa, Hawaii)
5 Hypersthene in dacite (Showa-shinzan, Japan)
6 Quartz in quartz porphyry (Jozankei, Japan)

* Total iron.

Chemical compositions of these glass inclusions were determined by an electron probe microanalyzer. Specimens mounted in plastic were polished on one surface. The grain which contained glass inclusions just on the polished surface was selected under binocular microscope and was analyzed. A few examples of the results are given in Table 1.

Glass in olivine is composed mainly of silica, alumina, lime and small amounts of Fe and Mg. When plotted on the silica-alkali and MgO-Total iron-alkali diagrams, glass in olivine of the tholeiitic basalts falls in the tholeiitic field and that of alkali basalts in alkali basaltic field. The ratio $(Mg/Mg + Fe)_{ol}(Mg/Mg + Fe)_{glass}$ in the present case ranges between 2 and 3, whereas the same ratios in some

Hawaiian basalts are 1.3-1.4. From this difference as well as the chemical composition of the glass inclusions, it may be inferred that the glass inclusions represent the residual liquids after the crystallization of olivine.

Glass in hypersthene in dacite (Showa-shinzan) which contains abundant silica and alumina with minor alkali has same composition as groundmass of the host dacite (Oba, 1967).

Glass in quartz is also very rich in silica and alumina, showing the nature of the residual liquid when all phenocrysts had crystallized. Authors' abstract.

YPMA, P.J.M., & SIMONS, J.H., 1969, Genetical aspects of the tin mineralization in Durango, Mexico (abstr.): Geol. Soc. Thailand Newsletter, v. 2, no. 4, p. 22-23.

The tin belt in Durango and Zacatecas is closely related to rhyolites+latites and the inclusions are low temperature and low salinity. (E.R.)

YUDIN, I.M., 1969, Copper deposits of Kounrad: Izd. Moscow Univ., Moscow 1969, (sic., as quoted in Bogoyavlenskaya, et al., 1971, in this volume).

YURK, Yu. Yu., MARCHENKO, E. Ya., LUM'KO, V.P., & PONOMAR'OVA, R.G., 1971, Willemite from apogranitic metasomatites: Dopov. Akad. Nauk Ukr. RSR, Ser. B. 1971, v. 33, no. 6, p. 536-538, (in Ukrainian). CA 75(10) 101 (1971). Authors at Inst. Miner. Resur., Simferopol, USSR).

Data are presented on the occurrence, chem. compn., and phys. properties of willemite from apogranitic metasomatites. The formula of willemite, obtained on the basis of chem. anal. and IR spectra, is close to theoretical. The mineral also contains Be 0.1-0.25, Nb 0.01, Ti 0.025-0.05, Zn, Pb, and Sn 0.001-0.0025%, and traces of Ge, In, and V. The homogenization of gas-liq. inclusions in willemite indicates that it was formed at 490-60°.

ZAKHARCHENKO, A. I., 1968, The formation of mineral-forming solutions and ore bodies associated with granite, in Problems of regional metallogeny and endogenic ore formations (1966): Vses. Nauchno.-Issled. Geol. Inst. (VSEGEI) Trudy, no. 155, p. 81-103 (in Russian)

A review of Zakharchenko's extensive work on inclusions in granites and pegmatites, and of the literature in the field, including gas analyses and a table (#6) of 20 analyses from various pegmatites, greisens, skarns, and hydrothermal veins, for Cl, F, SO_4, HCO_3, K, Na, Mg, Ca, and pH. (ER)

ZAKHARCHENKO, A. I., 1971a, Gaseous-congealed inclusions of residual melt in granites, aplites, and pegmatites, and their role in the knowledge of granites and the genesis of pegmatites, in Investigations of mineral-forming solutions and melts in inclusions in minerals, N. P. Ermakov and L. N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials, (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 66-75, (in Russian).

The examns. were made to explain differentiation and ore-specialization of the magmatic complexes as well as the formation of the early magmatic deposits of many important minerals. Expts. were carried out at 659-100°, at 100-2500 atm. during 2-5 yrs. The inclusions are residues both of the melts and the soln.-melts forming the surrounding rocks. They are composed of 70-80% solid phase and 20-30% gaseous, both contg. much Li and F. Pegmatites were formed from the light fusible residual melts, contg. a lot of volatile components, taking part in the formation of the most differentiated internal zones. An increase of the amts. of the light volatile components (LV) (N_2, H_2, CO_2, halogens, etc.) was accompanied by enrichment in the rare elements (RE), but H_2 and other reducing agents prevented that process. Thus, the high-temp. magmatic formations do not contain any high concns. of RE. LV react both as fluxes and carriers for some compds. CA 78 (10) 127008z (1973).

ZAKHARCHENKO, A. I., 1971b, On specialization of granites and conditions of formation of related ore deposits (abst.): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v. 2, p. 670-671 (in English) (Author at All-Union Geological Research Institute (VSEGEI), Leningrad, USSR).

At present it has been well established that there is a regular petrochemical specialization of successive phases of intrusive rock complexes (units) from predominantly basic ones to more acid and more alkaline ones with different ore content (Vinogradov, 1962; Taylor, 1964, etc.). Such specialization can be clearly observed in post-orogenic complexes; it is usually explained by crystallization differentiation. The author has carried out the geological-petrochemical investigations and studies of fluid inclusions of the granites in Kazakhstan and other regions of the USSR; he succeeded in determining in a more precise manner the chemical and dynamic properties of petrochemical and ore specialization of these granites and of formation of certain ore deposits.

1. The specialization of the rocks has been established which leads to the formation of two branches of granites; a) adamellites and plagiogranites greatly enriched in Na and Cl; and b) potassium granites up to alaskite which are greatly enriched in fluxing rare alkalies and, apart from Cl, in F, B, and others. In the former granites, Na and Cl are good mobilizers, especially during the post-magmatic period, of Pb, Zn and partly Cu, and it is precisely with such granites that the ore deposits of these metals are associated (the Zmeinogorak complex of rocks and Pb and Zn deposits of Rudny Altai). In the latter granites the increase in the content of K, rare alkalies and F is accompanied by the accumulation of rare metals (W, Sn, Mo and others). The deposits of rare metals or chamber pegmatites are associated with such granites.

2. In deeply exposed post-orogenic massifs of K-granites one can often observe, in the upward direction, an extremely gradual phase transition of increasingly specialized rocks with accumulations of fluxing F, Li, Rb, etc., and with the great increase in gas content or porosity due to escaped volatiles. The above facts as well as the presence of more and more easily fusible specialized gas-solidified inclusions of former melts, and experimental data, have permitted the author to establish, in addition to crystallization differentiation, the presence and intensive development of emanation differentiation which plays an important role in the processes of differentiation and specialization of granites.

3. It has been established that in the granites specialized into rare metals, the formation of W, Mo and Sn deposits takes place during the early hydrothermal stage only in the areas of active tectonic movements closer to the more specialized varieties of granites. However, in the similar granites formed under more quiet conditions there are no rare metal deposits in spite of frequently more distinct specialization of granites; instead, one can observe accumulations of chamber pegmatites. Such selective conditions, as well as the place and time of formation of the rare metal deposits, on one hand, and of chamber pegmatites, on the other hand, are due to specific features of the late- and post-magmatic emanations (Khitarov, 1967; Kadik, 1965; Zakharchenko, 1968) and completely different dynamic characteristics of their formation. (Author's abstract).

ZARKA, Albert, and TOURAY, Jean-Claude, 1971, Microstructures and inclusions in dolomite geode crystals, Eugui, Spain; optic and thermometric data; topographic x-ray analysis: Acad. Sci., C.R. Ser. D., v. 272, no. 6, p. 769-771 (in French).

ZATSIKHA, B.V., BOYCHUK, M.D., & BOCHKOV, A.A., 1969, Conditions of formation of the accessory mineral holmquistite of the Priazov' region: Akad. Nauk SSSR, Geol. Zhurnal, v. 29, no. 2, p. (in Russian).

The tectonic zone of Sorokinsk (Priazov' region) shows pegmatites in gneisses and amphibolites with associated hydrothermal veins. Those veins contain tourmaline, biotite, apatite, and quartz. Accessory holmquistite comes from the alteration of biotite. Holmquistite occurs in grey-blue radiated masses (2-3 cm) which are syngenetic with grey quartz and spodumene. The chemical analysis of holmquistite gives the following formula:

$$H_3O_{.25}Na_{.03}Li_{1.60}\ [Mg_{1.97}Fe^{++}_{0.93}Mn_{.04}Ca_{.04}]\ 2.98$$

$$[Fe^{+++}_{.79}Al_{1.24}]\ 2.03\ [Si_{8.04}O_{22}]\ (OH)_{1.96}F_{.04}$$

Thermodifferential curves show an endopeak at 945°C and an exopeak at 965°C. Fluid inclusion studies show heterogeneous, CO_2-rich, secondary inclusions and low-temperature fluid inclusions in quartz associated with tourmaline. Primary gas-liquid inclusions without CO_2, in tourmaline, homogenized at 345-325°C in the liquid phase; - in apatite early secondary inclusions had T_H 290°C. Secondary inclusions had T_H 290°C; and - in spodumene secondary inclusions had T_H 235-200 and rarely 145-135°C. Leachates of spodumene give the following results (corrected for the solubility of spodumene):

	Na^+	Li^+	Ca^{++}	Mg^{++}	Mn^{++}	Total
mg. equiv.	.005	.110	.004	.003	.001	.123
	Cl^-	SO_4^{--}	HCO_3^-	CO_3^{--}		Total
mg. equiv.	.004	.011	.063	.012		.090

The crystallization is: tourmaline, biotite, apatite with amblygonite, montebrasite, spodumene and holmquistite, sulfides. Hence the solutions were essentially lithium-bicarbonate-rich and temperature was at a minimum of 290-200°C when the holmquistite was formed. (B. Poty)

ZATSIKHA, B. V. and LYASHKEVICH, Z. M., 1971, Physico-chemical features of fluoritization, associated with Proterozoic syenites of the eastern near-Azov region, in Investigations of mineral-forming solutions and melts in inclusions in minerals, N. P. Ermakov and L. N. Khetchikov, eds., All-Union Institute for the Synthesis of Raw Materials (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, p. 40-44, (In Russian).

ZEVAKIN, N. N. & MOSKALYUK, A. A., 1971, On physico-chemical conditions of formation of hydrothermal quartz veins in West Pamirs (abst.): International Geochemical Congress, Moscow, 1971, Abstracts of Reports, v.1, p. 360-361 (in English) (Authors at All-Union Geological Research Institute (VSEGEI) Leningrad, USSR).

The hydrothermal quartz veins of West Pamirs are found mainly in the rocks of sedimentary - metamorphic sequences represented by sandstones, quartzites, shales and marbles. The rocks form folds of north-eastern trend; they are intruded by granitoids.

Most of quartz veins (66%) are confined to sandstones and quartzites. 18% of quartz veins are found in shales, 9% - in granitoids, 6% - in marbles and 1% in amphibolites.

The distribution of crystal-bearing veins is as follows: sandstones and quartzites - 89%, marbles and granitoids - 5%, shales - 1%. No crystal-bearing veins have been found in amphibolites.

The non-crystal-bearing quartz veins are characterized by slight near-vein alteration of rocks, essentially silicification. The rock alteration near the crystal-bearing veins is sericitization, carbonatization, albitization and kaolinitization, mainly near the crystal-bearing cavities.

The quantitative characteristics of loss and addition of main components in the course of these alterations have been obtained. The loss of SiO_2 in the course of the near-vein alterations of sandstones is equal to 400-700 kg/m^3, reaching sometimes 1290-1480 kg/m^3.

The thermometric studies have shown that formation of quartz veins and rock crystal which took place when temperature was dropping from 450-400°C to 150-130°C, was due to a single geological process. The non-crystal-bearing quartz veins were formed within a narrow temperature interval (450-400°C) irrespective of enclosing rocks. The crystal-bearing quartz veins and rock crystal are characterized by a wider temperature range of formation, from 400-300°C to 200-150°C.

The inclusion liquids in crystal-bearing quartz veins in the West Pamirs are characterized mainly by a potassium chloride composition. As for concentrations, these liquids are brines (800-1000 grams per liter).

The experiments on solubility of silica and other components have shown the solubility of SiO_2 (at $t = 275°C$ and $P = 800$ atm.) equal to 0.81 g/l in water, 1.59 g/l in alkaline medium and 1.63 g/l in acid medium. According to geological and experimental data, the silica required for formation of rock crystal was dissolved from enclosing rocks by alkaline solutions as well as acid ones. (Authors' abstract).

ZHUZE, T.P., SERGEYEVICH, V.I., BURMISTROVA, V.F., & YESAKOV, Ye. A., 1971, Solubility of hydrocarbons in water under stratal conditions : Akad. Nauk. SSSR Doklady, v. 198, no. 1, p. 206-209 (in Russian). Translated in Doklady Acad. Sci. USSR, v. 198, p. 211-214 (1971). Authors at Institute of Geology and Extraction of Mineral Fuels, Moscow.

An experimental study pertinent to the problem of the origin of immiscible hydrocarbon droplets in fluid inclusions, and other aspects. (E.R.)

TRANSLATIONS SECTION

Items presented here are selected on the basis of 1) availability of translation, 2) significance to inclusion research, 3) lack of publication elsewhere, and 4) date of publication. Some older items are thus included where particularly significant. Photographs do not reproduce well and are generally not included, but the photo caption translations are given. No attempt has been made to bring the rather obscure Russian literature citations up to Western bibliographic standards. (Ed.)

ANDRUSENKO, N.I., TIMOFEEVSKY, D.A., GREBENCHIKOV, A.M., and ADRIANOVA, S.I., Formation temperatures of gold-ore deposits on inclusions in minerals: (Authors at Nonferrous, Rare, Precious Metals Institute, Moscow, USSR). (Editor's note: This paper was submitted for the 1972 COFFI Symposium at Montreal, but was only read by title there, and was received too late for inclusion in the previous volume of COFFI. As Dr. Andrusenko has kindly provided an English translation, it is presented here, after extensive editing).

U.S. and Canadian scientists were the first to study inclusions in the minerals of gold-ore deposits. Phillips (1868) discovered liquid inclusions in quartz in several gold deposits of California and got the first information on their homogenization, at 80,100 and 185°C. Courtis (1890) noted that quartz from rich ore, as compared to quartz without gold, contains many more primary inclusions. Beck and Weed (1909) found inclusions of solutions with liquid carbon dioxide and determined the temperature of disappearance of the gas bubble at 30°C. Bruce (1941) made the first chemical analyses of inclusions in quartz, from the Sturgeon River deposit (Canada) which showed the presence of highly concentrated (15%) chloride and sulfate solutions with potassium, sodium and in smaller degree calcium and magnesium. Smith (1948, 1951) and Boyle (1954) made the first decrepitation studies of quartz from gold mines of Ontario, Quebec and the Yellowknife region (Canada) and found that the temperature of explosion increases with depth; the direction of the movement of solutions, in their opinion, may be defined with the help of gradients in decrepitation temperatures.

Later Roumanian scientists Savul, Pomîrleanu, Manilici, and Borços (1966), discovered that the formation temperatures of quartz veins in North Dobruga and Transylvania were 350-250°C and 200-150°C, according to the data of homogenization of the inclusions. Miyazawa (1971) found that the hydrothermal gold-silver veins of Japan were formed at 230-180°C. Rozshkov and Andrusenko (1972), with the help of homogenization of inclusions, determined two ranges of temperatures of quartz formation from the large, deep, Kolar gold deposit (India, State of Mysor); they are 380°-320°C and 290-180°C.

The thermometric study of minerals from gold-ore deposits in the USSR began to develop widely during the last two decades (Koltun, 1958; Lyakhov and Piznyur, 1970; Goncharov, et al., 1972; Moiseenko and Phautyanov, 1971 and many others). The most complete information concerns the gold ore regions of Transbaikalia, Northeastern Asiatic USSR, and the Urals, and the deposits of Kusnetsky Alatan, Kazakhstan, Middle Asia, and Salair have been studied less thoroughly. Although the thermometric results are incomplete, their comparison gives a general idea of the temperature peculiarities of formation of gold ore deposits.

The common feature is that the temperature often depends on the depth of formation of deposits. The majority of thermometric investigations of gas-liquid inclusions show that the temperature of mineral formation of near-surface deposits are not more than 420°C, while in deep deposits the range of temperature extends to 600°C (sometimes to 800°C). This explains why skarn formation, greisenization, high temperature automorphism, etc., often precedes productive mineralization.

The state of aggregation and the type of homogenization of inclusions indicate also another difference between the deposits of different depth. Deep deposits are polygenetic pneumatolytic-hydrothermal, sometimes with repeated presence of high temperature gas-liquid fluids (Darasunsky deposit), while the near-surface deposits are only hydrothermal. The activity of gaseous fluids there can take place .
additional intrusives.

Thus, the inclusions of gaseous solutions in the minerals of gold deposits may to some extent be a criterion for their depth, for the nearness of magmatic bodies, and an indication of repeated intrusions during the formation of deposits. For example, in the Kochkarsky deposit the phenomena of pneumatolysis is verified by inclusions homogenizing according to the second type, in quartz-tourmaline formations (t = 450-370°) in the late ore-stage, after hydrothermal solutions were active. This is explained (Yermakov, 1970) by the influence of a new intrusion, the "alaskite" magma.

Syngenetic gas-liquid inclusions of different density, but with similar homogenization temperatures, result from effervescense due to sudden drops in the pressure of the mineralizing medium and hence indicate shallow depths. In addition, pressure fluctuations cause interstage and intrastage inversion temperatures up to 150°C, as determined on inclusions from many deposits (Agatovsky, Arkharly, Itaka, Ogancha, Pyasbashy etc). On the whole the temperature regime of gold-ore deposits is characterized by decreasing temperatures.

Judging from the state of aggregation and the type of homogenization of the inclusions, the gold bearing mineral complexes in the deposits of all depths were deposited from hydrothermal solutions. In the near-surface deposits the productive mineralization occurred at 360-100°C. In the medium and deep deposits the temperature interval of gold mineralization is a little wider (410-100°). The temperature of crystallization in the typical intermediate depth deposits was almost the same as in those that had been formed in the interval between near-surface and hypogene deposits. In the first case the range of productive mineralization is 380-100°C; in the second and the third case it is correspondingly 410-140 and 400-100°C.

Gold mineralization in deposits of various types occurred at different temperature intervals, and sometimes several different productive stages, with different temperature ranges, may be observed in a single deposit. The most common temperature interval for the gold mineralization of all stages is the range from 250 to 120°C.

The temperature drop during gold deposition for any given stage covers a wide range: in near-surface deposits it is 5 to 140°C (generally 25-50°); in intermediate depth deposits it is 15 to 205°C (generally 45-95°); and in the deep deposits it is 100 to 200° (generally 100°). Thus, this temperature drop tends to increase with increase in depth.

The main part of the gold mineralization within any one productive stage, as determined by homogenization of sygenetic inclusions in quartz in gold nuggets, occurs over a temperature drop of not more than 5-50°C (LyaKhov and Piznyur, 1970; Davidenko, 1968).

The fineness of gold in deposits of all depths changes over a wide range (Table 1). In near-surface deposits this range is from pure silver to pure gold; in intermediate and deep deposits it is from pure gold to electrum. As we know, many investigators considered the question about the reason of variation of fineness of gold and the gold-silver ratio in gold-ore. They tried to connect this parameter with the depth and formation temperature of the deposits.

Analysis of the data on USSR gold-ore deposits shows that the fineness of gold is related to the depths and temperatures of formation. Thus, groups of near-surface deposits, formed at 360 to 300°, had gold with fineness from 220 to 960, and at those formed 250 to 190° and 145-105°C had gold with a fineness 120-966 and 468-325 correspondingly. The same is found if we compare data on intermediate and deep deposits, in which the fineness of gold varies only from 472 to 1000 in minerals that were formed at different temperatures and depths.

The wider range of variations in fineness in the near-surface deposits must be connected with the greater range of physical and chemical parameters of mineral formation on this level. The prevalence of gold of low fineness in such deposits is apparently caused by rapid cooling at near-surface conditions (Samusikov, 1970). The data above show that gold finess does not depend on the temperature of the mineral-forming solutions.

The same may be said about the gold-silver ratio in different deposits. In similar depth deposits there is no connection between the gold-silver ratio and formation temperature. For any given depth there may be a deposit ranging from gold-rich (Au/Ag 1.0-10.0) to silver-rich (Au/Ag 0.1).

Thus the following conclusions can be drawn:

1. The temperature interval of mineral formation for intermediate and deep gold deposits was 600-50°C and for near-surface deposits 420-50°C.

2. According to the state of aggregation and the type of homogenization of inclusions, intermediate and deep deposits are pneumatolytic-hydrothermal while near-surface deposits are exclusively hydrothermal.

3. The gradual temperature drop during deposition that is characteristic of most deposits is broken by sharp (up to 150°C) interstage and intrastage increases and decreases.

4. Gold-bearing mineral assemblages in deposits of various origins are formed in the range 410-100°C. In this range productive and economic gold mineralization can occur at various temperature subranges, most frequently from 250° to 120°C. Temperature drops of 5° to 205°C occur in individual deposits, and are larger in the deeper deposits. The drop for any given mineralization stage does not exceed 20-50°C.

5. The fineness of gold and the gold/silver ratio are not controlled by temperature, but depend on other physico-chemical conditions.

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Laz'ko, E.M., Doroshenko, V.P., Koltun, L.I., Ljachov, Y.V., Mjaz N.I., and Piznyur A.V., 1971, O fisiko-chimicheskin usloviyah formirovaniya postmagmaticheskih mestorozshdeniy Vostochnogo Zabajkalya. Tezisi dokl. na mezshdunarodnom geohimicheskom kongresse, t.I, M.

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Fineness of gold vs. formation temperature and

Au/Ag ratio in near-surface deposits

Formation temp. of gold stage	Gold fineness	Au/Ag
360-300	220-960	0.02-1.5
250-190	120-966	
195-165	670-800	0.01-14.0
145-105	470-825	

Table 1.

Temperature conditions of formation and fineness of gold in Soviet gold deposits

Deposit	Temperature of mineralization °C		Temperature drop during gold mineralization	Gold fineness	
	Entire deposit	Gold stage	Median/extremes	Gold fineness	Gold fineness in deposits
Near-surface deposits	420-50	360-105	$\frac{25-50}{5-140}$	120-975	125-610
Intermediate depth and transitional to near-surface deposits	440 (to 530) - 50	410-140	$\frac{40-80}{20-150}$	500-1000	60-340
Intermediate and deep deposits	600 (to 860) - 30	405-100	$\frac{50-100}{15-205}$	470-1000	50-450

ANUFRIEV, YU. N., MOSKALYUK, A. A., and BELIK, D. M., 1971, Evolution of the composition of mineral-forming solutions on the basis of two deposits of rock crystal in the Urals, in Investigations of mineral-forming solutions and melts in inclusions in minerals, N.P. Ermakov and L.N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, (in Russian). [p.30-39]

On the basis of 110 analyses of the aqueous extracts from quartz crystals in two occurrences of rock crystal in the Urals a conclusion is made on the evolution of the composition of the mineral-forming solutions during the process of quartz formation in the sequence: quartz of the non-rock-crystal-bearing veins - quartz of the rock-crystal-bearing veins - crystals of rock crystal. The composition of the solutions changes from hydrocarbonate - chloride - calcium - sodium and chloride - calcium - sodium through chloride - sodium - calcium to chloride - sodium. The relations between the content of Na^+ in percent-equivalents and the total cation content in mgm-equivalents in solutions from quartz crystals from different groups are examined.

The results of the analyses of the aqueous extracts can be used for evaluating quartz veins when prospecting for hidden mineralization. (Authors' abstract).

Many data on the chemical affinity of the solutions in inclusions in minerals that have been published over the last few years (9, 10, etc.) confirm that the composition of these solutions is related to the geological environment in which the minerals formed. Such a relationship is not accidental and allows one to speak with absolute conviction on the principal similarity of the composition of the solutions in inclusions and of the solutions from which the crystals grew. Experimental evidence does not contradict this either (8, 11). Thus it becomes possible to determine from the liquid inclusions in minerals the character of the evolution of the composition of the mineral-forming solutions during the formation of mineral deposits. The discussion will be only about the evolution of the composition of the readily-soluble compounds, since only the latter are preserved in the solution in inclusions at the present time.

We investigated the change in the composition of solutions during the formation of two deposits of rock crystal in the Urals. Both deposits are located in the marginal part of the Eastern Urals Uplift, in the zone of the development of highly metamorphosed Siluro-Ordovician rocks (4).

The deposits differ considerably from each other in their geological-structural characteristics, but genetically they are similar. The quartz veins in both deposits are of hydrothermal origin, whereas druses of quartz are of metamorphogenic (lateral-secretion) origin.

In the deposits there are quartz veins with rock crystal and quartz veins without rock crystal. They are of the same age. As a result of superposed processes the vein quartz of the veins with rock crystal (especially that near the druses) was subjected to extensive recrystallization. The earliest-formed quartz is that of the quartz veins without rock crystal, whereas the latest is that of the quartz crystals in the druses. Recrystallized quartz of the quartz veins with rock crystal occupies a somewhat intermediate position.

A large number of samples (over 100) were taken from each of the three kinds of quartz from both deposits for investigating the chemical composition of the mineral-forming solutions. In studying the deposits of rock crystal such a bulk investigation of the chemical affinity of the solutions was made for the first time. The analyses were made by the aqueous extracts method described by A.I. Zakharchenko and A.A. Moskalyuk (6).

Depending on the relationship between the primary and secondary inclusions in the sample, the bulk composition of the solutions can undergo substantial variations, sometimes with a large deviation from the increases. On the average the Cl^- content increases from 67 to 84%-equivs, and Na^+ from 46.5 to 82.5%-equivs., with a simultaneous decrease in the HCO_3^- content from 28.5 to 13%-equivs., and of Ca^{+2} from 47 to 17.3%-equivs.

If in the first deposit the solutions in all types of quartz are chloride type then in the second deposit the solutions from the quartz of the veins without rock crystal have a bicarbonatic-chloride rather than a chloride composition with a considerable preponderance of HCO_3^- over Cl^-. Simultaneously, in their cation part there is a preponderance of Ca^{+2} over Na^+. The solutions are of the bicarbonate-chloride-calcium-sodium type ($HCO_3ClCaNa$). The evolution of the solutions in the second deposit occurs in the same direction as in the first deposit, i.e. through solutions of the ClNaCa type to solutions of the ClNa type. Moreover, the content of Cl^- increases from 33 to 64-65%-equivs., and of Na^+ from 44 to 78%-equivs., with a parallel decrease in the HCO_3^- content from 53 to 18%-equivs., and of Ca^{+2} from 52 to 18%-equivs. In all the types of solutions from the second deposit, the content of SO_4^{-2} and Mg^{+2} is more noticeable than in the first deposit, and during the evolution of the composition of the solutions it does not show any special tendency to decrease.

The change in the content of the four chief constituents in the solutions during their evolution is shown in fig. 3. The diagram clearly shows that the change in the relative content of the principal cations and anions in both deposits is in the same direction. Moreover, there is another peculiarity that is characteristic of the first deposit and that is not so well developed in the second deposit. It consists of a more rapid change in the composition of the cation part of the solutions (which is determined by the degree of steepness of the slope of the corresponding plot) in comparison with their anion part.

Interesting conclusions can be drawn from an examination of the change in the relative contents or individual constituents. An examination of the behaviour of, for instance Na^+, is illustrative. Fig. 4a, b shows the relationship of the Na^+ content, expressed in %-equivs., to the sum of all the cations contained in the solution, expressed in mgm-equivs. The first dimension reflects the percentage content of the cation examined in relation to the sum of all the cations contained in the solution. The second indicates the total content of cations in the sample, which as has been stated already, depends on the concentration of the solutions in the gas-liquid inclusions and on the total volume of these inclusions in the sample.

Earlier we had noted (2, 3) that quartz of the veins with rock crystal usually is characterized by a higher content of soluble compounds than the quartz from the veins without rock crystal. In any case, the decrepitation character of these quartz samples indicates that in the former, judging by the number of impulses, there are more sufficiently-large inclusions than in the latter deposit. This correlates with the results of the analyses of the aqueous extracts. Moreover, statistics indicate that in the quartz of the veins without rock crystal of the first deposit, the average weight-total of the cations comprises 0.296 mgm-equivs., and in the quartz of the veins with rock crystal it is 0.421 mgm-equivs., or 1.5 x more. In the second deposit the total content of dissolved compounds in the quartz samples is lower than in the first deposit; however, the same relationships apply here too. In quartz of the veins without rock crystal the average cation content is 0.104 mgm-equivs., whereas, in the quartz of the veins with rock crystal it is 0.204 mgm-equivs., or twice as much. But in this series in both deposits the role of Na^+ in the solutions increases.

The most interesting relationships between the content of Na^+ in %-equivs. and the sum of the cations in mgm-equivs. occur in the second deposit (fig. 4b). The graph shows a distinct separation of the areas of distribution of the points characterizing the solutions from quartz of the veins with rock crystal and of those without rock crystal. The former are characterized by a higher total cation content, and by a considerable percentage of Na^+ in them; moreover, the points characterizing these solutions are concentrated in the upper right part of the graph, whereas, the points characterizing the solutions from quartz of the veins without rock crystal are located in its bottom left part. The areas do not overlap and a clear demarcation line can be drawn between them.

The same characteristics are noted also in the first deposit, but are less pronounced (fig. 4a). The quartz of the veins without rock crystal of this deposit, when compared with the same kind of quartz from the second deposit, is different because in addition to the differences characterized by a low content of dissolved compounds, there are also differences with a high content of dissolved compounds. On the basis of this, the area of distribution of the points characterizing the solutions from this quartz group from the first deposit, which is shown on the graph constructed on the same scale, becomes more elongated and less well-defined, although as in the case of the second deposit, it is also located in the lower left part of it.

The materials presented in this paper show the perspective of studying the evolution of the composition of mineral-forming solutions by analysis of aqueous extracts from quartz. The data obtained can have an applied significance, and in particular, allow one to separate quartz veins that are supposedly with rock crystal from their general mass. The latter becomes particularly important when prospecting for hidden mineralization.

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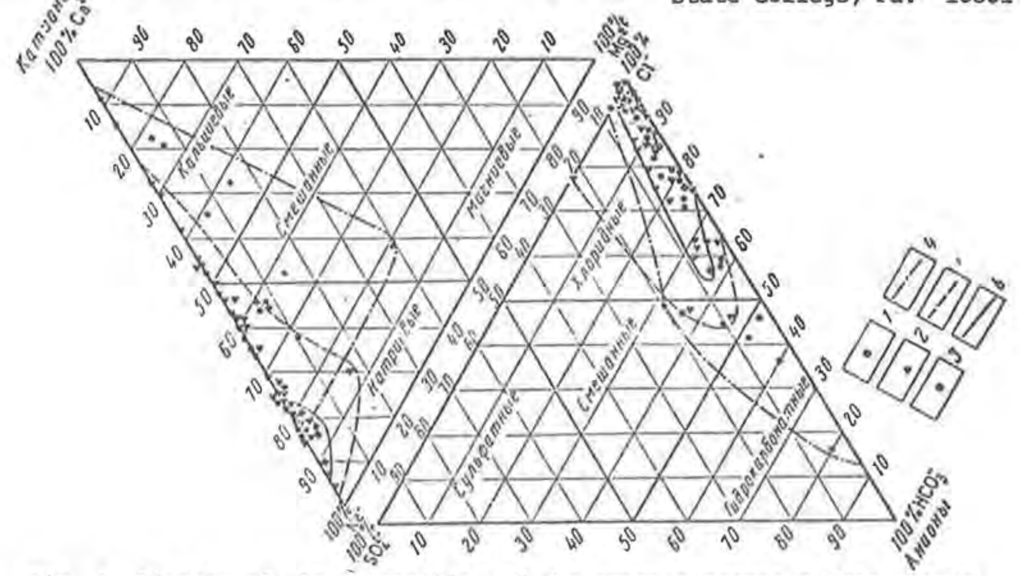


Fig. 1 Diagram of the composition of the aqueous extracts from quartz samples of the first deposit
Cation and anion composition of the solutions
1. in quartz of veins without rock crystal
2. in quartz of veins with rock crystal
3. in crystals of rock crystal
Contours of the zones of scatter of points of solution compositions
4. from quartz of veins without rock crystal
5. from quartz of veins with rock crystal
6. from crystals of rock crystal

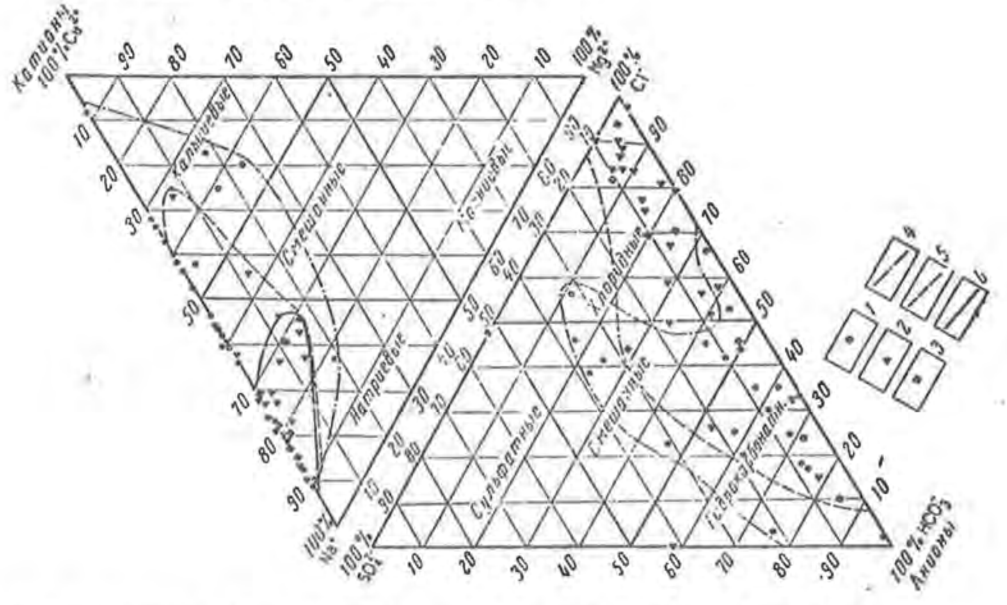


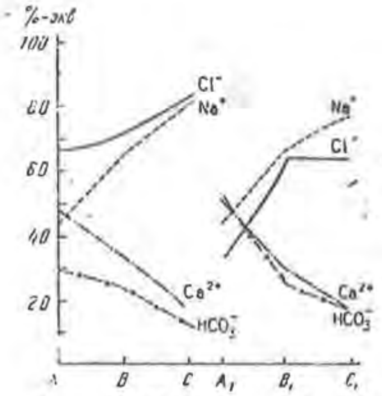
Fig. 2 Diagram of the composition of aqueous extracts from quartz samples of the second deposit (same notes as in Fig. 1; Ed.)

Table 1 Results of Analyses of Aqueous Extracts of Gas-liquid Inclusions in Quartz of the Second Deposit
(from calculations for 100 gm. of sample)

			Cations					Anions				
Quartz Group	Sample #	Units of Measurement	K^+	Na^+	Mg^{2+}	Ca^{2+}	total, mgm-equiv.	Cl	F	SO_4	HCO_3	total, Mgm-equiv.
Quartz of veins without rock crystal	538	mgm.	0,03	0,94	ND	1,13		2,13	ND	0,12	1,83	
		mgm-equiv.	0,001	0,041		0,056	0,098	0,060		0,002	0,030	0,092
		%-equiv.	1,02	41,83		57,15		65,26		2,14	32,60	
	467	mgm.	0,23	1,14	ND	2,10		2,13	ND	0,12	7,30	
		mgm-equiv.	0,006	0,049		0,105	0,160	0,060		0,002	0,120	0,182
		%-equiv.	3,75	30,62		65,63		32,96		1,09	65,95	
	557	mgm.	0,26	1,34	0,48	3,05		1,59	TR	0,84	11,89	
		mgm-equiv.	0,006	0,058	0,040	0,152	0,256	0,045		0,018	0,125	0,258
		%-equiv.	2,34	22,65	15,62	59,39		17,44		6,97	75,59	
Quartz of veins with rock crystal	191/11	mgm.	0,12	2,22	0,24	0,78		3,19	TR	0,60	3,66	
		mgm-equiv.	0,003	0,096	0,020	0,039	0,158	0,090		0,012	0,060	0,162
		%-equiv.	1,90	60,76	12,66	24,68		55,55		7,41	37,04	
	191/7	mgm.	0,66	2,88	TR	1,93		6,92	ND	0,96	3,66	
		mgm-equiv.	0,017	0,125		0,096	0,238	0,166	ND	0,020	0,060	0,162
		%-equiv.	7,14	52,52		40,34		67,48		8,13	24,39	
	191/21	mgm.	0,21	5,55	ND	1,50		9,58	ND	0,96	1,83	
		mgm-equiv.	0,005	0,241		0,075	0,321	0,270	ND	0,020	0,030	0,320
		%-equiv.	1,56	75,08		23,36		84,38		6,25	9,37	
Crystals of rock crystal	1722	mgm.	0,31	0,72	ND	0,30		0,85	TR	0,72	0,91	
		mgm-equiv.	0,008	0,031		0,015	0,054	0,024		0,015	0,015	0,054
		%-equiv.	14,81	57,41		27,78		44,46		27,77	27,77	
	691/5	mgm.	0,49	1,99	TR	0,40		2,66	0,03	0,24	1,64	
		mgm-equiv.	0,013	0,087	TR	0,020	0,120	0,075	0,0002	0,005	0,027	0,109
		%-equiv.	10,83	72,50		16,67		68,81	1,83	4,59	24,77	

ND = not detected

TR = trace



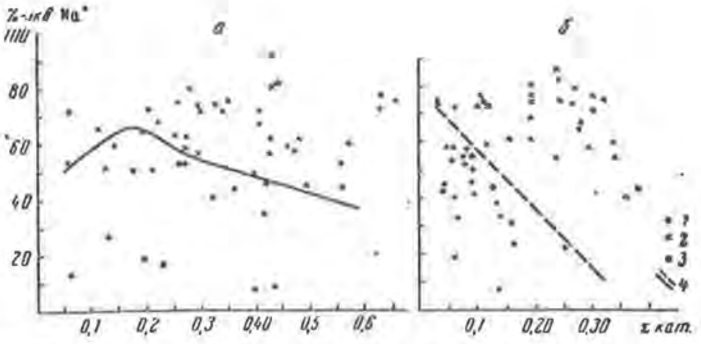


Fig. 3 Diagram of the change of the average contents of the principal anions and cations in solutions from inclusions in quartz

Content of components
A in quartz of veins without rock crystal from the first deposit
A_1 in quartz of veins without rock crystal from the second deposit
$B\ B_1$ in quartz of veins with rock crystal
$C\ C_1$ in crystals of rock crystal

Fig. 4 Plot of the relationship between the percentage content of Na^+ and total cation content (mgm.-equiv.) in solutions from quartz of the first deposit (a) and second deposit (b).

Points characterizing the quartz:
1. quartz from veins without rock crystal
2. quartz from veins with rock crystal
3. crystals of rock crystal
4. line delimiting the areas of distribution of points characterizing solutions from quartz of veins with rock crystal and veins without rock crystal.

Table. 2
Average Compositions of the Solutions from Quartz Samples of Various Types (in % equiv.)

Quartz group	number of analyses	First deposit		number of analyses	Second deposit	
		formula	solution type		formula	solution type
Quartz of veins without crock crystal	20	$\frac{Cl_{67}HCO^{3}_{28,7}SO^{4}_{4,5}}{Ca_{47}Na_{46,5}Mg_{6,5}}$	ClCaNa	22	$\frac{HCO^{3}_{53}Cl_{33}SO^{4}_{14}}{Ca_{52}Na_{44}Mg_{4}}$	HCO3ClCaNa
Quartz of veins with rock crystal	38	$\frac{Cl_{72}HCO^{3}_{24}SO^{4}_{4}}{Na_{66}Ca_{33}Mg_{1}}$	ClCaNa	22	$\frac{Cl_{65}HCO^{3}_{25}SO^{4}_{10}}{Na_{66,6}Ca_{30}Mg_{3,4}}$	ClNaCa
Crystals of rock crystal	4	$\frac{Cl_{84}HCO^{3}_{13}SO^{4}_{3}}{Na_{82,5}Ca_{17,3}Mg_{0,2}}$	ClNa	8	$\frac{Cl_{64}HCO^{3}_{18}SO^{4}_{18}}{Na_{78}Ca_{18}Mg_{4}}$	ClNa

BUTUZOV, B. P., KHETCHIKOV, L. N., and SHAPOSHNIKOV, A. A., 1971, Inclusions in synthetic crystals and their significance in thermobarometry of minerals, in Investigations of mineral-forming solutions and melts in inclusions in minerals, N.P. Ermakov and L.N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, (pp.7-14) (in Russian)

The paper gives the characteristics of the methods of obtaining and using artificial crystals of quartz, mica, and diamond, and also presents some results for studying the conditions of mineral formation under the conditions of a careful determination of the possible effect of a series of factors on the results obtained is shown. (Authors' abstract).

The authors take note of the (synthetic) hydrothermal growth of quartz, fluorite, calcite, corundum, rutile, zincite, water-soluble materials, etc. (Table). Commercially produced crystals of quartz, diamonds, and mica occasionally contain solid, gas-liquid, and gas inclusions.

Table of partial listing of crystals grown by various methods, other than hydrothermal, over the last few years (17).

Method	Chemical composition of crystals
Verneuil	Ga_2O_3, Y_2O_3, MnO, $MgTiO_3$, Mg_2SiO_4, $MgFe_2O_4$, NiO, TiC, TiB_2 Ti_2O_3, $MnFe_2O_4$, Fe_3O_4
Czochralski	Al_2O_3, LaF_3, $NiFe_2O_4$, $CaWO_4$
Zone melting	TiO_2, Al_2O_3 - organic compounds, alkali halides.
Travelling solvent	GaP, GaAs, SiC
Solution in a melt (flux)	TnS, [illegible] Ga_2O_3, ThO_2, TiO_2, $ThSiO_4$, ZnO, BeO, MgO, Al_2O_3, MnO, Fe_2O_3, NiO, GeO_2, Y_2O_3, In_2O_3, SnO_2, ThO_2, UO_2, ZrO_2, $BaTiO_3$, $PbTiO_3$, $NaNbO_3$, MWO_4, $MMoO_4$ (M-Mg, Ca, Sr, Ba, Zn, Cd), spinels: $MgAl_2O_4$, $MgFe_2O_4$, $NiFe_2O_4$, $ZnFe_2O_4$

When necessary, comparatively large gas-liquid inclusions can be obtained artificially. Such inclusions form under known conditions and thus make it possible to judge the accuracy of the information on the physical-chemical conditions of mineral formation, which we obtain from studies of natural inclusions in minerals.

The paper considers the problems of the preparation and application in current technology of quartz, mica, and diamonds, and also contains results of the study of inclusions in these minerals.

Synthetic quartz

The principles of hydrothermal crystal growth are summarized.

Two types of impurity can enter a quartz crystal:

1) Non-structural impurities in the form of crystal-line or colloidally-dispersed phases, that form in the aqueous alkali medium under certain values of T, P, and solvent concentration.

2) structural impurities consisting of the elements capable of substituting for silicon in the quartz structure, that are present in the solution.

The harmful impurities are solid, and gas-liquid inclusions in crystals. The former are micro-aggregates, 2-3 mm. in diameter, of silicates from the pyroxene and hydrowollastonite group and also amphibole and quartz. Over the past few years their composition, conditions of formation, and effect on the properties of quartz have been studied thoroughly at VNIISIMS.

Gas-liquid inclusions are usually distributed along the interface between the seed and overgrowth (9, 13). They form at the start of crystallization. When the conditions of growth change or during the interrupted growth of synthetic crystals, alternating zones of inclusions form in their inner parts; the thickness of these zones is determined by the duration of the corrosion of the crystal before the next cycle of growth. The inclusions have tubular, club-shaped, acicular, and other shapes, elongated in one direction. Their axes are mutually parallel and are oriented at a definite angle to the surface of the seed plate, depending on its optical orientation. The coefficient of filling of the vacuoles by the liquid phase in all inclusions corresponds to the degree of fill of the autoclave by the solution before the experiment.

A study of gas-liquid inclusions in artificial quartz makes it possible to evaluate the possibility of using them for elucidating the physical chemical conditions of natural mineral formation and also to adjust the quartz synthesis process.

At VNIISIMS the solution compositions and thermodynamic conditions favoring or hindering the entry of beneficial or harmful structural impurities into the growing quartz crystal were determined (5). A knowledge of the laws of phase formation and of growth led to the development of the technology of the growth of quartz monocrystals, which are comparable, in their properties, to the best natural crystals, and in a few instances, are superior to them in certain parameters.

Synthetic mica - fluoroplogopite

The properties of fluorophlogopite and its superiority over natural mica are discussed.

Depending on the conditions of crystallization, composition of the initial charge, crystallographic orientation of the growing faces, and other factors, the mica crystals contain a greater or lesser quantity of inclusions. These inclusions differ from those in quartz in their composition, state of aggregation, and morphology. As was shown by I.N. Anikin (3) they consist of droplets of mother melt or glass, dendrites of iron, crystals of forsterite, chondrodite, and also accumulations of the fluorides of K, Mg, and other metals. Frequent gas inclusions, consisting of irregularly distributed vacuoles within the crystal, are filled essentially with gaseous silicon tetrafluoride (14).

Synthetic diamond

Diamonds are grown under high T and P in a molten metal from graphite source material; the process for the slow growth of large crystals was worked out at VNIISIMS (7).

The inclusions are thread-like segregations of the mother melt, distributed along definite crystallographic directions (10). The more perfect the crystal the thinner the inclusions. Foamy inclusions (apparently aragonite), and thin plates of graphite also occur. They all seriously reduce the mechanical strength of the diamond crystals.

The significance of inclusions in artificial crystals for thermobarometry of minerals

As is evident from the brief review of the characteristics of inclusions in artificial minerals above, their state of aggregation, composition, and morphology correspond to the conditions of the mineral-forming environment. During the hydrothermal growth of quartz, calcite, and other minerals gas-liquid inclusions are formed, the ratio of the liquid and gas phases in the autoclave and in the inclusions being approximately the same. An increase in the concentration of the mother solution leads to the formation of multiphase inclusions containing small crystals of various minerals in addition to liquid and gas. Inclusions in mica, obtained from a melt with a high concentration of volatile components, are represented by droplets of this very melt, and individual components comprising the composition of the batch, as well as gases. In diamonds, which have been synthesized under conditions which are different in comparison with those for quartz and mica, there are only solid inclusions. Thus, judging by the state of aggregation, inclusions in minerals reflect the conditions of mineral formation. The composition of the inclusions likewise is determined by the characteristics of the mother medium. Thus, if quartz is grown in sodium carbonate solutions, the principal component of the liquid phase is sodium. Addition of high concentrations of sodium chloride to the sodium carbonate solution leads to the formation of a solid phase in the inclusions in the form of small crystals of halite, whereas, if sodium chloride is replaced by potassium chloride, sylvite is formed (16).

In inclusions in mica crystallized from a fluoride melt, fluorides of potassium and magnesium are usually predominant; however, if natural feldspar with a comparatively high sodium content (up to 2.5%) is introduced into the composition of the batch, then chiolite ($Na_5Al_3F_{14}$) is identified in the inclusions as a captive mineral.

As was shown by analysis of individual inclusions (14), their gaseous component corresponds completely in composition to the composition of the gases in the initial medium environment. However, depending on changes in certain conditions of growth of the crystals, e.g. fluctuations in the magnitude of the temperature drop, the composition of the inclusions changes. Thus, Anikin (3) showed that with a small temperature drop in the crucible and slow crystallization of the mica, fluorides of potassium and magnesium are predominant in the inclusions. For noticeable temperature drops in the melt, the inclusions are represented fundamentally by droplets of this same melt (glass) and only in the final stages of crystallization are the vacuoles filled with gaseous fluorides.

The crystallographic facetting of minerals, which is related to changes in the conditions of growth of crystals, also affects the special features of the composition of the inclusions. Thus only an analysis of a large real [sic] material, rather than of isolated, sometimes hapharzardly chosen inclusions, can characterize sufficiently fully the mineral-forming environment.

In the analysis of inclusions of crystals grown hydrothermally, usually there is a discrepancy between the concentration of the initial solutions and the content of salts in the inclusions. As a rule, the concentration of the mother substance in the inclusions is lower than the concentration of the initial solution. Often the inclusion solutions and the spent solutions have contents of salts that are close (11).

The pH of individual inclusions and of the mother solutions usually differ very little, whereas, the pH of the aqueous extracts does not reflect the concentrations of hydrogen ions in the initial environment. Generally, in using the data of the analysis of the aqueous extracts for the determination of the chemical nature of the mineral forming environment one must take into account a series of factors, and in particular the total volume of the inclusions, the analytical possibilities of the methods used for determining these or other components, etc. Without taking these factors into account, considerable errors can creep into the determination of the concentrations and compositions of solutions from the aqueous extracts (12).

An investigation of gas-liquid inclusions in crystals, grown under known conditions, offers the possibility of using with more validity the existing methods of thermobarometry for determining the conditions of natural mineral formation. It is well known that the homogenization temperature of solutions depends on their density. Having studied inclusions in artificial minerals, we obtained these relationships for solutions of various compositions. Thus, for sodium carbonate solution, in which quartz is grown, a change in the degree of fill of the bomb from 0.9 to 0.6 leads to an increase of more than 150°C in the homogenization temperature. Of course, in natural solutions, which have a more complicated composition, the relationships between the density and the homogenization temperature will be different; however, the order of the values will be preserved. The concentration of the solutions also exerts a considerable influence on their homogenization temperature, which in the case of a high concentration (tens of %) of certain components in the solutions approaches the growth temperature of the crystal.

It is worth noting the necessity of applying the correction for the pressure existing at the time that the crystal grew, to the homogenization temperature of the solution (13, 15). The difference between the growth temperature of the quartz and the homogenization temperature of the solutions in the inclusions at a pressure of 200 atm. is only 10°C, and for a pressure of 1500 atm. it exceeds 100°C, when the other conditions are the same.

The data obtained from a study of inclusions in artificial minerals indicates the necessity for an extremely careful interpretation of the results obtained in decrepitation studies of inclusions. It is customarily assumed that the decrepitation temperature usually is higher than the growth temperature of the crystal. However, this is not always so. As was shown by us in the example of inclusions in artificial quartz, for pressures up to 700 atm., the temperature of the start of decrepitation is higher than the growth temperature of the quartz; but if, at a pressure of 100 atm. the correction is 64°C, then at a pressure of 700 atm. it decreases to 12°C. for pressures above 900 atm., the temperature of the start of decrepitation is lower than the temperature of growth of the quartz; moreover, as the pressure increases the correction increases progressively.

This relationship is explained by the change in the homogenization temperature of the inclusions with an increase in pressure, and the necessity of overheating in relation to the homogenization temperatures; the amount of overheating required to shatter the quartz grains decreases with high initial pressures of the solutions enclosed in the inclusions.

An increase in the density of the solutions leads to a decrease in the difference between the decrepitation and growth temperatures of quartz crystals. Moreover, at constant pressure, the sequence of peaks on the decrepitation plots will correspond to the sequence of temperature changes during the crystallization process. However, if the density change is accompanied by a pressure change, cases can arise when the sequence of peaks on the decrepitation plots will be reversed in relation to the changes in the crystallization temperature (13).

The bursting temperature of the inclusions is related directly to their size. In the case of inclusions in quartz it has been shown that a change in the size of the inclusions from 0.1 to 0.3 mm. lowers the temperature of the start of decrepitation by 15-18°C. This phenomenon is related to the occasional occurrence of identical temperatures of the start of decrepitation and similarities of their plots for samples of quartz synthesized at different temperatures and pressures.

Sometimes the number of inclusions in minerals is estimated from the number of explosion impulses recorded by the apparatus. However, the number of explosions is often related to the size of the inclusions: the smaller the number of inclusions the lower the percentage of them that will explode, even with considerable overheating. Inclusions in quartz having a diameter of 0.001 mm. often do not burst. Therefore, the number of explosions for each size fraction in the crushing of the samples can be compared only in the interval down to the minimum size of the bursting inclusions.

Thus, the investigation of solid and gas-liquid inclusions in artificial crystals confirms the possibility of using them for studying the conditions of mineral formation. The existing methods of thermobarometry enable us to obtain sufficiently objective information about these conditions. However, in working with inclusions it is essential to consider carefully the possible influnce of a series of different factors on the results obtained.

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Labour, Scientific Research Institute
for the Synthesis of Mineral Raw
Materials.

* M is the abbreviation for Moscow presumably

DOLGOV, Yu. A., 1968, The composition of gases in processes of endogenic mineral formation: Internat. Geol. Congress, 23rd Session, Talks by Soviet Geologists, Problem 7, p. 101-111, Izdat. "Nauka", Moscow, 1968 (in Russian).

Summary in English

Change of temperature field intensity during the heat exchange processes between intrusion and country rocks is characterized by parabolic gradient. Parabola cuts the two-phase equilibrium curve and has two branches in liquid and gas field. The gas aggregate state exists up to depths of intrusion formation no more than 7-8 km. Solutions, as a rule, become subcritical owing to their salt concentrations.

The certain dependence of gas mixture composition on temperature of minerogenesis is established as the results of gas analyses from single inclusions.

The lower limit (of depths and temperature) of atmospheric gases in endogenous minerogenesis processes is established.

Experimental data and natural observations indicate unequivocally the significant role of gases in processes of endogenic mineral formation, associated with post-magmatic activity. Observations of the compositions of gases associated with magmatic activity refer mainly to studies of volcanic gases (Shepherd, 1938; Basharina, 1953; Rubey, 1955; Naboko, 1959; White and Waring, 1965, etc.). The experimental data show that gases aid in the transfer and deposition of a significant amount of petrogenic and metallogenic elements and their compounds (Ovchinnikov, 1963).

Along with studies confirming the significant mineral-forming activity of gases, there has continued to exist the point of view that the role of gases in processes of mineral formation is either limited to present surfaces and areas close to them or it is denied altogether. For a correct solution of this problem, two aspects must be considered: (1) The aggregate state of water and of solutions of more complex composition is controlled by the evolutionary intensity of the temperature field of the Earth's crust (average terrestrial geothermal gradient 35 degrees/km.); (2) the aggregate state of mineral-forming solutions is determined by the intensity of the temperature field associated with the thermal activity of the intrusive.

The first case was considered by Smith (1954, 1963), Ingerson (1965), and other investigators. It was shown that for waters the liquid state of aggregation is preserved even at maximum values of the geothermal gradient characterizing the evolutionary intensity of the temperature field of the Earth's crust. If intrusives, with which one can associate processes of endogenous post-magmatic mineral formation, are absent, it is perfectly evident that all the theoretical conclusions resulting from consideration of the aggregate state of water and of more complex mineral-forming solutions, do not in this variant have any relation to endogenous post-magmatic mineral formation, and cannot be used as an argument for the impossibility of the existence of gaseous mineral-forming solutions in the process of post-magmatic ore formation.

From the theory of heat exchange, it follows that the distribution of temperatures for some amounts of transmitted heat is more accurately characterized by a parabola of second order (Beinik, 1959) and corresponds to the formula: $O = \mathrm{erf}\ (1/\sqrt{4}\mathrm{Fo}_x)$. A graph of the dependence of the dimensionless temperatures O on the dimensionless time Fo_x shows a parabolic rule of the distributed temperatures. The initial heating of the country rock under the influence of the intrusive is carried out in accord with this general and obligatory rule. Thus, any intrusive located at relatively small depth creates a temperature fluctuation on the background of the evolutionary intensity of the temperature field of the given area of the Earth's crust. These temperature fluctuations with time are equalized in the process of heat exchange.

For this, in order to go from a parabolic paleogeothermal gradient to a paleogeothermobasic one and to keep the parabolic form characterizing the distribution of temperatures, one must preserve the corresponding changes of temperatures and pressures with time, i.e. to limit the conditions: $dP/d\tau = dT/d\tau$. Then the parabola acquires the magnitude of one of the possible paleogeothermobasic gradients, characterizing the change of P-T conditions in the process of origin of the intrusive.

These introductory comments, based on generally known theoretical assumptions, not only substantiates the obligatory development of pneumatolytic processes of mineral formation, but also limits the field of their action at definite intervals of depth. On the graph (Fig. 1), it is seen that the field of development of pneumatolysis depends on the depth of formation of the intrusive and the starting temperature of formation. Three lines of geothermal gradients are shown, of which none intersects the curves of two-phase equilibrium of water or of water-salt solution and the two curves of paleogeothermobasic gradients in the form of parabolas for intrusions of different depths of formation and different beginning temperatures of crystallization. The field of pneumatolytic mineral formation will be the greater, the higher the initial temperature of intrusion, and the lower the depth of formation of the intrusion.

There exists a second difficulty for indicating a considerable role of the gas phase in processes of endogenic mineral formation, consisting in the fact that solutions of any density and any composition in the field of high pressure and temperature are considered critical, or fluid, by analogy with pure water. The fluid, supercritical state is generally characterized by the fact that the "fluid" has the properties of a gas and a liquid simultaneously, and in this way deviates from the gaseous state, but there is ascribed to the "fluid" an exaggerated greater activity (sic.) and a much larger field of existence.

Study of inclusions with critical filling have shown that the homogenization occurs at high temperatures without change of the position of the phase boundaries between liquid and gas. Together with this, the width of the meniscus diminishes, which indicates the equalization of the densities and concentrations of the liquid and gas (Fig. 2). The disappearance of the phase boundaries proceeds instantly; however, rapid filming shows that the "instant" is 1/7 sec. In this brief span of time there occurs boiling, which begins with the appearance of large bubbles and concludes with very small bubbles and complete homogenization. Differences in the states by temperature are noted within the range 0.1-0.05°.

Inclusions with critical filling occur no oftener than one in a thousand. The remaining inclusions are characterized by an entirely definite aggregate state (superheated vapor or superheated liquid).

Study of gas-liquid inclusions shows (Fig. 3, table 1) that the mineral-forming solutions in the Earth's crust are not pure water; they are mainly solutions of chlorides, bicarbonates, hydrous carbonates, and to a lesser degree sulfates, borates, and phosphates. Aqueous extracts of inclusions and ultra-micro analysis of individual inclusions show that in most cases the solutions contain chlorides of the alkali metals. Among these, NaCl is usually present in greatest amount.

After the experimental study of the system H_2O-NaCl by Sourirajan and Kennedy (1962), there remains no doubt that aqueous salt solutions raise the pressure and temperature of the critical point, depending on the concentration. Thus, for example, a solution of more than 20% concentration of NaCl has a critical point at a temperature above 600° and a pressure of more than 900 atm. Salt concentrations in various inclusions, especially high-temperature ones, are rather high (Table 1) in topaz from granitic pegmatites they attain 25-26% (in NaCl equivalents), which corresponds to a critical temperature of about 680° and a critical pressure above 1200 atm.

The temperatures of melting of pegmatite-bearing granites are close to the critical magnitudes listed above for aqueous salt solutions. Hence it follows that post-magmatic solutions, right after the formation of the intrusive, can have subcritical state, as was assumed by Fenner (1937).

For intrusions of small depth (3-8 km), pegmatites and early high-temperature ore veins of the pneumatolytic phase are certain. Within the temperature limits of existence of a gas phase, high-temperature minerals crystallized. Under conditions of the hydrothermal stage, there may occur further crystallization of these minerals, but the amount of mineral mass deposited under hydrothermal conditions is often much less than in the pneumatolytic stage of mineral formation.

Sometimes, with a combination of particular thermodynamic and chemical conditions of mineral formation, even such a mineral as quartz can cease crystallization under hydrothermal conditions. In Fig. 4 is shown such a case, where nearly all of the quartz is of pneumatolytic origin. The quartz plate shown in the photograph (Kazakhstan, Kent) has a high-temperature zone of quartz, for which a temperature of formation not lower than 600° has been established. The specific pattern of inversion fractures (α-β-transition under rapid cooling) and the multitude of monotypic gas inclusions in these fractures indicate uniformity of the temperature and aggregate (gaseous) state of the mineral-forming solutions. The high-temperature zone of the crystals of quartz was deposited from pneumatolytic solutions and constitutes not less than 90% of the total mineral mass of quartz. A narrow outer band of β-quartz was partly deposited from gaseous solutions (approximately at 400°). Only the exterior part of the outer zone consists of hydrothermal quartz, which comprises not more than 3-5% of the total mass of quartz.

Table 1 (p. 103) Concentrations of salts in inclusions of various minerals

Mineral	Concentration of salts, wt %	Notes
Quartz core	19.9	Method of aqueous extraction
Quartz, honeycomb	18.7	
" "	17.1	Pegmatites of Maidental
Quartz	12.8	(V. S. Polykovskii)
Amethyst	11.4	
Topaz	26.0	Cryometric method (concentration of salts in equivalents)
	26.2	
Beryl	25.7-26.2	Volynian pegmatites
Quartz	26.2	(Yu. A. Dolgov)
Fluorite, violet	6.0-30.0	Kazekhstan (L. Sh. Bazarov)
" , green	11.0-37.0	
Nepheline	8.0-26.0	Botogol (T. Yu. Bazarova)

Ermakov (1949) first called attention to gaseous inclusions as objective criteria of the formation of minerals from the gas phase. Proof of the regular existence of gas phases and their significant role in processes of endogenic mineral formation was needed in that paper, because it is doubtful if it would have been expedient to study gases which play no role in mineral formation or are generally absent.

The study of the composition of gases was made by the method of volumetric ultramicrochemical analysis of individual inclusions in minerals. Gas from inclusions, opened in a special device (Slavyanskii and Krestnikova, 1953), were kept in a liquid, for which inertness had been demonstrated as to absorption of the components of the gaseous mixture. The gas bubbles are absorbed by individual absorbents for each component of the gas mixture. Excluded is the possibility of absorption by each of the preceding absorbents of the later components of the gas mixture. Determinations were made of H_2S+SO_2, CO_2, CO NO H_2, O_2, and N_2+ rare gases (residual). Supplementary determinations were made of heavy and light hydrocarbons, methane, NH_3, and Cl_2. The analyses gave satisfactory results on standard gas mixtures, and also in the determination of the composition of gases from synthesized crystals of quartz, for which the composition of the gases taking part in the synthesis was known. The sensitivity of the method is 0.3-0.5%, the average quadratic deviation 0.4%, the average arithmetic 4% from the measured magnitudes. The minimum size of analyzed inclusions is 0.001 mm (sic). The optimum diameter of gas bubbles, for which the best correspondence of actual and spherical forms was attained, is 0.4 mm. Smaller bubbles give better correspondence, but the relative error of the measurements increases. More detailed information on the method has been published previously (Dolgov and Shugurova, 1966).

About 1000 analyses of individual inclusions and more than 500 analyses with parallel measurement of temperature of homogenization have been carried out (chemist-analyst N. A. Shugurova). Besides the particular task, which was the accumulation of gas analysis data for minerals of various temperatures of formation, the possibility appeared to show in a preliminary form the dependence of changes of the composition of the gas mixture with temperature. Gases were studied from inclusions of various minerals, formed at different temperatures, pressures, and from different depths (Table 2).

A dependence is observed of the composition of the gas on the temperature of formation. Low-temperature gas inclusions are characterized by the presence of nitrogen and oxygen in atmospheric ratio and CO_2. On transition to medium-temperature inclusions in the temperature interval 250-300°C, the atmospheric ratio of oxygen and nitrogen is upset, which indicates limited depth of penetration of air into the Earth's crust. On transition to the higher temperature region (450-700°C), the content of CO_2 changes and the content of sulfur gases (SO_2, H_2S) increases.

The change of CO_2 content is recorded for granitic chambered pegmatites of Sarybulaka (Kazakhstan), and increase of the contents of sulfur gases in the composition of the gas mixture was established for granitic chambered pegmatite of Volynia (Ukraine) and for the Kent pegmatite (Kazakhstan). For the Volynian pegmatite, the content of sulfur gases at temperatures above 600° attained 60% and decreased regularly with decrease of temperature. Below 400° the sulfur gases are absent from the gas mixture and the relative content of CO_2 increases.

Higher-temperature inclusions were also studied, for example nepheline from pegmatitic nepheline syenite rocks (eastern Sayan, Urals). Homogenization of the inclusions in the liquid phase occurred at temperatures above 840° (Kerkis and Kostyuk, 1965). The gases in these inclusions were predominantly CO_2. For the Lovozero alkalic massif (Kola Peninsula), along with high content of CO_2, a predominant amount of hydrocarbons was observed in secondary inclusions in individual cases.

The data obtained permit one to present a graphical scheme of the probable distribution of the ingredients of the gaseous mixture taking part in endogenic mineral formation, and their dependence on temperature

Table 2 (p. 108) Composition of gases and temperatures of homogenization of individual inclusions in various minerals

	Temp. Homogen.°C	SO_2+H_2S	CO_2	CO	O_2	H_2	Hydro-carbons	N_2+rare gases	Author
Kyanite, N.E. Transbaikal	--	--	100	--	--	--	--	--	--
Nepheline (eastern Sayan)	760-850	0,0	97-82	--	--	--	90,73	3,0-18,0	T. Yu. Bazarova
Nepheline from foyaite, Kola Peninsula	680-620	0,0	9,27	--	--	--	90,73	0,0	T. Yu Bazarova
Topaz (Volynia)	520	78,59	17,37	0,0	0,0	0,0	0,0	4,0	
Quartz honeycomb, Volynia	380	23,8	71,8	0,0	0,0	0,0	0,0	4,7	
	460	30,9	67,5	0,0	0,0	0,0	0,0	1,6	
	320	7,3	88,5	0,0	0,0	0,0	0,0	2,8	
Quartz honeycomb, Transbaikal	480	44,5	45,40	0,0	0,0	0,0	0,0	7,8	
	360	13,92	84,08	0,0	0,0	0,0	0,0	1,85	
Quartz honeycomb, Kazakhstan	520	12,5	80,85	0,0	0,0	0,0	0,0	6,7	
Morion (smoky quartz), Transbaikal	240	0,0	77,2	0,0	0,0	0,0	0,0	22,9	
	340	6,0	88,0	0,0	0,0	0,0	0,0	6,0	
Morion (smoky quartz), Volynia	460	38,9	62,1	0,0	0,0	0,0	0,0	0,0	
Tourmaline, Transbaikal	370	49,64	42,60	0,0	0,8	0,0	--	6,2	I. T. Bakumenko
	310	32,62	28,86	4,2	1,26	0,0	--	26,70	I. V. Motorina
Tourmaline, Urals	--	18,3	63,7	0,0	4,78	0,0	--	13,1	"
Fluorite, Kazakhstan	440	0,0	97,0	0,0	0,0	0,0	--	3,0	L. Sh. Bazarov
	300	0,0	87,0	1,53	0,0	6,75	--	4,2	N. A. Shugurova
	220	0,0	15,75	0,0	20,62	0,0	--	65,3	"
Rock crystal, Kazakhstan	120-200	0,0	14-27	0,0	0,0	0,0	--	86-73	"
	140-235	0,0	33-40	0,0	0,0	0,0	--	67-60	"
	140-260	0,0	41-97	0,0	0,0	0,0	--	59-3	"
Sphalerite, Salair	100-180	0,0	34,3	0,0	15,3	0,0	--	50,4	"
Calcite, Salair	100-180	0,0	44,0	0,0	15,25	0,0	--	43,75	"
Galena, Salair	--	0,0	43,7	0,0	12,2	0,0	--	44,1	"

(Fig. 5). Evidently this scheme cannot be taken as universal. Besides the general regularity, there exist episodic deviations, which depend on the composition of the gases in the intrusive and the country rocks, and also on the chemical reactions arising between pore solutions and country rocks during their activation by magmatic heat. These deviations have a transient character, because any gas components, set free during the crystallization of the magma, strive to be distributed in the Earth's crust in correspondence with the intensity of the temperature field. The moving force of such a distribution is provided by differences of volatility of the ingredients of the gas mixture and by thermal diffusion. Both of these factors depend on the temperature and on the magnitude of the pressure. Besides the general evolutionary tendencies, factors exist that disrupt the evolutionary development of thermodynamic parameters (Dolgov, 1963, 1964).

Data on inclusions in topaz show that decrease of temperature corresponds to decrease of pressure and of density of solutions. Along with this the reduction of pressure and density of solutions proceeds first of all at the expense of gases that are more volatile than water. In predominant amounts they migrate from the region of high pressure (pores of country rock) into the region of low pressure (fractures, of increasing volume). Cryometric experiments on the decrease and freezing of gases in inclusions confirm this course of events. Characteristic for this group of inclusions are different ratios of CO_2 and aqueous salt solution. Complete separation of the mixture does not occur, but the most volatile components become predominant in the region of low pressures. Thus, for example, at T=600°, the volatility [vapor pressure?MF] of water equals 630 atm., that of CO_2 1240 atm.

Analyses of gases from inclusions in nepheline from nepheline syenites and similar rocks (Petersil'e and others, 1961; Linde, 1961; Ikorskii, 1964, Bazarova, 1965) show that in some cases hydrocarbons predominate, in other cases CO_2. It has also been established that for deep intrusions high contents of CO_2 are more often characteristic, those of hydrocarbons are rarer. Observations on inclusions of minerals of deep facies of metamorphism (kyanite) showed that solutions of isolated pores contain one or two liquids, strongly compressed, without gas bubbles. In inclusions with two liquids, one of them, as confirmed by cryometric analysis, is CO_2. It often predominates in volume over aqueous salt solution. All the observations given above and the analytical data permit one to construct a diagram (Fig. 5), illustrating in preliminary form the composition and distribution of gases in processes of endogenic mineral formation.

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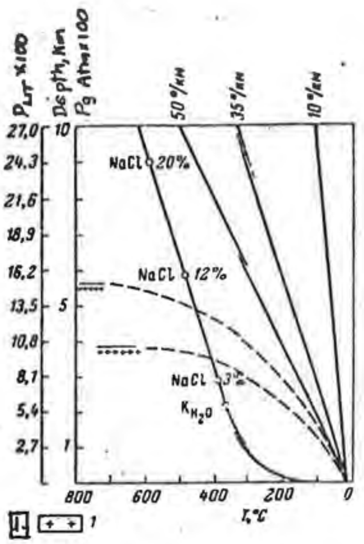
Fig. 1 (p. 102) Graph of parabolic paleogeothermal gradient and position of curves relative to two-phase equilibria for pure water in the system H_2O-NaCl. 1-granitic intrusive

Fig. 2 (p. 104) Homogenization of inclusions with critical filling. Interval of photographs (from 1 to 8) 0.14 sec., change of temperature 0.1-0.05°. x 200.

Fig. 3 (p. 105) Liquid and gas inclusions containing solid phases (X150). Left row--inclusions homogenized in the liquid, right row, in the gas.

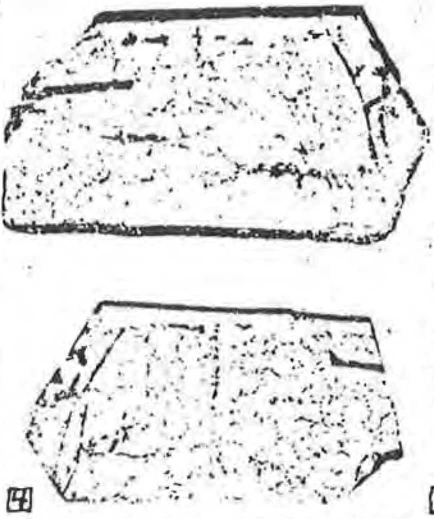
Fig. 4 (p. 106) Quartz of pneumatolytic origin, with restricted hydrothermal mineral formation. One-half natural size

Fig. 5 (p. 109) Scheme of the distribution of gases in the Earth's crust in dependence on the temperature. The lower dotted line shows that there may be hydrocarbons in place of CO_2



P_{Lit} ×100
Depth, km
P_g Atm×100
50 °/km
35 °/km
10 °/km
27,0
24,3
21,6
18,9
16,2
13,5
10,8
8,1
5,4
2,7
10
5
1
NaCl 20%
NaCl 12%
NaCl 3%
K_{H_2O}
800
600
400
200
0
T,°C
1

1



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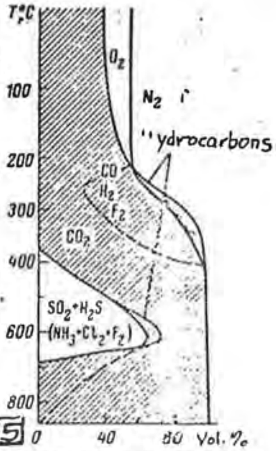
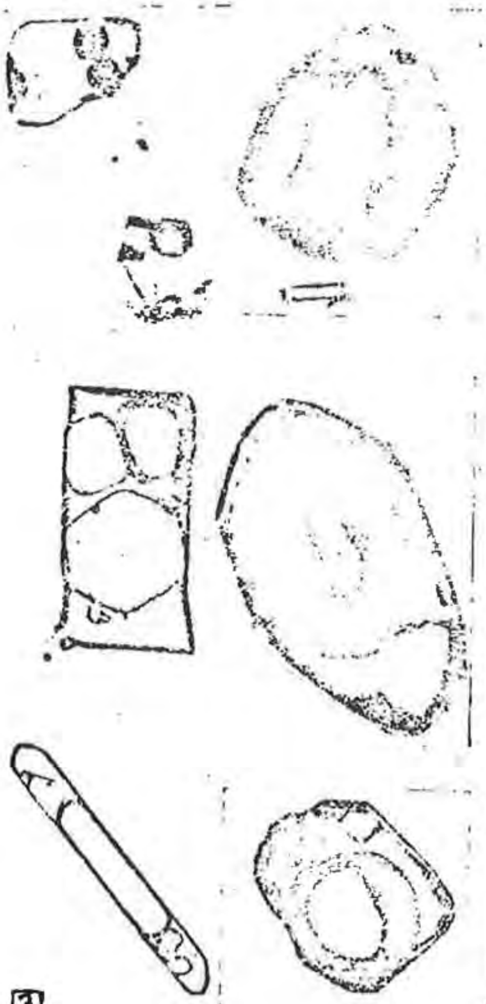


T,°C
100
200
300
400
600
800
O_2
N_2
''ydrocarbons
CO
H_2
F_2
CO_2
SO_2+H_2S
$(NH_3+Cl_2+F_2)$
0
40
80
Vol. %

5



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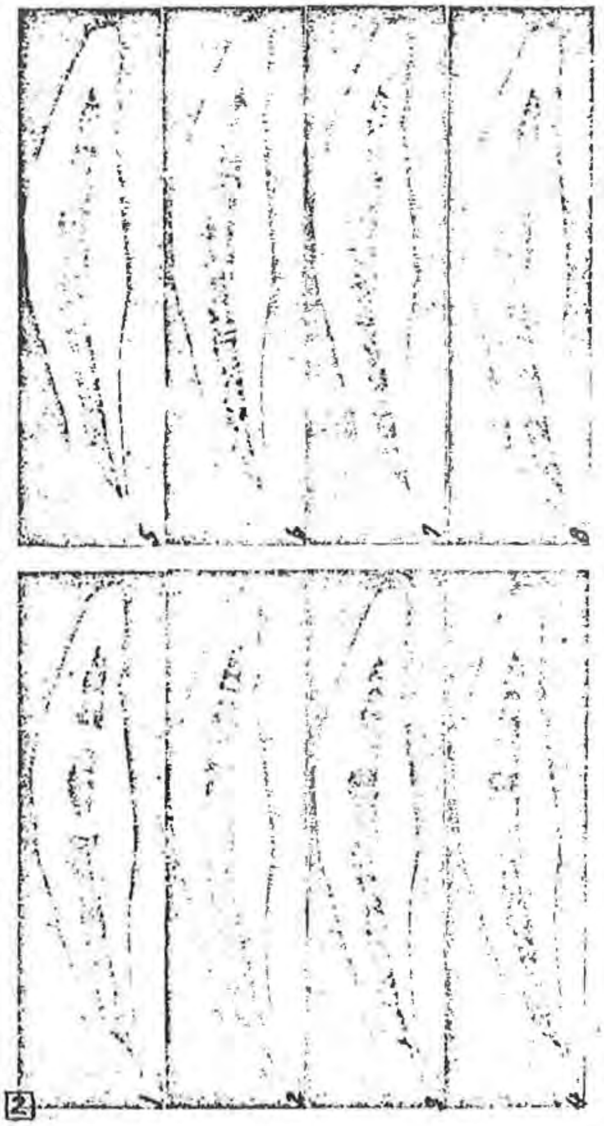

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ERMAKOV, N. P., and KUZNETSOV, A. G., The use of thermobarogeochemistry methods in the search for hidden ore deposits (Authors at Moscow State University and Shakhtinsky Polytechnical Institute). (Editor's note: This paper was submitted for the 1972 COFFI Symposium at Montreal, but was only read by title there, and was received too late for inclusion in the previous volume of COFFI. As Prof. Ermakov has kindly provided an English translation, it is presented here, after extensive editing).

Secondary inclusions of liquid and gaseous solutions in ore-bearing rocks have provided essentially new possibilities for detailed exploration on pneumatolytic-hydrothermal deposits. The decrepiphonic and thermometric methods for searching for hidden ore deposits are being developed in the Soviet Union (Ermakov, 1957, 1966, 1968). This paper deals with some aspects of such methods in the search for ores in polymetallic deposits in the Northern Caucasus.

The Sadonsky and Zgidsky hydrothermal vein deposits occur in the Ossetia Mtns., in the Sadono-Unal anticline. The core of this anticline consists of Paleozoic granites, and the flanks of Jurassic effusive and sedimentary rocks (Azizbekov, et al., 1962). Polymetallic ore bodies, averaging 1.5-2.0 m in thickness, are located in northeast-striking fault zones. These occur mainly in the granites and to a lesser degree in sedimentary and volcanic rocks.

Five stages of mineralization are recognizable in the overall mineralization at Sadonsky (Prokopenko, 1950): quartz-pyritic, productive quartz-polymetallic, with up to 85% of lead-zinc ores, quartz-calcite-pyrrhotite, calcite-polymetallic and calcite. The formation of the ore zone in the Zgidsky deposit occurred in 4 stages: quartz, mangan-siderite, productive polymetallic and calcite.

Homogenization studies on inclusions in ore-bearing quartz and sphalerite from the productive polymetallic mineralization revealed that the main ore stage at these two deposits formed at 240-336°C. Native bismuth (m.p. 271.3°C) is present in some of these polymetallic ores, proving indirectly that the stated temperatures are correct (sic.).

Ore-bearing granites are characteristically light-gray and have a medium-grained, hypidiomorphic granular texture. Their consist of: plagioclase 20-30, microcline 30-40, quartz 25-30, muscovite and biotite 5-8, and common hornblende 2-4 percent; accessory minerals are apatite, sphene, zircon, rutile, and magnetite. Close to the ore bodies the granite has been sericitized, chloritized, carbonated, silicified, and pyritized.

To demonstrate the use of thermobarogeochemistry techniques in exploration we took samples or ore-bearing granites every other 25 m from 10 sections across the ore zones of the two deposits out to a maximum of 200-300 m.

Quartz grains were selected from these samples after crushing to 0.25-0.50 mm, then separated repeatedly with bromoform-alcohol solutions and handpicked under a binocular microscope.

Gaseous-liquid inclusions were studied under the microscope, on doubly polished sections in thin section, and more rarely in grains in immersion liquid with a refractive index close to that of quartz. Secondary inclusion homogenization was carried out in the Ermakov thermochamber, 1950 system. Inclusion decrepitations in quartz from granite were performed in a decrepitometer of the type RUD-I. Two grams of 0.25-0.50 mm grains were heated to 700° at 10°/min.

Weight loss was determined with a torsion balance on a 500 gr sample, heated continuously to 800° in 90 minutes. The temperature was measured with a thermocouple and millivoltmeter. The porosity determination on ore-bearing granites (Table 3) was made with the water saturation method. In the cryometric investigations a mixture of solid CO_2 and ethyl alcohol was used, making it possible to cool the cryochamber to -72°C and determine the temperature at the point of the saturation's complete freezing (sic.).

Polished sections of quartz from granites in these two deposits show the following types of inclusions: 1) primary, solidified melts and dry gases, 2) secondary, especially gaseous, and 3) secondary, liquid (very common). The characteristics of these secondary liquid inclusions are presented in table 1.

Many measurements have shown that secondary carbon dioxide and water liquid inclusions in quartz of the granites homogenize at 32°-311°C. These secondary inclusions in country rock quartz are a result of the hydrothermal lead-zinc mineralization in the region, and their wide range of homogenization temperatures comes from the mixed carbon-dioxide water inclusions and the many stages of mineralization. The presence of spatially separate productive polymetallic veins and nonproductive quartz-pyritic, mangan-sideritic, calcite and other veins, as well as those occurring outside the deposit, made it possible to identify two groups of inclusions in the country rock quartz: I, Inclusions formed as a result of ore solutions responsible for the major polymetallic ore bodies penetrating into near-vein rocks: These are characterized by homogenization temperatures of 210-310°C; and II, Inclusions formed from low temperature post-ore hydrothermal solutions filtering through country rocks; these have homogenization temperatures <140°C.

On studying profiles across the Sadonsky and Zgidsky deposits, we established that type I inclusions increase significantly in homogenization temperature toward ore (Fig. 1). It is worth noting that the (maximum) temperatures of such inclusions out in the country rock are 25-40° lower than those veins themselves.

Decrepitation maxima for the quartz revealed a similar picture out to a distance of 200-300 m from ore (Fig. 2). In nearly all cases decrepitation temperatures were 25-80° above homogenization temperatures. It was also noted that close to ore there is an abrupt increase in the total number of explosions (pulses) on heating to 700°C (Fig. 3). Examination of a number of decrepigrams permitted us to delineate an outer halo of "steaming" surrounding both ore bodies, where decrepitation activity of the altered granites is 5-7 times higher than the background decrepitation activity of the unaltered granite. Closer in to the ore bodies there is an inner halo of intensive "steaming", wth decrepitation activity 2-4 times higher than that of the outer halo, and 15-20 times higher than the unaltered background (table 2). At the Sadonsky deposit the outer steaming halo in the country rocks is 2-4 times larger than the geochemical halo established by trace elements indicators.

Table 1- Characteristics of steaming haloes adjacent to ore at the Sadonsky and Zgidsky deposits

Halo	Distance from ore (m)	Mean rate of solution cooling (C°/m)	Mean decrepitation activity (pulses)
Inner halo of intensive steaming	0.5-25	1.8	376-474
Outer halo of steaming	25-200	0.3	75-210
Unaltered rocks	>1000	-	16-30

Table 2.
Dependence of decrepitation activity on quantity of secondary inclusions

Distance from ore (m)	A number of calculations (sic.)	Number of inclusions over 0.1 mm^2	Decrepitation activity (pulses)	Effective porosity (%?)
1	20	2510	474	1.71
25	15	1622	376	1.26
100	10	684	153	0.80
200	10	331	75	0.73
1000	20	96	19	0.67

The combination of a large outer steaming halo and a comparatively narrow near-ore halo of intensive steaming is favourable for practical use of the decrepitation method in detailed exploration.

To explain the decrepitation activity we have calculated number of inclusions exceeding 1 mk (sic) in quartz from granite at various distances from these ore bodies (Table 3).

The inclusion calculations carried out show the decrepitation activity to be directly dependent on the quantity of relatively large inclusions adequate to be detected by a device of a given sensitivity. Both the amount and size of secondary inclusions progressively increase toward ore. Far from ore the secondary inclusions are more frequently of regular geometric forms, while near ore they show a more varied morphology: Weight loss on heating also increases regularly toward ore (Table 4). This weight loss is mainly a result of decrepitation of secondary inclusions. Toward ore one can also notice a 5-10-fold increase in the number of multiphase secondary inclusions with daughter minerals in 100 meters, indicating a significant decrease in lateral penetration from the vein. There is also an increase in carbon dioxide toward ore.

Table 3

Weight loss of quartz on heating

Distance from ore (m)	Number of determinations	Weight loss (%)
1	10	0.23
5	3	0.19
25	3	0.11
50	2	0.08
100	5	0.06
200	5	0.05
300	3	0.02
1000	10	0.02

The cryometric investigations were also useful, since the average temperature of complete freezing decreased toward ore: 200m, -35.1°C; 100 m, -38.6°, 25m, -41.3° and 1m, -46.8°C. These preliminary data indicate an increase in solution concentrations toward ore. Internal inclusion pressures calculated from the CO_2 contents also increase toward ore in both deposits. At first approximation, it was established that at 200m from ore, the pressure is 110-140 atmospheres; at 100m, 170-180 atms., and close to ore, 210-220 atms. Thus at a distance of 200m from ore, the pressure was only about one-half the value at the vein.

In conclusion, investigations of inclusions in quartz from the Sadonsky polymetallic ore district have revealed that homogenization and decrepitation temperatures of secondary inclusions, decrepitational activity of rocks, total number of inclusions and their sizes, weight loss on heating, concentration of salts, and CO_2 pressure of hydrothermal solutions which transformed country rocks gradually and successively increase toward ore. Hence these first experiments show that by determining the direction of change of these parameters, one can and must use them in the search for hidden ore deposits of hydrothermal origin. Of course, these experiments should be repeated and tested in various geological environments, and on both metallic and non-metallic deposits, in order to improve both the technology and the methods of such investigations of inclusions in ore and rock minerals.

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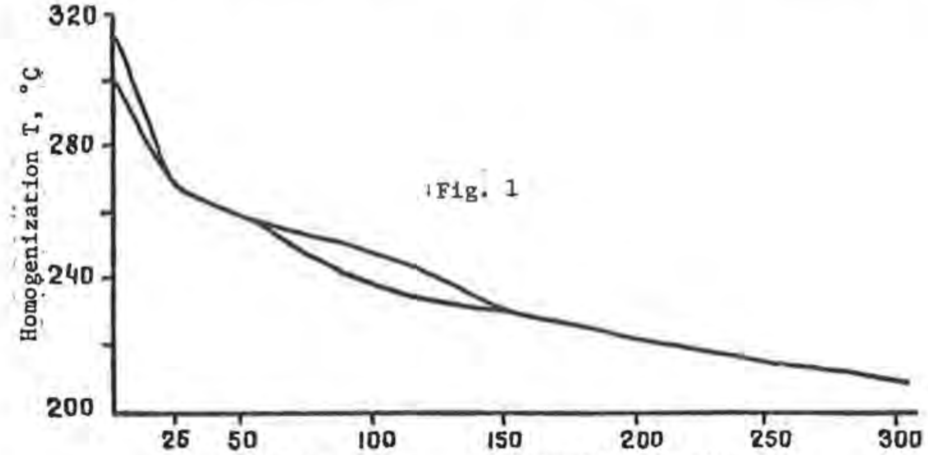

Fig. 1

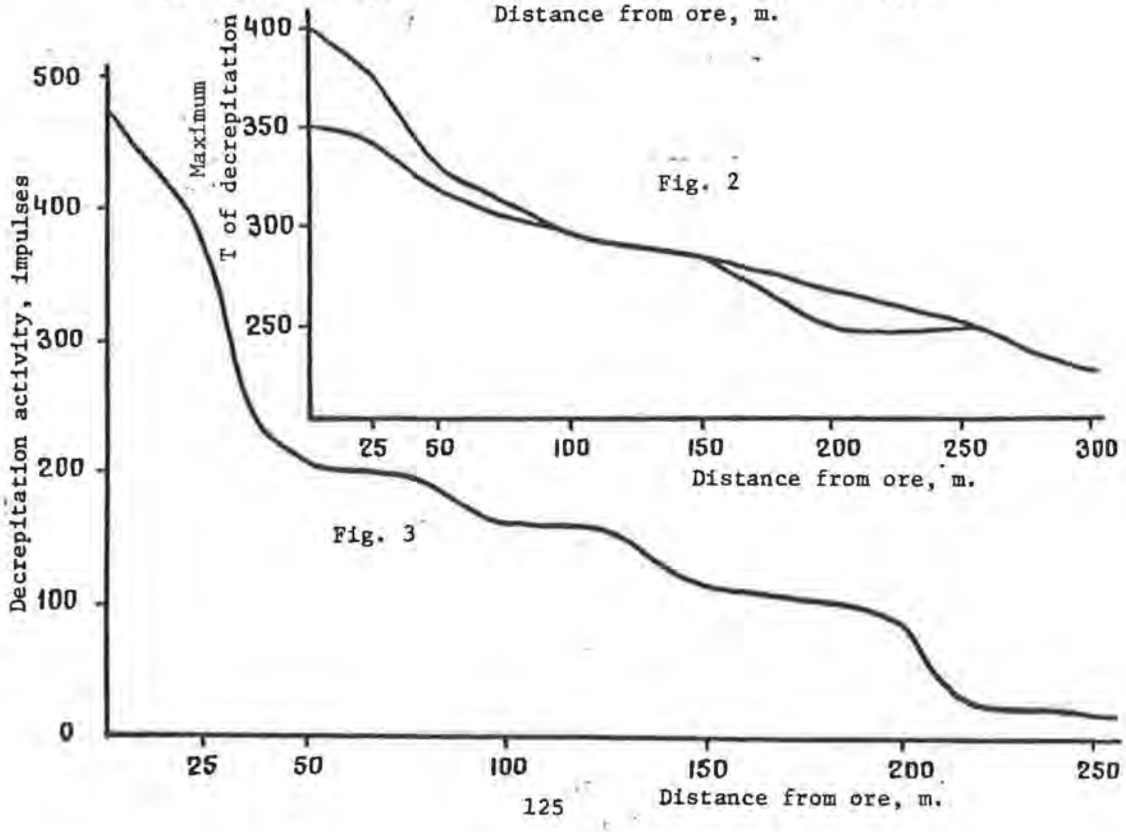

Fig. 2

Fig. 3

IMAI, H., and TAKENOUCHI, S., 1971, Report of the Japanese Committee on Inclusions in Minerals: Jour. Mining Metall. Inst. Japan, v. 87, no. 1001, p. 546-560 (in Japanese); translation by the authors.

The Japanese Committee on the Inclusions in Minerals was set up in October 1969, under the sponsorship of the Mining and Matallurgical Institute of Japan. The meeting was held three times during the last two years. This photographic album is the work of the committee for these two years. The photgraphs of the inclusions in minerals, which were studied by the members of the committee, are collected in this album.

The members of the committee are as follows:

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Chairman: Hideki IMAI
Secretary: Sukune TAKENOUCHI

Microphotographs:

Microphotographs of inclusions are arranged as follows. 1. Two-phase inclusions, 2. Gas inclusions, 3. Monophase inclusions, 4. CO_2-bearing inclusions, 5. Polyphase inclusions, 6. Volcanic glass and crystal inclusions, 7. Observation by freezing-stage microscope, 8. Inclusions in artificial crystals, 9. Observation by electron microscope, 10. Inclusions from neighbouring countries of Japan.

Abbreviation is as follows. B: bubble, L_2: aqueous solutions, L_1: liquid CO_2, G: glass, X: crystal, H: gas hydrate, I: ice, Th: homogenization temperature, S: salinity.

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I. Two-phase (liquid) inclusions

1. Quartz (Takatori W mine, Ibaragi) Contains a little CO_2, Th:305°C, S:3.5 wt%.
2. Quartz (do.) Contains a little CO_2, Th:297°C, S: 2.8 wt%.
3. Fluorite (do.) Contains CO_2, Th:321°C, S: 4.5 wt%.
4. Cassiterite (do.) Primary inclusion, Th: 343°C, S: 8.8 wt%.
5. Topaz (do.) Primary inclusions, Th: 338°-357°C, S: 2.4-4.0 wt%.
6. Topaz (do.) Secondary inclusion?
7. Rhodochrosite (do.) Primary inclusions, Th: 290°-320°C.
8. Cassiterite (Ohtani W mine, Kyoto) Th: 295°-345°C, S: 6.5-9.0 wt%.
9. Scheelite (do.) Th:260°-330°C, S: 6.1-8.7 wt%.
10. Hubnerite (Kaneuchi W mine, Kyoto) Th: 280°-337°C, S: 8.0-8.5 wt%.
11. Scheelite (do.) Th: 275°-292°C, S: 7.5-8.7 wt%.
12. Quartz (Hirase Mo mine, Gifu) Th: 270°-285°C.
13. Quartz (Ashio Cu mine, Tochigi)
14. Quartz (Chichibu Fe-Cu mine, Saitama) Occurred with pyrrhotite.
15. Hedenbergite (do.) Th: 330°C.
16. Garnet (do.)
17. Vesuvianite (Mitate Sn mine, Miyazaki)
18. Dipside (do.)
19. Hedenbergite (Kamioka Pb-Zn mine, Gifu)
20. Quartz (Osarizawa Cu mine, Akita)
21. Sphalerite (do.) Th: 276°C, S: 7.3 wt%.
22. Sphalerite (Budo Pb-Zn mine, Niigata) Th: 256°C, S: 9.6 wt%.
23. Sphalerite (Toyoha Pb-Zn mine, Hokkaido)
24. Sphalerite (jokoku Mn mine, Hokkaido) Th: 168°-178°C.
25. Sphalerite (Ohe Mn mine, Hokkaido) Th: 170°-235°C.
26. Quartz (do.) Th: 183°-212°C.
27. Rhodochrosite (do.) Th:18°-205°C.
28. Fluorite (Hiraiwa fluorite mine, Gifu) Th: 98°C.
29. Fluorite (Igashima fluorite mine, Niigata) Th: 80°-170°C.
30. Quartz (Hosokura Pb-Zn mine, Miyagi)
31. Quartz (do.) S: 2.4 wt%.
32. Quartz (Chitose Au-Ag mine, Hokkaido)
33. Barite (Furutobe kuroko mine, Akita) Barite in siliceous ore, Th: 179°C, S: 3.9 wt%.
34. Barite (do.) Barite in kuroko ore. Th: 188°C. S: 5.2 wt%.
35. Barite (Shakanai kuroko mine, Akita) Barite in kuroko ore, Th: 150°C, S: 4.0 wt%.
36. Anhydrite (Asahi gypsum mine, Fukushima)
37. Anhydrite (Uzen-Oguni gypsum mine, Yamagata)

II. Gas inclusions

38. Quartz (Onigajo, Kumano City, Mie)
39. Quartz (Chitose Au-Ag mine, Hokkaido)
40. Quartz (do.)

III. Monophase inclusions

41. Barite (Minami-Shiraoi mine, Hokkaido) Liuqid inclusions.

IV. CO_2-bearing inclusions

42. Quartz (Ohtani W mine, Kyoto) Inner bubble disappeared at 22°C. Estimated CO_2 concentration: 33 wt%.
43. Quartz (do.) Liquid CO_2 disappeared at 22.5°C. Estimated CO_2 conc.: 16 wt%.
44. Quartz (Takatori W mine, Ibaragi) Low density, estimated CO_2 conc.: 40-50 wt%.
45. Quartz (do.) High density, Th: 262°C, S: 2.6 wt%.
46. Quartz (Taishu Pb-Zn mine, Nagasaki)

47. Quartz (Tama Au mine, Iwate) Inner bubble disappeared at 30°C.

V. Polyphase inclusions
    48. Topaz (Naegi, Gifu) Pegmatite, Th: 393°C, S: 6.1 wt%.
    49. Beryl (Yamanowo, Ibaragi) Pegmatite.
    50. Fluorite (Obira Sn mine, Ohita)
    51. Fluorite (do.) S: 5.3 wt%.
    52. Fluorite (Takatori W mine, Ibaragi)
    53. Topaz (do.) Th: 343°C, S: 2.4 wt5.
    54. Rhodochrosite (do.)
    55. Axinite (Chichibu Fe-Cu mine, Saitama) Th: 340°C.
    56. Axinite (do.) Th:311°C.
    57. Vesuvianite (do.)
    58. Quartz (Nan-etsu Pb-Zn mine, Niigata) Th: 230°C, S: 5.1 wt%.
    59. Quartz (Taishu Pb-Zn mine, Nagasaki) Th: 366°C, S: 30 wt%, X_1: halite, X_2: calcite, X_3: opaque mineral.
    60. Quartz (do.) Th: 312°C.
    61. Quartz (Takatama Au-Ag mine, Fukushima) Th: 208°C.
    62. Quartz (Taishu Pb-Zn mine, Nagasaki) Quartz in granite, S: 40-50 wt%.
    63. Quartz (Chichibu Fe-Cu mine, Saitama) Quartz in quartz-diorite.
    64. Quartz (Onigajo, Kumano City, Mie) Phenocryst in quartz porphyry.
    65. Quartz (Tokuryu Au mine, Hokkaido) Phenocryst in rhyolite.

VI. Volcanic glass and crystal inclusions
    66. Olivine (Shinshiru-jima, Chishima Islands) Olivine in volcanic ejecta.
    67. Olivine (Oshima-Ohshima, Hokkaido) Olivine in volcanic ejects.
    68. Olivine (Miyake-jima, Tokyo) X: plagioclase.
    69. Quartz (Chitose Au-Ag mine, Hokkaido) Quartz grain in acidic tuff.
    70. Quartz (Chitose Au-Ag mine, Hokkaido) Quartz phenocryst in rhyolite.
    71. Plagioclase (Yakedake, Nagano) Phenocryst in andesite, Gm: pale green glass.
    72. Quartz (Shiroyama, Tsukui-gun, Kanagawa) Quartz in pumice of Quaternary tuff.
    73. Quartz (Kishu Cu mine, Wakayama) Quartz in acidic rocks.
    74. Quartz (Koza, Wakayama) Phenocryst in quartz porphyry.
    75. Quartz (Ashio Cu mine, Tochigi) Phenocryst in rhyolite.
    76. Quartz (Yaso Cu mine, Fukushima) Phenocryst in rhyolite.
    77. Quartz (Onigajo, Kumano City, Mie) Phenocryst in quartz-porphyry.
    78. Quartz (Tokuryu Au mine, Hokkaido) Phenocryst in rhyolite.
    79. Cassiterite (c) and sericite (s) inclusions in vein-quartz. (Takatori W mine, Ibaragi)

VII. Observation by freezing-stage
    80. Rhodochrosite (Takatori W mine, Ibaragi) CO_2-bearing inclusion.
    81. Quartz (Ohtani W mine, Kyoto)
    82. Quartz (Kaneuchi W mine, Kyoto)
    83. Quartz (Hosokura Pb-Zn mine, Miyagi)

VIII. Inclusions in artificial crystals
    84. Quartz P: primary inclusion, S: secondary inclusion
    85. Quartz Secondary inclusions in a curved fracture.
    86. Quartz Secondary inclusion
    87. Quartz
    88. Quartz L: seed, R: grown
    89. Quartz One of the inclusions shown in Fig. 88.
    90. NaCl Grown at 350°C and 160 kg/cm^2

IX. Observation by electron microscope (Replica figure)
    91. Fluorite (Hoei Sn mine, Ohita)
    92. Fluorite (do.)
    93. Fluorite (Hiraiwa fluorite mine, Gifu) a: {100}, o: {111}
    94. Fluorite (Igashima fluorite mine, Niigata) a: {100}

X. Inclusions from neighbouring countries of Japan
    95. Fluorite (Shimpo fluorite mine, Chuncheon, Kanqwen-do, Korea) Th: 110°C.

96. Fluorite (Kumi fluorite mine, Chungcheong Puk-do, Korea)
Th: 154°C, S: 0.5 wt%.
97. Quartz (Talseong W mine, Kyeongsang Puk-do, Korea) Bubble disappeared at 202°C, and halite disappeared at 254° C.
98. Quartz (do.) Bubble disappeared at 162°C, and halite disappeared at 277°C.
99. Olivine (Mauna Loa, Hawaii) Phenocryst in olivine basalt, Sp: spinel.
100. Olivine (do.)
101. Olivine (Kilauea, Hawaii) Phenocryst in olivine basalt.
102. Fluorite (Keumhwa fluorite mine, Kangweon-do, Korea)
a: {100}, m: {311}
103. Fluorite (do.)

KALYUZHNYI, V. A., (ed.), 1971, Mineral-forming fluids and parageneses of pegmatite minerals of the zanorish* type in the Ukraine (fluid inclusions, thermobarometry, geochemistry): Kiev, Naukova Dymka Press, 216 pp. (In Ukrainian with 2-page Russian Resume). (Contents and Introduction translated by Dorothy B. Vitaliano; Resume by D. Alverson).

(*On visiting Dr. Kalyuzhnyi's laboratory in L'vov, I found that the obscure Russian term <u>zanorish</u>, which is not in most Russian or Ukrainian dictionaries, refers here to pegmatites with large, crystal-lined central cavities, sometimes as large as 400 cubic meters in volume. Ed.).

CONTENTS (p. 216 in original)

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(* Could also be translated <u>substantial</u> or <u>essential</u>)

<u>Introduction</u> (p. 3-4 of original)

With the development of geochemical and physicochemical investigations of mineral deposits, the need for factual data on the chemical composition, (state of)aggregation, and thermobarometric characteristics of the mineralizing solutions has increased. Particularly felt is the lack of such information in recent works, where the description of endogenetic solutions is based only on the study of the paragenetic associations of minerals -- the solid products of chemical interactions in the earth's crust. In theoretical works on hydrothermal mineralization (Betekhtin, 1953), metasomatic replacement of minerals (Korzhinsky, 1956), the conditions of origin of endogenetic ore deposits (Sobolev et al, 1967; Smirnov et al, 1968), the forms of transfer of rare metals (Beus, 1961), geochemistry (Shcherbina, 1962; Smit [Smith?]), 1967), problems of the origin of waters on the earth (Derpgol'ts [Derpholz?]), 1962, the hydrochemistry of surface waters (Gerling et al, 1962)(+) the origin of hydrocarbons and bitumens in magmatic rocks (Florovskaya, 1967; Petersil'ye, 1960), the authors use information obtained by study of microscopic inclusions in minerals--relicts of deep solutions. Many publications on fluid inclusions specifically concerned with certain deposits are aimed at settling practical problems of geological exploration.

The parageneses of the minerals of granite pegmatites in general, and of the Zanorish syngenetic [pegmatites] in particular, formed in the unique physicochemical conditions of the transition from magmatic to hydrothermal crystallization. The regularities of the evolution of the formation of mineral assemblages in this period form the basis of theoretical principles concerning numerous groups of postmagmatic mineral deposits. The mineral associations alone do not always unambiguously clarify the conditions of mineral formation. It is necessary to establish a more detailed thermodynamic and physicochemical sequence of changes in the course of mineralization. These problems will be solved by a thorough (?) investigation of the physical properties and chemical composition of fluid inclusions in minerals.

Inclusions in minerals whose main component is an aqueous solution are produced during the whole process of pegmatite formation, by the trapping of portions of the surrounding mother liquid by the crystal. The particular value of investigating deep solutions via the fluid inclusions in minerals lies in the possibility of solving problems in the origin of mineral deposits in the historic aspect, namely, the reproduction of the sequence of development of the process in time and space.

The proffered work is devoted to an investigation of the pegmatites of Zanorish type in the Ukraine, which have been studied for their mineral parageneses and the physicochemical properties of the mineralizing fluids (the term "fluid" is used here in the broad general sense of a very mobile flowing substance of the earth's crust--a magmatic melt or a gaseous or aqueous solution). In general it makes no claim to be an exhaustive solution of the complex problems of pegmatite formation, but is regarded as a first attempt to summarize the work of a collective of investigators in this field (where the usual methods of investigation of mineral parageneses have been combined with a considerable measure of precision (of) analyses of fluid inclusions for perhaps the first time) and to record the main features of the complicated endogenetic process.

(The rest of the introduction tells who wrote which section of the monograph--these names have been added to the appropriate entry in the table of contents as they are not listed within the text--and who did the following analyses: analyses of water extracts; flame photometric determinations; X-ray and electronographic [electron microscope?] measurements of the minerals; mass-spectrometric chemical analyses of the gases; spectral analyses; determinations of the carbon isotopic composition of carbon dioxide inclusions. The laboratory assistants are also acknowledged, and the person who did the field work in the pegmatite regions. Finally, thanks are expressed to several individuals who reviewed the work critically and to others who cooperated and aided in the field work).

Resume (p. 214-215 of original)

The geochemical and thermodynamic characteristics of the process of formation of zanorysh pegmatites of the Ukrainian crystalline shield are presented in this work based on a study of relicts of the mineral-forming media (inclusions in minerals), of mineral parageneses and the typomorphic characteristics of minerals.

Syngenetic pegmatites of the zanorysh type within intrusions originated at the endocontact of a crystallizing granitic melt with incompletely consolidated basic rocks. The protopegmatitic melt segregates in the magma as a result of the concentration of more easily fusible and volatile components in regions of lowered pressure, which fluctuate. The low pressure regions are the result of the thermal contraction of the total volume of the intruded magma on consolidating and the support of the load of overlying rocks by the congealing crust at the top of the intrusive.

According to the state of the pegmatite as a physico-chemical system, two stages in its development are clearly recognized, which are delineated by the conditions of the α-β conversion of the modifications of quartz (about 573-600°): the pre-inversion [stage] (outer zones of the pegmatite crystallize, mainly from the melt), and the post-inversion [stage] (the Zanorysh region and zones of superimposed metasomatic alteration formed by the action of hydrothermal and pneumatolytic solutions). The moment of inversion in almost all pegmatites is fixed by the "honeycomb" fracturing in the quartz.

The widespread development and characteristics of the metasomatic processes caused by the different relationships between the activities of sodium, potassium and fluorine, make it possible to distinguish among the essentially quartz-feldspar zanorysh pegmatites [the following]: albitized (albitic), microclinized (microclinitic) and topazized.

In the enclosing granites and pegmatite minerals of the pre-inversion stage inclusions of melt have not been found, but gaseous syngenetic inclusions have been investigated in detail. In granites, in the direction toward the pegmatite (at distances of 8-10 m from it), the content of CO_2 increases (from 3-8 to 70-80%) and the amount of nitrogen together with rare gases decreases (from 75-80 to 13-19%). In inclusions from the graphic zone the gas component is also characterized by a higher content of CO_2, increasing, depending on the degree of metasomatic reworking, from 17 to 80%; nitrogen decreases correspondingly from 75 to 25%. That the inclusions containing CO_2 are syngenetic to the "graphics" is evidenced by the lower content of the heavy isotope C^{13} ($\delta C^{13} = -1.9$) compared to carbon dioxide from the late types of inclusions (δC^{13} in the zanorysh reaches - 1.5). In the post-inversion stage, according to the relative time of formation, in the quartz of pegmatites, 10 types of inclusions have been identified, each of which characterizes the state of the mineralizing solution at a specific period of crystallization. Similar inclusions have been found in other minerals: in topaz, microcline, siderite, beryl, etc.

The study of the evolution of post magmatic solutions by inclusions, at a number of pegmatite bodies, enables us to recognize three acidic and two alkaline periods in the activity of solutions (fig. 59). The alternation of these periods determines the change in mineral parageneses in the metasomatic alteration of previously formed rocks and in hydrothermal crystallization in cavities of the zanoryshes and in miarolytic cavities (fig. 74). This variable regime of the acid-alkali potential is caused by the disruption in hermeticity and by the relative degrees of closure of the pegmatite system during the contractional compression of the surrounding host-rock granite, which is caused mainly by the transformation of quartz. The post-inversion stage is characterized by a close connection of geologic-structural, tectonic factors to the thermodynamic characteristics and chemistry of the mineralizing solutions (temperature, pressure, state of aggregation, concentration). If, at the early stages of emplacement (crystallization from the magmatic melt) the conditions were similar for pegmatitic segregations located alongside, then in the post-inversion stage, against the general background of changes in the thermodynamic parameters are imposed the local factors, which determine the individual characteristics of the development of pegmatites (opening up by contractional fractures at different times; various scales of collapse, composition and characteristics of deep-seated solutions percolating upward, etc.). The study of inclusions reconstructs the regime of change in the geochemistry and thermodynamics of pegmatite-forming fluids and makes it possible to explain correctly the individual characteristics of post-magmatic differentiation of matter in different pegmatites, and of the typomorphism of minerals within the same body. In this plan, in the work, conclusions are given concerning the conditions of crystallization of quartz, topaz, accessory silicates of beryllium, cassiterite, and clay-mica minerals.

MANUCHARIANTS, B. O., On the conditions of formation of jasperoid Hg-Sb deposits, (Author at Institute of Mineralogy, Geochemistry and Crystal-chemistry of Rare Elements, Moscow, USSR) (Editor's note: This paper was submitted for presentation at the 1972 COFFI Symposium at the IGC at Montreal, but was only read by title at that meeting. It did not arrive in time to be included in the previous issue of COFFI. As Dr. Manuchariants has kindly provided an English translation, it is reproduced here, after extensive editing).

Introduction

This paper presents results of investigations of certain Hg-Sb deposits of the jasperoid-type of Tien-Shan. These were formed at the contact of limestones and overlying shales, and are localized in thick, (≤ several tens of meters) jasperoid-horny breccia (sic) horizons. The latter were formed by metasomatic silica replacement of separate limestone layers. Geological and structural conditions of their localization were examined in detail by Poyarkov (1955) and by Fedorchuk (1964). The main hypogen minerals of telethermal Hg-Sb jasperoid deposits are antimonite, quicksilver, quartz, fluorite and calcite; secondary minerals include pyrite, arsenopyrite, antimony sulfosalts, grey ore, livingstonite, getchellite, gold, galena, sphalerite, realgar, orpiment, sericite, dickite, barite, etc.

Commonly the hydrothermal mineralization is divided into three main stages: pre-ore, productive stage, and post-ore. The pre-ore stage is represented by metasomatic replacement of limestone layers by silica along the contact with shales, i.e. by the formation of interformational jasperoid-horny breccia deposits. Two main stages, differing in the mode of formation, can be isolated in this process. First is the major metasomatic replacement (formation of "jasperoid" quartz, fine-grained to cryptocrystalline) and then the deposition of silica as comb quartz in open cavities and as isolated veinlets, and extensive development of early fluorite.

There are very minor early sulphides such as pyrite and arsenopyrite, and also sericite, in this initial stage; calcite is of rather limited distribution.

Thermobarometric investigations

The main stage gangue and ore minerals, and some pre-ore and post-ore minerals, were examined for inclusions. The productive ore period is noted for fluorite, comb quartz, barite, and calcite, and associated with them antimonite, quicksilver, livingstonite and getchellite. This ore period overlaps with the late phase of jasperoid formation. The productive stage minerals showed three types of inclusions (Fig. 1): a) single-phase, pure carbon dioxide (appearing while hydrothermal solutions were boiling up,(sic.)) b) two-phase, gaseous-liquid; and three-phase (gas-water solution - liquid carbon dioxide). Thermobarometric investigations of these types are given in Table 1.

Homogenization temperatures of inclusions in minerals of the early part of the productive stage were in the range of 250°-160°C. Thus primary inclusions in early fluorite associated with antimonite in the Abshir deposit homogenized at 245°-220°C. These data and the presence of equal quantities of carbon dioxide in inclusions in both minerals indicate 250-240°C as the upper limit of antimonite crystallization. Primary inclusions in cinnabar(?) from the mercury and mercury-antimony deposits of Karasu and Chauvai homogenize at 210-160°C. Similar homogenization temperatures obtained on barite with cinnabar(?) localized along the growth zones, were determined by Banschikova, for the deposit at Tijikrut. The homogenization temperature of primary inclusions in comb quartz and fluorite, fixing the upper limit of antimonite and cinnabar(?) crystallization, were 260-220°C (complex jasperoid deposits of Abshir, Terek, Kara-Kamar, etc). The homogenization temperature of primary inclusions in comb quartz and fluorite from monomineralic antimony deposits commonly ranges from 160 to 200°C. Our data are based mainly on the formation temperature of the late jasperoid phase and are in a good agreement with estimated data of Spencer (1917), who determined the formation temperature of jasperoids in Ely (Nevada) by the gaseous phase volume method (160 to 270°C). These data also agree with the ideas of Lindgren (1925), Tarr, W.A. (1933), Lovering (1962), and others.

It should be noted that the intensity of replacement of limestone by silica is weakest in those deposits such as Terek and Abshir where the process of formation of jasperoid took place at the highest temperature (other factors such as pressure, solution composition, etc., being equal). This affects the thickness of metasomatites (commonly 5-10 m). The intensity of replacement increases in deposits formed at lower temperatures, yielding jasperoid horizons up to 30-40 m thick. This agrees well with experimental data obtained by Alexander et al. (1959), Kennedy (1950), Ellis (1959), Lovering (1962), Holland and Borcsik (1965), and others on the solubility of silica and calcium and magnesium carbonates as a function of temperature, pressure, composition and pH of the solutions.

Homogenization temperatures of minerals from the latter part of the productive stage, e.g., calcite with late cinnabar and antimonite along growth zones, as at Zarkhok, Kadamdgai, Terek and Chauvai, indicate crystallization in the range 140-120-90-75°.

Comparison of the temperatures obtained for the jasperoid deposits with homogenization temperatures of inclusions in quartz associated with antimonite of polymetallic, normal hydrothermal deposits such as Nagolnaia Tarasovka, Buduk, etc., (240-175°C) proves the identity of the formation temperatures of the same parageneses for various types of deposits.

Ore-forming solution pressures were calculated by carbon dioxide densities in gaseous-liquid inclusions using the temperatures of carbon dioxide partial homogenization and complete homogenization and the P-V-T data on carbon dioxides by Vulakovitch and Altunin (1965), and Kennedy, (1954). As shown in Table 1, formation of antimony and quicksilver deposits took place over a wide pressure range, from several hundreds to 1500 atm. and hence indicates the feasibility of Hg-Sb mineralization down to considerable depth. It proves also the conclusions made by Fedorchuk (1955, 1959) on the great vertical range of Hg-Sb mineralization. Phase studies of inclusions in minerals of Hg-Sb deposits of Tien-Shan showed that carbon dioxide was a constant component in these fluids. Analyses of carbon dioxide by the conductometric method are given by Manuchariants et al. (1970). This work shows that hydrothermal solutions forming Hg-Sb deposits were characteristically high in carbon dioxide concentration (up to 5-8 mole per liter). These large amounts of carbon dioxide show its significance in the ore-forming process and, at least, the weakly acid character of ore-forming solutions. The overwhelming majority of carbon dioxide-bearing inclusions were found in gangue and ore minerals crystallized at the beginning of the productive stage; minerals crystallized during the late-pre and post-ore periods had no inclusions containing carbon dioxide. Furthermore, the carbon dioxide content of inclusions decreases from early to late parageneses, showing an alkalization of the ore-forming solutions from loss of carbon dioxide by degassing and carbonation reactions. This agrees well with geological evidence of carbonate development at the end of the ore-forming process.

Data from the literature on other mercury provinces agree with these propositions. Liquid carbon dioxide was determined in gaseous-liquid inclusions by Roedder (1962), Vasiliev (1968), Koltun and Golovchenko (1962), Kalyuzhnyi and Koltun (1953), and Shamrai and Trufanov (1968), in quartz and calcite associated with cinnabar from the Red Devil mine (Alaska), Aktashskoe (Gorhyi Altai), and Nikitovka (Donbass) deposits, and from some deposits of the North Caucasus. In addition, Bailey and Everhart (1964) describe a case of a heavy flow of carbon dioxide from an exposed fracture zone at the New Almaden deposit.

High concentrations of bicarbonate ions are typical not only of the gaseous-liquid inclusions (Fedorchuk, et al. (1963), and Maslova (1963)) but also of thermal spring waters depositing antimony and mercury sulphides. Chemical analytical data of White and Roberson (1962) and by White (1970) showed that hydrothermal fluids as they ascended to the surface, were made alkaline by the loss of carbon dioxide during the pressure drop. There are two main mechanisms of loss of carbon dioxide (and increase in alkalinity) in ore-bearing solutions from jasperoid deposits: a) carbonation reactions and b) degassing. The near-surface antimony and mercury showings associated with recent hydrothermal action probably experienced degassing. But a typical feature for various types of Hg-Sb deposits is the fact of carbon dioxide pressure decrease, regardless of the method involved.

Results of thermobarometric investigations of inclusions in minerals of jasperoid-type Hg-Sb deposits of Tien-Shan

Deposit	Mineral	Temperature		Pressure (atm.)
		Homogenization, (+2°C)	Decrepitation, (+5°C)	
Abshir	quartz-II^{x}	220-200		1520-1225
	fluorite^{x}	245-220	70	
	pyrite	-	180	
	arsenopyrite	-	180	
	antimonite	-	140	
	calcite	90-8(sic)	-	
Kara-Kamar	quartz-II	260-165		
	antimonite	-	120	
	calcite			
Terek	quartz-II^{x}	254-226		700-950
	antimonite	-	110	
	calcite	90-65		
Chauvai	quartz-II^{x}	214-180	-	
	fluorite-I	215-160	-	
	fluorite-II^{x}	175-135	-	
	fluorite-III	128-108	-	350-200
	antimonite	-	80	
	cinnabar-I^{x}	210-160	70	
	Iceland spar with cinnabar-II	110-70		

x) Liquid carbon dioxide is present.

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ORLOVA, L. M. (VASIL'CHIKOVA), 1971, Determination of alkalies in micro-inclusions in quartz by the method of aqueous extraction using small samples, in Investigations of mineral-forming solutions and melts in inclusions in minerals, N.P. Ermakov and L.N. Khetchikov, eds., All-Union Institute for the Synthesis of Mineral Raw Materials, (Tr. vsesouz. nauchno-issled. inst. sinteza mineral. syr'ya), Trudy, v. 14, 170-171 (in Russian)

The sodium and potassium content of aqueous extracts was determined by flame photometry. The change in the content of alkalies in hydrothermal solutions in relation to the temperature and the stage of quartz formation was demonstrated on a specimen of quartz crystal-bearing quartz veins. (Author's abstract).

The author assumes that the inclusion fluids are true samples of the mineral-forming solution, and notes that the fundamental defect of the aqueous extract method is the averaging of the compositions of inclusions of different ages, since a whole variety of gaseous and liquid inclusions is extracted totally. The author states that this method is the fundamental method of chemical analysis of gas-liquid inclusions in transparent and opaque minerals.

Aqueous extracts from crystals of rock crystal, vein quartz, and the enclosing quartzites, from two quartz crystal deposits in one of the regions of the Soviet Union, were investigated after the determination of the homogenization temperatures of each sample.

Prior to analysis the sample was boiled in concentrated hydrochloric acid to remove absorbed impurities and hydrated iron oxides from the surface. Then it was washed carefully with distilled water and dried at 80-100°C. It was crushed to a grain size of 0.5 to 1 mm. It was sorted under the microscope to remove pieces with intergrowths and inclusions of other minerals, and was then ground in an agate mortar. The ground sample (2 gm.) was extracted with distilled water at 60°C for 15 min. with constant stirring. Then the extract was filtered through a Shott funnel (no. 4), transferred to a 25 ml. measuring flask and the Na^+ and K^+ determined by flame photometry. The results of the analysis of the aqueous extracts were averaged on the basis of 2-3 control analyses on the same sample (see Table).

Results of analyses of aqueous extracts of quartz in two deposits

Sample	Homogenization temperature range (°C)	Content in 100 gm. of sample (mgm.) K^+	Na^+	$Na^+:K^+$ ratio
		Deposit A		
		Low temperature vein		
Quartz crystal	480-120	0.116	0.602	3.62*
Vein quartz	480-150	0.167	1.840	9.83*
Quartzite	480-150	0.352	2.03	5.76
		High temperature vein		
Quartz crystal	600-170	0.249	0.427	1.71
Vein quartz	640-230	0.291	0.965	3.32
Quartzite	650-160	Not analyzed (feldspar ingrowth)		
		Deposit B		
		Low temperature vein		
Quartz crystal	520-120	0.321	0.89	2.77
Vein quartz	580-150	0.436	2.89	6.62
Quartzite	640-120	0.845	3.17	3.76
		High temperature vein		
Quartz crystal	610-120	0.364	0.88	2.43
Vein quartz	630-200	0.528	2.51	4.75
Quartzite	660-160	Not analyzed (feldspar ingrowths)		

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*Ed. note - These numbers do not agree with the analyses presented.

From the table it is evident that the Na^+ and K^+ content in the solutions increases regularly from crystals of rock crystal to quartzite. Thus, in the low temperature veins the total composition of the solutions is characterized by a higher content of Na^+ compared with that in the high temperature veins, whereas the K^+ content is lower in the low temperature veins than in the high temperature veins. The $Na^+:K^+$ ratio is a maximum in extracts from vein quartz and a minimum in rock crystal. Low temperature veins of quartz and of rock crystal have a higher Na/k ratios (in absolute value) than the high temperature ones.

Thus this method can be used to clarify the differences in the total composition of the solutions of low- and high-temperature quartz crystal bearing veins.

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INDICES TO VOLUME IV

The user should keep in mind the following features of these indices. Where several different items in the given category occur on the same page, either the number of such items or "m" (for multiple) 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.

Author Index: Only first authors are listed.

Subject 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 well result in occasional incorrect or omitted entries. Some pertinent entries are included under a given subject even though the index word does not occur in the abstract. The deposit type is indexed only where known to the Editor without research, and hence some may be incorrect. The type terms such as porphyry copper and Mississippi Valley are used loosely. Analyses for specific elements are indexed only when they are particularly significant; thus semiquantitative spectrographic analyses are generally ignored. The mineral host for the inclusions studied is indexed except for decrepitation studies. Entries that would include too many pages (such as Homogenization, Quartz) are omitted.

Deposit Index: 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.

AUTHOR INDEX (See page 137)

<u>SUBJECT INDEX</u> (See page 137)

DEPOSIT INDEX (See page 137)

VOLUNTEERS NEEDED

The Editor would appreciate very much 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 covering various segments of the literature, preparing abstracts, indexing, and translation (particularly from the Russian). These jobs can be partitioned into as small units as desired, and every little bit of help helps.