FLUID INCLUSION RESEARCH

Proceedings of COFFI

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

Volume 9

1976

Fluid Inclusion Research

Volume 9

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The editors would appreciate any help that can be offered by the readers in issuing future volumes of Fluid Inclusion Research - Proceedings of COFFI. Help is particularly needed in covering various segments of the literature on a regular basis, preparing abstracts, indexing, and translation. These jobs can be partitioned into as small units as desired; please contact either editor at the above addresses. On an informal basis, it would be most helpful if readers could send to the editors reprints of even just reference citations of pertinent literature. Such help is particularly useful to avoid missing obscure publications, or ones in which the presence of inclusion data may not be obvious from title or abstract. If important papers have been missed in previous volumes, they also should be noted.

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ANN ARBOR

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Preface

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

The purpose of the publication is to provide entrée to the literature with English abstracts or annotated bibliographic citations of all items from the world literature published during the volume year that either contain fluid inclusion data or are pertinent to some aspect of fluid inclusion work. This covers all types of fluid inclusions (aqueous, organic, silicate melt, sulfide melt, gas, etc.), causes and mechanisms of trapping (including various types of immiscibility), physical, chemical, and isotopic data, and data on experimental studies of systems pertinent to the interpretation of all types of phase changes occurring in inclusions, as well as to the sources of such volatiles or fluids and their interactions with rocks. These data are generally given without editorial value judgments except in the case of obviously contradictory or obscure statements. Extent of coverage varies in part as an inverse function of the availability of the original text to the average Western reader and in part as a direct function of the usefulness of the data. In addition to abstracts and citations, we publish English translations of inclusion papers from foreign languages, where available and not otherwise published in English, and notices of meetings and symposia.

Most of the translations from Russian sources in this volume are by the associate editor. Included among these are the abstracts of 78 of the 255 papers presented at the Fifth All-Union Conference on Thermobarometry held at Ufa (in the Urals), September 20-27, 1976, and 123 other items from the Russian literature. There are 79 items from other foreign language sources and 324 items from the English language literature for a total of 604 abstracts, citations, or annotated citations, plus subject and locality or deposit indices. (As all 8 items in Translations section are also listed in the Abstract section, no author index is needed).

Although each abstract is duly credited, the editors wish to acknowledge, in particular, the help of Dr. M. Fleischer, of the U.S. Geological Survey, who provided translations of several items and helped with many citations. Chemical Abstracts, of Columbus, Ohio, has most graciously permitted the use of a limited number of their copyrighted abstracts, as indicated in the abstract citations. Drs. Maurice Pagel and Arthur Barabas of CRPG, Nancy, and Dr. Chris Eastoe of the Univ. of Tasmania have collaborated to provide translations of numerous French items. Many other individuals, too numerous to list, have helped by sending the editors books, reprints, references, and copies of abstracts. We particuarly are indebted to Professor Ermakov, Chairman Emeritus of COFFI, for copies of Russian books; to H.E. Belkin for library searches; and to Mrs. Wieslawa Kozlowski for her extensive typing help.

We are particularly fortunate to present here, through the courtesy of Prof. D.A. Brown of the Australian National University, a complete translation of the four most pertinent chapters in a 1975 Russian book dealing with melt inclusions. This summarizes the extensive Soviet studies (145 references) on melt inclusions, the equipment used, and the interpretation of the data obtained.

To authors of pertinent articles that have been omitted or are misquoted here through haste, or through language difficulties, we extend our apologies and our request to have these things called to our attention; to authors whose original abstracts have been drastically shortened, edited, or revised, we offer a reminder that the following "abstracts" are not intended to be abstracts of the whole paper, but only that part most pertinent to inclusion workers. The obvious inconsistencies in citation, transliteration, abstracting, and indexing are strictly a result of lack of editorial time. A vigorous effort is being made to make future volumes much more current than this one. 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 twenty-five cents per page.

June 28, 1978

Edwin Roedder, Editor
Andrzej Kozlowski, Associate Editor

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Notices of Meetings and Symposia

The Fifth All-Union Conference on Thermobarometry met at Ufa (in the Urals), September 20-27, 1976; Professor N.P. Ermakov of Moscow University was the convenor. It was attended by 310 persons from USSR, plus 7 from other countries (ČSSR, Bulgaria, Romania, and Poland), from 85 organizations, and celebrated the 25th anniversary of the study of fluid inclusions in the USSR, as marked by the publication of Prof. Ermakov's book in 1950. Prof. Ermakov accepted a 5-year chairmanship of the Soviet section of COFFI. During the meeting 255 papers were presented; translations of the abstracts of 78 of these are in this volume. These are taken from the 206-page abstract volume (only 600 copies printed; e.g., see Andrusenko and Glukhov, 1976).

A symposium on "Crystal growth and habit" was held in conjunction with the third joint meeting of the Mineralogical Society of America and the Friends of Mineralogy, February 13-14, 1977, in Tucson, Arizona.

A meeting on "Current research on fluid inclusions and on mineral deposits" was held at Durham, England, December 14-17, 1976, under the sponsorship of the Mineral Deposits Study Group of the Geological Society and the Applied Mineralogy Group of the Mineralogical Society. Abstracts of some of the papers presented were printed in the program of the meeting and are given here. Others were printed only in vol. 86 (1977) of the Transactions Inst. Mining and Met., and hence will be given in the next volume of Fluid Inclusion Research (vol. 10).

A short course on "Fluid inclusion equipment and methods" was held in March, 1978 at Imperial College, London, given by Prof. Andrew Rankin. Most of the course was devoted to the practical aspects of fluid inclusion studies, and was well received.

There have been two meetings of the Inclusion Group of the Societé française de Mineralogie et Cristallographie. The first was held in December 1975 and resulted in a special issue of the Bulletin Soc. fr. Min. et de Crist., vol. 99, no. 2-3, 1976, with 23 papers in French, all presented here in English abstract (or full translation).

The second meeting of the Inclusion Group was held February 16 and 17, 1977, at Toulouse, with 16 papers presented. English translations of the abstracts will be published in the next volume of Fluid Inclusion Research.

A special session on Fluid and melt inclusions was held September 26-28, 1977, at the Midwest American Geophysical Union Meeting, at Purdue University, West Lafayette, IN, (with Edwin Roedder as convenor). Abstracts of the seven papers presented will be published in the next volume of Fluid Inclusion Research.

The Sixth International COFFI Symposium on Fluid Inclusion Research, with Edwin Roedder as convenor, will be held August 17, 1978, at Salt Lake City, Utah, as part of the Fifth Quadrennial Meeting of the International Association on the Genesis of Ore Deposits (IAGOD). Twenty-six abstracts were submitted and will be found in the next issue of Fluid Inclusion Research.

The Eleventh General Meeting of the International Mineralogical Association will be held in Novosibirsk, USSR, on Sept. 4-10, 1978, on the invitation of the Academy of Sciences of the USSR and the All-Union Mineralogical Society, with Dr. N.V. Sobolev, Inst. of Geol. & Geophysics, 630090 Novosibirsk-90, as Secretary General.

The Sixth All-Union Conference on Thermobarogeochemistry is planned for Sept. 19-22, 1978 in Vladivostok, to be hosted by the Far East Scientific Center of the Academy of Science of the USSR (Director Dr. Valetin Grigor'evich Moiseenko), with Dr. Miroslava Igor'evna Efimova as Scientific Secretary, 690022 Vladivostok-22, Geological Institute, USSR.

Organization of COFFI

The Bureau of COFFI consists of six officers as follows: Chairman Emeritus - N.P. Ermakov, U.S.S.R.; Chairman - E. Roedder, U.S.A.; First Vice-Chairman - S. Takenouchi, Japan; Second Vice-Chairman - F.P. Mel'nikov, U.S.S.R.; Third Vice-Chairman - M. Solomon, Australia; and Secretary - G. Deicha, France. The following series of Regional Representatives have also been established to provide foci for coordination and exchange of information on COFFI activities, and to help assure complete coverage of the world literature by forwarding reprints or citations to the editors.

Africa: Dr. H.M. El Shatoury, Associate Professor of Geology, Egyptian Atomic Energy Authority (presently at Geology Department, Faculty of Science, University of Sanaa, Sanaa, Yemen)

Australia: Dr. Ronald W.T. Wilkins, CSIRO, Minerals Research Laboratories, P.O. Box 136, North Ryde, N.S.W. 2113, Australia

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U.S.A.: Dr. Edwin Roedder, U.S. Geological Survey, National Center, Stop 959, Reston, VA 22092, USA

U.S.S.R.: Professor Evgenii Mikhailovich Laz'ko, Dept. of Geology, L'vov University, Shcherbakova 4, L'vov, Ukr. SSR, USSR.

Abbreviations

Note: The following abbreviations are used in part of these abstracts to save space. (It is planned to eliminate most such use of abbreviations in future volumes.) The correct form of the word (noun, adjective, verb, plural, etc.) can be obtained from context. The Cyrillic sequence, *а,б,в,г,д,е* are converted to abcdef.

alk.	alkaline
alt.	altered
amorph.	amorphous
anal.	analysis
app.	apparatus
aq.	aqueous
assemb.	assemblage
assoc.	associated
atm.	atmosphere
avg.	average
calc.	calculated
char.	characterized
chem.	chemical
chrom.	chromatographic
coef.	coefficient
comp.	composition
conc.	concentrated
conds.	conditions
corr.	correction
cpd.	compound
crit.	critical
d.	density
decrep.	decrepitated
dep.	deposit
dept.	department
det.	determined
devel.	developed
diam.	diameter
diff.	difference
dist.	distinguish
distrib.	distribution
dm.	daughter mineral
dxl.	daughter crystal
equil.	equilibrium
est.	estimated
estab.	established
evid.	evidence
evol.	evolution
exam.	examined
exper.	experimental
extr.	extracted
F	degree of fill
form.	formation
fract.	fractionated
G	gas
gen.	generation
geochem.	geochemical
geol.	geological
HC	hydrocarbon
heterog.	heterogenization
homog.	homogenization
hyd.	hydrothermal
ident.	identification
ign.	igneous
inc.	inclusion
inst.	instrument, institute
invest.	investigated
iso.	isotopic
L	liquid
lab.	laboratory
max.	maximum
meas.	measurement
mech.	mechanism
meta.	metamorphic
min.	mineral, mineralization
obs.	observation
org.	organic
P	pressure
peg.	pegmatite
phen.	phenocryst
phys.	physical
P inc.	primary inclusion
pneu.	pneumatolytic
ppt.	precipitate
prelim.	preliminary
prep.	prepartion
prod.	production
prop.	property
PS	pseudosecondary
qual.	qualitative
quan.	quantitative
ref.	reference
sal.	salinity
sat.	saturation
sed.	sedimentary
sol.	solution
soly.	solubility
spec.	spectroscopy
std.	standard
strat.	stratigraphic
syn.	synthetic
T	temperature (^{o}C)
T_D	temperature of decrepitation
T_F	temperature of formation (i.e., trapping)
T_{Frz}	temperature of freezing
T_H	temperature of homogenization
T_M	temperature melting
tech.	technique
thdy.	thermodynamic
theor.	theoretical
therm.	thermometer
univ.	university
V	vapor
xl.	crystal
xline	crystalline
xlized	crystallized
(...)	part of author's abstract omitted.

Abstracts, Translated Abstracts, or Annotated Citations to World Literature, 1976

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

ABE, H., and AOKI, M., 1976, Experiments on the interaction between Na_2CO_3-$NaHCO_3$ solution and clinoptilolite tuff, with reference to analcimization around Kuroko-type mineral deposits: Chemical Geol., v. 17, p. 89-100.

AKELLA, J., 1976, Partitioning of chromium between coexisting olivine, spinel and melt, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 751. Author at NASA, Houston, TX.

AKIMTSEV, V.A. and KUDRIM, B.V., 1976, Primary inclusions in tantalite-columbite from rare-metal pegmatites: Soveshch. Molodykh Uchenykh Mineral., Geokhim., i Metodam Issled. Mineral (Tezis. Dokladov), Primor. Otdel., Vses. Mineralog. Obshch., Dal'nevostoch. Geol. Inst., Vladivostok, p. 34 (in Russian; translation courtesy of Michael Fleischer).

1. Inc. in xls of tantalite-columbite from rare-metal granitic peg. were studied. Tantalite-columbite forms aggregates, and also idiomorphic, well-shaped xls up to 5 cm. diam.

2. Four types of inclusions were recognized: (1) P xline; (2) P incs. of sol.-melt; (3) Ps inc. of sol.-melt; (4) S G-L.

3. The phase comp. of the P inc. of sol.-melt was: gas $\leq$ 20 vol %), liquid CO_2 ($\leq$30%), aq. salt sol. ($\leq$ 80%), and solid silicate phases ($\leq$ 50%).

The Ps inc., according to morphology and phase comp. were analogous to the P inc. of sol.-melt.

4. Complete homog. of the P inc. occurred in the liquid phase at 560-400°. The d of the homog. sol.-melt was 1.4 g/cm^3.

5. P at T_H of 580° is 2800 ± 500 atm.

6. Of the volatile components, important roles during the xliz

of tantalite-columbite belong to water and CO_2.

7. A photoelastic effect was found around the P xline inc. On heating, the colored aureole disappears at 440 to 540°, and returns in part as the T drops.

AKINCI, Ömer, 1976, Fluid inclusion study of Bulancak sulphide veins: Geol. Soc. of Turkey, Bull., v. 19, p. 45-52 (in Turkish with English captions and abstract). Author at Maden Tetkik ve Arama Enstitüsü, Ankara, Turkey.

Data based on a study of more than 2500 primary and secondary fluid inclusions in transparent ore and gangue minerals are given. The data include measurements on the temperature, pressure, density and salinity of the inclusions present in the Southern Bulancak Deposits, Eastern Black Sea Ore Province of Turkey.

The inclusions were moderately saline, salinity varying with the range 13.2 equivalent wt. % NaCl to almost fresh water indicated by a density change from 0.74 gr/cm^3 in the early vein stage to 0.98 at the end of the base metal sulphide stage. These variations may reflect the mixture of deeply circulating meteoric waters with rising, saline, hydrothermal fluids.

Homogenization temperatures ranged from ca 80°C to 340°C. Inclusions show a temperature rise from ca 230 to 330°C in the early vein stage, and eventually boiling conditions were reached. At a later stage the fluids cooled from 330°C to ca 80°C in the base metal sulphide stage. The highest temperatures were obtained from the Tekmezar Group of veins, in comparison to the Dariköy group of veins, indicating a horizontal temperature zoning.

Evidence of boiling conditions and geological data suggest that the depositional pressures were 85-90 bars indicating a 1000 m hydrostatic load. Data obtained from isotherms indicates that the ore-bearing fluids rose along NW-SE trending faults. Fluid inclusion studies combined with geological data are considered to be useful parameters in mineral exploration to pinpoint richest part of the orebody. (Author's abstract)

ALBAREDE, Francis, 1976, Some trace element relationships among liquid and solid phases in the course of the fractional crystallization of magmas: Geochim. Cosmo. Acta, v. 40, p. 667-673. Author at Universités de Paris 6 et 7, Institut de Physique du Globe, Department des Sciences de la Terre, Laboratoire de Géochimie et Cosmochimie, Paris 05, France.

ALTHAUS, E. and WALTHER, J., 1976, Fluid inclusions in minerals from carbonatites (abst.): Geological Society-Mineralogical Society (Britain) Symposium on fluid inclusions, Univ. of Durham, Abstracts of meeting (unpaginated), to be published in Trans. I.M.M. Sect. B.

Calcite and apatite can both be primary magmatic phases in carbonatites. Fluid inclusions in these minerals can be interpreted as samples of the original fluid phases that coexisted with the original melts and can therefore furnish data on their composition at the magmatic stage.

Apatite crystals of the carbonatite from the Kaiserstuhl in southwestern Germany contain fluid inclusions of different types. Mode of occurrence and shape of the inclusions suggest that they are of primary origin. Both the pattern of distribution in the crystals and the heterogeneity in chemical composition suggest different generations formed under varying conditions. They contain liquids (H_2O, CO_2) and gases (CO_2) in different ratios and frequently one or more of the solids NaCl, KCl and $NaHCO_3$, besides other, still unidentified, solid phases. Some inclusions contain bituminous hydrocarbons. Many arguments appear to support the conclusion that the apatite crystals are of hydrothermal rather than igneous origin. Since they are intimately intergrown with rare-earth ore minerals (pyrochlore, dysanalyte), the igneous origin of the latter is questionable. The very small primary inclusions in the carbonate minerals contain fluids different from those in apatites. Their composition accords with an igneous origin. (Authors' abstract)

AMOSSE, Jean, 1976, Experimental determination of the pressure and temperature of formation of a quartz-wolframite vein. Theorical approach: Bull. Soc. Fr. Minéral. Cristallogr., v. 99, p. 121-127 (in French). Author at Laboratoire Electrochimie, E.N.S. Grenoble 38 Saint Martin d'Heres, France.

The fluid inclusion method was used to obtain the temperature of formation of quartz from the wolframiferous vein of Borralha (Portugal). The pressure was determined by measuring the $\frac{\Delta l}{l}$ variation of the wolframite lattice after annealing at high temperature to remove the stresses. By measuring the compressibility coefficients of wolframite, we could apply the equation of state of solids to obtain the pressure of formation. The temperature of formation gave the limiting conditions, and an hypothesis about the filling of the vein gave the initial conditions required to integrate the equation of heat transfer. The good agreement between theoretical and experimental results justifies the initial assumptions. (Author's abstract)

Note by M. Pagel - Homogenization temperatures between 192 and 275°C, melting temperatures between -5.5 and -8°C, and estimated presure of 1500 bars give formation temperatures of 325 to 430°C. Temperature variations are related to the position with respect to an acid intrusion.

AMSTUTZ, G.C., and BERNARD, A.J., eds., 1976, Ores in Sediments: New York, Springer-Verlag, 350 pp.

Twenty-four chapters summarizing various aspects, including both specific occurrences and processes. (ER)

ANDERSON, A.T., 1976a, Coalescence ascent and crystallization of the 1974 Fuego magma: a progress report, (abst.): Amer. Geophys. Union Trans., v. 57, p. 346. Author at Dept. of Geophysical Sciences, Univ. of Chicago, Chicago, IL 60637.

Tephra which fell Oct. 14 (sample VF-74-50) contain two groups of plagioclase xls: 1) most abundant are subhedral xls (An 91-84) char. by one or two zones of inc. of glass 30 to 200 µm from the rim; 2) rare xls having a clear central core (An 90) with a ragged outline surrounded by an oscillatory zoned rim (An 88). Most of the xls are broken. Intact single xls longer than about 0.5 mm of both groups are asymmetrically zoned. For example: a set of oscillations on one (201) face may be traced to the opposite face where the same set is 10 to 300 % thicker. In two xls of the first kind for which data are complete inner and outer-oscillatory zones are thickest on the ($\bar{2}01$) face of the xl marked by the thinnest intervening zone of inc. of glass and gas. I explain the asymmetric zoning by assuming that the rate of advance of a xl face is governed both by diff. through the melt and by flow of melt to the face. The bottom face of the growing xl "sees" fresh liquid, the top face "sees" depleted liquid. Consequently the trailing face grows fewer oscillations. The reversal in asymmetry observed for the inc.-rich zone is explained by growth during flotation by gas bubbles which nucleated along the growing xl faces. The xls grew from a high-alumina basalt with 4 ± 2 wt. % H_2O, 0.14 % S and 0.13 % Cl at an est. d. and viscosity of 2.32 gm/cm^3 and 70 to 700 poise. Millimeter-sized plagioclase phen. could fall through such a melt at rates between 1 and 10 cm/hour, if viscous interactions between neighboring xls are neglected. The relation between settling rate and xliz rate is not understood. (Author's abstract).

ANDERSON, A.T., 1976b, Magma mixing: petrological process and volcanological tool: J. Volcanol. Geotherm. Res., v. 1, p. 3-33. Author at Dept. Geophys. Sci., Univ. Chic., Chicago, Ill.

Magma mixing is a widespread, if not universal igneous phenomenon of variable importance. The evidence for magma mixing is found primarily in glassy tephra; the consolidation of lava obscures the evidence. Inclusions of glass in big crystals in tephra, because of their greater range in composition compared to the whole rock and the residual glass, indicate that the big crystals were derived from separate systems which mixed together prior to and during eruption. The observed or reconstructed concentration of K_2O in inclusions of glass in large crystals represent the composition of the contaminant and host systems. Selective enrichment in K_2O during entrapment of melt by growing crystals is shown to be negligible. The weight percents of K_2O in host, contaminant and residual glass and bulk rock determine the proportions of contaminant and host required to yield either the residual glass or bulk rock. In several cases the proportion of contaminant required is substantially larger than the proportion of crystals in the hybrid magma; therefore, by a heat budget argument, the contaminant was partly liquid when contamination began. In some tephra individual phenocrysts contain glasses which are more silicic toward the center of the crystal indicating that the crystal grew from a melt whose composition changed in the opposite sense to that expected for progressive solidification of a closed system. Space-time associations of compositionally distinct glassy tephra with contaminated magmas suggest coexistence of basaltic and silicic melts within magma systems. Evidence of contamination is present in most tephra studied so far. Magma mixing appears to be the prevalent process whereby contamination occurs. Magma mixing seems to be particularly evident in systems where there is independent evidence for a vapor-saturated magma reservoir. Probably vapor saturation promotes mixing in magma systems. Magma mixing probably is an important mechanism of compositional diversification (differentiation) of volcanic rocks from continental margin and possibly other environments.

Textural evidence of the onset of magma mixing can be related to disturbance of a complex reservoir immediately before ascent and eruption. Thus, conditions before mixing can be ascribed to the reservoir. In this way it is possible to learn about the reservoir: its composition, its diversity, its depth, its walls. It is also possible to learn about the causes of eruption: whether by increase in gas pressure due to either progressive consolidation, or heating from below by an injection of hot magma, or by encounter with groundwater; whether by buoyant rise. Evaluation of these problems requires also a thorough knowledge of the chronology of particular eruptions. Thus, magma mixing is a useful volcanological tool. (Author's abstract)

ANDERSON, D.E., and GRAF, D.L., 1976, Multicomponent electrolyte diffusion: Annual Review of Earth and Planetary Sciences, v. 4, p. 95-121. Authors at Dept. of Geol., Univ. of Illinois at Urbana-Champaign, Urbana, Illinois 61801.

A thorough review of theory and experiment. (ER)

ANDRUSENKO, N.I. and GLUKHOV, A.P., 1976, Temperature zoning of Au-Ag ore mineralization at certain deposits of the Okhotskiy-Chukotskiy volcanogenic belt, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 34 (in Russian; translation by A. Kozlowski).

Zoning was studied at Au-sulfantimonide and Au-argentite deposits of the Au-Ag formation. At the first deposit a general decrease of T_H from NE to SW was found. Conditions of precipitation of the productive association: Au-quartz-adularia - hydromicas (plus Ag sulfasalts) was 265 - 190°C in the central part of the ore field, where the mineralization is connected with the early (425 - 270°C) quartz-Bi association; 245 - 160°C at the N part of the ore field, coexisting with quartz-carbonate (65* - 140°C) and sulfide-quartz-feldspathic (265 - 160°C) associations; 220 - 120°C at SW range of the ore field, where also post-productive, quartz-carbonate-fluorite association (190 - 95°C) is developed.

At the second deposit in the upper part of the vertical section the quartz-adularia-chlorite plus argentite (productive) association prevails, that formed at 340 - 240°C. In the lower part of the section, the earlier quartz-sulfide (430 - 180°C) and late quartz - rhodonite - rhodochrosite plus helvite (410-220°C) associations are found. For two last associations boiling of hydrotherms at 360 and 320°C was recognized, being also the initial point of precipitation of ores. T_D of ore minerals are higher by 20 - 40°C (modal values) in the places of crossing of ore zones, compared with T_D of ore zones. (Authors' abst.)

*Probably a misprint; 165°C? 265°C? (A.K.)

ANDRUSENKO, N.I. and ZHADNOVA, T.P., 1976, Temperature conditions of gold ore mineralization in Precambrian deposits of E. part of Baltic shield (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept., 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 31-32 (in Russian; translation by A. Kozlowski).

Au-sulfide mineraliz. with Ag (unusual for Precambrian shields), has T_H 280-240 and 180-100°C. Au-quartz veins of Middle Proterozoic age contain G/L incs. with T_H 380-340°C and essentially G (CO_2) incs. (From authors' abst.)

ANDRYANOVA, S.I., AMINOV, V.B., and VALYASHKO, L.M., 1976, Conditions of formation of the gold-ore deposit in the Lena region, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol.,

p. 33 (in Russian; translation by A. Kozlowski).

Au-quartz veins and zones of Au-quartz-sulfide mineralization occur in stratified, fractured and porous coal-bearing shales (effective porosity 4-11%). The content of organic matter (to 5%) and sulfides correlate with each other. The formation of ores was under the action of cyclically changing conditions at T 360 - < 80°C. Abrupt changes of T reached 200°C. Main mass of gold precipitated at the final, low T stage (200 - 80°C). CO_2 content in quartz of various stages ranges from 17 to 99.6 vol. % in individual inclusions, mean value for the whole deposit, 44 vol. %.

In quartz of the productive stage this value is 44.29 vol. %; CO_2 is possibly derived from carbonates of host rocks. (Authors' abst.)

ANFILOGOV, V.N., and PURTOV, V.K., 1976, Mechanism of the interaction of solutions with magmatic bodies in pores: Geokhimiya, 1976, no. 9, p. 1400-1403 (in Russian).

APOLLONOV, V.N., 1976, Ammonia in sylvite of Verkhnekamskoe deposit: Akad. Nauk SSSR, Doklady, v. 231, no. 3, p. 709-710 (in Russian). Author at Moscow State Univ., Moscow.

NH_4Cl in sylvite occurs in concentration 0.007-0.14%, giving an IR absorption band at 1408 cm^{-1} and probably forming small solid inclusions often described as NaCl. Pertinent to composition of solid and liquid inclusions in salts. (A.K.)

ARKHIPCHUK, R.Z., 1976, Thermobarogeochemical criteria of depth of formation of fluorite deposits from Transbaikal'ye: Geol. Rudn. Mest., v. 18, no. 5, p. 91-97 (in Russian). Author at Buryatian Geol. Office, Ulan-Ude.

Vein fluorite deps. occur in fault zones in intrusive rocks, xline schists and limestones of Proterozoic and Paleozoic age. Main thermobarogeochem. criteria of depth of form. are found as follows (author's Table 1; translated by A.K.):

Criterion	Facies of depth of dep.	
	Subvolcanic (0.5-2.0 km)	Hypabyssal (2.0-3.5 km)
Filling of incs. in vein mins.	Two-phase G/L, rarely three-phase with L_{CO_2}	Essentially G, L/G, L_{CO_2}, polyphase with L_{CO_2} and dms
Type of min.-form. sols.	Hyd.	Pneu.-hyd.
T_H of incs. in main fluorite min., °C	220-120	480-240
T_H of incs. in latest fluorite, °C	100-75	190-140
Difference between T xliz. of main veins and thin veinlets	T xliz. of veins ≫ T xliz. of veinlets	Absent or T xliz. of veins < T xliz. of veinlets
Char. of change of T from wall-rock to center of vein	Increase near wall-rock	Decrease
T decrease per 1 cm of thickness of fluorite vein, °C	1.0-2.5 and more	Not discernable, rarely 0.6°C
Contrast of T zonality	Very distinct	Weak

Chem. comp. of water leachates of incs. in fluorite	HCO_3-F-Ca	F-Ca-K
Conc. of volatiles in ores, ml/kg	6-13	19-23
Main comp. of G in incs.	N_2 and CH_4	CO_2
Conc. Cl in sol., %	5-15	27-38
Density L-CO_2 in incs. of main generation of fluorite, g/cm^3	0.46-0.63	0.64-0.77
Calc. P of fluorite-forming sols., atm.	50-440	570-910 and higher
Examples of deps.	Naranskoe, Khurayskoe, Barun-Ul'skoe, Titovskoe, Tret'yakovskoye, Abagaytuyskoe, Kalanguyskoe, Garsonuyskoe	Novopavlovskoe II, Zormenikskoe, Nizhnechikoyskoe, Khamneyskoe, Antonovskoe

ARNDT, N.T., 1976, Melting relations of spinifex-textured komatiites at one atmosphere; a comparison with the crystallization of natural komatiite lavas, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 756-757. Author at Geophysical Laboratory, Washington, DC.

ARNORSSON, S.A., KONONOV, V.I., and POLAK, B.G., 1976, Gases of Icelandic hydrothermae: Bull. volcanologique, v. 39, no. 1, Special issue (Geochemistry of volcanic gases), p. 1-14. First author at Dept. of Natural Heat of National Energy Authority, Reykjavik, Iceland.

The main hydrochemical types of Icelandic hydrothermae are recognized as well as the regularities in their distribution. Nitrogenous thermae are spread mainly in the areas of Pre-Quaternary flood-basalts; carbon-dioxide thermae are peculiar of the volcanic zone of Snaefellsnes peninsula, whereas nitrogenous-carbon-dioxide thermae are characteristic of the areas of Pre-Holocene volcanic activity in the Median neovolcanic zone and some adjacent areas. The special hydrochemical feature of the axial parts of Median neovolcanic zone is the presence of high-temperature hydrothermal systems with great amount of H_2 in the gas composition. Hydrogenous thermae of Iceland are considered to be a specific genetic type of hydrothermae, being formed in the zones of mid-oceanic ridges. The origin of H_2 is discussed. (Authors' abstract)

ASKHABOV, A.M., and BUKANOV, V.V., 1976, The role of dislocations in the regeneration of natural quartz crystals: Akad. Nauk SSSR, Doklady, v. 228, no. 4, p. 944-947.

AVDONIN, V.V., 1976, Stages of formation and zonality of wall-rocks from Tishinskoe pyrite-polymetal deposit, Rudnyi Altai: Geol. Rudn. Mest., v. 18, no. 1, p. 94-101 (in Russian). Author at Moscow State Univ., Moscow.

Late quartz-sulfide veins of ore stage bear quartz containing P incs. with T_H 320-340°C. In late, post-ore quartz-K-feldspar with dolomite, galena, sphalerite and chalcopyrite, P incs. in quartz have T_H 278-350°C and 165-240°C. Quartz veins connected with post-ore meta. are char. by T_H of P incs. = 180-240°C. (Abst. by A.K.)

BAKUMENKO, I. T., BAZAROVA, T. Yu., PANINA, L. I., CHUPIN, V. P. and SHATSKIY, V. S., 1976, Inclusions of melts in minerals of magmatic rocks, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 7-8 (in Russian; translation by A. Kozlowski). Authors at Inst. Geol. Geophysics Sib. Branch Acad. Sci. USSR, Novosibirsk 90.

Following varieties of melt incs. were distinguished: silicate melts, silicate melt-sols., silicate-salt melts, salt melts, and melt-sols. Early silicate melts become richer in fluids (H_2O, CO_2, sulfur gases) and salts, and in some cases, in ore components. The four latter varieties are char. of late stages of xliz. of granites, granite pegs. of alk. rocks and carbonates (sic; possible misprint instead of "carbonatites", A. K.). Silicate melt incs. are most frequent; they are glass or partly xlized, most of them bear a fluid phase (with prevailing CO_2 or N_2), more rarely L_{CO_2}. After homog. and rapid cooling the filling becomes glass. Silicate melt-sols. incs. are xlized and bear aq. sol. with G bubble. After homog. and cooling such incs. also become glass without separation of L phase. In silicate-salt and salt melt incs. solid phases strongly prevail, and fluids (L and G) are subordinate. Salts begin to dissolve at low Ts (150-300°C), and during cooling after homog. they xlize. Silicate-salt melt incs. and salt melt-sol. incs. contain a large vol. of solid phases, and smaller vol. of brine (and CO_2); this feature distinguishes them from G/L incs. of hyd. sols. and brines, bearing small amounts of solid phases.

BAKUMENKO, I.T. and DOBRETSOV, N.L., 1976, Magmatic origin of ophiolitic gabbros: Akad. Nauk SSSR, Doklady, v. 230, no. 6, p. 1425-1428 (in Russian). Authors at Inst. Geol. Geophysics, Sib. Div. Acad. Sci. USSR, Novosibirsk - 90.

Incs. were studied in 15 cm long anorthite xls from eucrite-like gabbro-pegs. from Sabzewar, Iran. G/L incs. are absent, P melt incs. are equant, 0.005 - 0.02 mm dia. Most incs. are xlized; they consist of clinopyroxene, plagioclase with n<n of host min., and glass. Anorthite xlized on the walls of inc. vacuole. T_H ranges from 1435-1380°C (center of xl) to 1350-1280°C (outer part of xl). T_H of incs. in this gabbro are similar to incs. in anorthite from gabbroic xenoliths in volcanites from Kamchatka (1375-1225°, 1320-1240°C for anorthite, 1185-1120°C for intercumulative pyroxene); the difference was found in presence of G (N_2+H_2O) incs. with P = 1.6 - 1.7 kbar, in mins. from Kamchatka. These data testify to magm., not metasom. origin of ophiolitic gabbro from Iran, contrary to previous statements. (Abst. by A.K.).

BAKUMENKO, I.T. and KOSUKHIN, O.N., 1976, Magmatic stage of pegmatitic process: Akad. Nauk USSR, Doklady, v. 231, no. 2, p. 430-433 (in Russian). Authors at Inst. Geol. Geophysics of Siberian Branch, Acad. Sci. USSR, Novosibirsk - 90.

Graphic intergrowths in granite pegmatites bear melt inclusions (aggregates of fine grains of feldspar and quartz plus G or G and L bubble). Such inclusions were found in aplite-like, pegmatoid-granite, pegmatoid and finely-block structures of various massifs. Dimensions of inclusions are very small, often precluding detailed studies and even finding them. Highest T_H were obtained for pegmatites and orthotectites of granulite facies of Aldan shield (790-840 and 840°C, respectively). Amphibole facies pegmatites yielded T_H up to 760°C. Pegmatites from E. Transbaikalia (massifs: Kyrinskiy, Dungalinskiy), Kalba, Kazakhstan gave low T_H: 610-620°C for granites, 580-600°C for aplite structures, 550-580°C for granophyres and 540-560°C for quartz of pegmatoid aggregates. This proves that low quartz may also crystallize from melts, and then it does not form reticulate fractures during rapid cooling. Pegmatites may crystallize either from water-poor melts or from water-rich ones; in the latter case the boiling of melt and forming of syngenetic inclusions of both melt and liquid aqueous phase was noted, at T = 560°C and P = 3.7-3.8 kbar. Low Ts of crystallization were probably caused by presence of fluorine compounds in melts. High T_H (up to 880°C) for inclusions in quartz from Kazakhstan pegmatites obtained by Bazarov (1968) were probably measured for anomalous inclusions. (Abstr. by A.K.).

BALITSKY, V.S., MOSGOVA, N.N., OZEROVA, N.A., DOROGOVIN, B.A., and KOMOVA, V.V., 1976a, Conditions of natural antimony and stibnite formation and their interrelation in antimony deposits from experimental data, and results of inclusions investigations (abst.): International Geol. Congress, 25th, Abstracts, p.   Abstract published in <u>Fluid Inclusion Research</u>, v. 8, p. 14 (1975).

BALITSKIY, V.S., MOZGOVA, N.N., OZEROVA, N.A., DOROGOVIN, B.A., and KOMOVA, V.V., 1976b, Formation conditions of natural antimony and stibnite and their interrelation with antimony deposits from the analysis of inclusions and experimental data <u>in</u> International Geol. Congress, 25th Session, Reports of Soviet Geologists (Tugarinov, A.I., et al., eds.), p. 182-194: Moscow, Izd. Nauka (in Russian with English summary). See same authors in <u>Fluid Inclusion Research</u>, v. 8, p. 14 (1975).

BANKS, N.G., 1976, Halogen contents of igneous minerals as indicators of magmatic evolution of rocks associated with the Ray porphyry copper deposit, Arizona: Jour. Research U.S. Geol. Survey, v. 4, no. 1, p. 91-117. Author at U.S. Geol. Survey, Menlo Park, CA.

The contents of Cl, F, and H_2O+ (calculated) in some hydrous igneous minerals in intrusive rocks of Laramide age (70-60 m.y.) near Ray, Ariz., appear to be related to the age and the chemistry of the whole-rock samples. Apatite and biotite in younger, more silicic rocks contain more F but less Cl and H_2O+ than apatite and biotite in older, more mafic rock; the same relations hold for F and H_2O+ in sphene. Correlations of the abundance of Cl, F, and H_2O+ in hornblende with rock chemistry and age are not as strong as for apatite, biotite, and sphene; igneous (?) epidote does not contain Cl and F in amounts detectable by electron microprobe analysis. The contents of Cl, F, and H_2O+ in whole-rock samples decrease with increasing differentiation index and decreasing age. Data for a single pluton of variable composition mirror the results for a suite of different plutons and dikes. The data are satisfactorily although not exclusively explained by postulating that the melt each contained progressively less Cl, F, and H_2O and that the hydrous minerals consumed most of the Cl, F, and H_2O in the magmas. The data may also be explained by postulating that (1) the stocks evolved Cl-bearing water during their ascent and crystallization, or that (2) Cl and H_2O were concentrated during differentiation of the stocks but the minerals failed to record their buildup. Both alternative explanations find problems with and require special conditions to satisfy field, chemical, and experimental data. If many of the special conditions are not met, a nearby batholithic parent to the stocks is not a favorable source of the mineralized fluids at Ray. Prophylitic alteration of biotite results in Cl-poor chlorites and may have provided some Cl to hydrothermal fluids; biotite may have also supplied some F to prophylitizing fluids through alteration. (Author's abstract).

BARKER, Colin, 1976a, Gas content of quartz from the GT-2 geothermal test hole, Fenton Hill, NM, (abst.): Amer. Geophys. Union Trans., v. 57, p. 353. Author at Univ. of Tulsa, Tulsa, OK 74104.

Xlizing min. trap gases in a variety of locations within the xls. Some of these contain gases with the same comp. as those in the growth medium while others contain unrepresentative gas samples. When min. are heated gases are released from diff. locations at diff. Ts and this forms the basis of the anal. procedures used. 100 mg quartz samples were heated at 8°C/min in a vacuum and the water release monitored with a mass spec. tuned to $m/e = 18$. Quartz from granite (4282 ft.), peg. (3701 ft.) and fissure fillings (5487 ft.) all showed an early gas release (0-200°C) attributable to surface absorption. This was followed at increasing T by gases released from fluid inc. As each inc. ruptured there was an instantaneous rise in water partial P followed by an exponential decrease. Peaks of this type continued until the quartz α-β transition when there was a sharp increase in water evolution. Few fluid inc. peaks were seen above this T. The granitic quartz also released gas between 850 and 900°C. The comp. of the evolved gas was obtained by continuously scanning the mass spectrum at 2min/scan at the T was raised. This showed that CO_2 was assoc. mainly with the fluid inc. The fluid inc. also contained traces of HCs. No sulfur gases were recorded. (Author's abstract).

BARKER, Colin, 1976b, Variation of organic matter composition with sedimentary basin type, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 766. Author at Dept. of Earth Sciences, Univ. of Tulsa, Tulsa, OK.

BARKER, D.S., 1976, Phase relations in the system $NaAlSiO_4$-SiO_2-NaCl-H_2O at 400°-800°C and 1 kilobar, and petrologic implications: Jour. Geol., v. 84, p. 97-106.

BARTON, P.B., JR., BETHKE, P.M., ROEDDER, E. and RYE, R.O., 1976, Model for mineralization, Creede, Colorado (abst.): U.S. Geol. Survey Prof. Paper 1000, p. 1-2.

An initial evaluation of the physical and chemical environment of ore deposition for the OH vein at Creede, Colo. For those mineral assemblages composed of pyrite, hematite, chlorite, quartz, K-feldspar, sericite, sphalerite, galena, and chalcopyrite, they concluded, with the aid of fluid-inclusion data, that the typical environment was as follows: temperature, 250°C; pressure, about 50 bars (the fluids were boiling near the top of the ore zone); pH, 5.4; $(Na_{0.9}K_{0.1})Cl$ salinity, about 1 molal; and total concentration of sulfur in solution, $10^{-1.7}$ molal. The iron content in sphalerite indicated that the activity of oxygen and sulfur varied considerably during ore deposition. Reactions between hematite, iron-rich chlorite, pyrite, quartz, and water controlled reduction-oxidation reactions and prevented the chemical environment from varying enough to form bornite, anglesite, or magnetite. The bulk of the ore was deposited from solutions that were clearly rich in sulfate rather than sulfide. At times, the chemical conditions became so reducing that H_2S would have been the dominant sulfur species in aqueous solution if equilibrium had prevailed. A chlorite-bearing buffer is incompatible in an environment in which equilibrium is maintained between oxidized and reduced sulfur species, unless large changes in the amount of total sulfur in solution are permitted. Since the mineralogical evidence does not support large changes in sulfur concentration, it was concluded that there were recurrent departures from reduction-oxidation equilibrium, which suggested a lack of reduction-oxidation equilibrium between aqueous sulfur species.

The ores were deposited from a freely convecting hydrothermal system and were probably initially charged with meteoric solutions, as indicated by the ^{18}O and D isotopic compositions of the ore fluid. The salts, metals, and sulfur, however, may have been derived from deeper sources. The circulating solutions extracted metals and sulfur from whatever sources were available at depth and deposited gangue and ore minerals near the top of the convecting cell in a hypogene enrichment process. Boiling caused the acid components (H_2S and CO_2) to vaporize and recondense in the cooler overlying rocks, this process leading to the formation of an intensely altered, sericite capping above the ore. Precipitation of ore was attributed to cooling and perhaps to a slight rise in pH in conjunction with a loss of acid constituents.

Clusters of finely banded, iron-rich zones in otherwise iron-poor sphalerite resulted from the introduction of small quantities of more reduced (magmatic?) fluid that imposed a local, temporary, low reduction-oxidation chemical signature upon the circulating system. Each successive pass of the same low reduction-oxidation pulse produced an iron-rich band in the sphalerite. The mass ratio of fluid to sphalerite deposited requires that only a few parts per million of zinc be deposited in each cycle. Combined with a previous estimate of flow rate, this ratio gives a geologically uncomfortable, but quantitatively tenable, estimate of length of time required for mineralization of from a few hundred to a few thousand years.

A circulating-fluid model for ore deposition has important implications for mineral exploration. Minerals having retrograde solubilities, such as molybdenite, anhydrite, and, under some circumstances, possibly chalcopyrite, are precipitated in the hottest part of the system. Those minerals with prograde solubilities (most ore minerals whose solubilities are known), however, are precipitated in the coolest portion of the system. In contrast to the conventional model, the circulating-system model predicts a wide, barren gap between the cool, shallow, and hot, deep facies of mineralization. Authors' abstract.

BASSETT, A.M. and DEICHA, Georges, 1976, Interconnections between syngenetic and epigenetic cavities within gems, gangue and rock-forming minerals (abst.): International Geol. Congress, 25th, Abstracts, p. 554. First author at Laboratorie de Geologie Structurale et Appliquee, Universite de Paris-Sud, 91405 Orsay, France.

Such studies shows that (1) syngenetic cavities and channels are often very difficult to distinguish from epigenetic, (2) epigenetic fissures or cracks often affect the primary cavities and channels by penetrating them and causing significant and confusing changes, and (3) recrystallization affects the whole net of discontinuities and leads to the disconnection of parts of the initial cavities, channels and cracks (necking-down, partial healing, etc). (From the authors' abstract)

BATCHELDER, J.N., 1976, Copper Canyon mine, Nevada (abst.): U.S. Geol. Surv. Prof. Paper 1000, p. 184.

The compositions of light stable isotopes and fluid inclusions in a porphyry copper-gold-silver deposit adjacent to an altered granodiorite laccolith at Copper Canyon mine near Battle Mountain in Nevada were determined. The total volume of the granodiorite is smaller than estimates of the amount required to provide a source for the water in the ore-forming fluids. Fluid inclusion water in quartz yielded δD values from -102 to -76 permil. Calculated δD values for water in equilibrium with biotite range from -99 to -76 permil. The calculated $\delta^{18}O$ values of water in equilibrium with quartz range from +2.7 to +9.2, and water calculated to be in equilibrium with biotite ranges from +5.8 to +10.4 permil. These data suggest that the ore-forming fluids were most likely composed of magmatic water that had mixed with some meteoric water during metallization in a convective-type system (Author's abstract).

BATCHELDER, J., THEODORE, T.G., and BLAKE, D.W., 1976, Stable isotopes and geology of the Copper Canyon porphyry copper deposits, Lander County, Nevada: Amer. Inst. Mining & Metal Eng. Trans., v. 260, p. 232-236.

Essentially same as abstract by Batchelder and Blake, 1975, Fluid Inclusion Research, v. 8, p. 18 (1975).

BATZLE, M.L., and SIMMONS, Gene, 1976, Microfractures in rocks from two geothermal areas: Earth Plan. Sci. Lett., v. 30, p. 71-93. Authors at Dept. of Earth Plan. Sci., Mass. Inst. Tech., Cambridge, MA 02139.

BAUMANN, L., BLANKENBURG, H.J., LEEDER, O., and PENTZEL, A., 1976, Genetic studies of glass sands by means of quartz inclusions: Zeitschrift für Angewandte Geologie, v. 22, no. 12, p. 555-559 (in German).

BEALES, F.W., 1975, Precipitation mechanisms for Mississippi Valley-type ore deposits: Econ. Geol., v. 70, p. 943-948. Author at Dept. Geol., Univ. of Toronto, Toronto, Canada M5S 1A1.

Recent work by Anderson (1973(COFFI, v. 6, p. 6-7, 1973)) is used to support the hypothesis that Mississippi Valley-type ores were formed by the mixing of two brines: basinal fluids and the host rock formational fluids. Ore emplacement was characterized by a lack of concurrent solution of host limestone. White sparry dolomite and less common calcite gangues were stable during sulfide precipitation. Superficially similar but fundamentally different ores have precipitated by other mechanisms; the Upper Mississippi Valley ores described by Heyl et al. (1959) and the ores of the Cracow-Silesia region described by Begacz et al. (1970) are possible examples. (Author's abstract). (See also Discussion by Ohle, 1976, (this volume), and reply (next item)).

BEALES, F.W., 1976, Precipitation mechanisms for Mississippi Valley-type ore deposits - a reply: Econ. Geol., v. 71, p. 1062-1064 (see also Ohle, 1976, this volume).

BEKTASHI, S.A., MEL'NIKOV, F.P., GADZHIEV, T.G. and KHASANOV, G.M., 1976, Bitumens in Jurassic volcanites of Little Caucasus, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 57 (in Russian; translation by A. Kozlowski).

In inclusions from volcanic rocks of the Somkhito-Agdamskaya zone on the NE slope of Little Caucasus, bitumens were found. Intercalations of bitumen-bearing volcanic rocks occur in: 1) differentiated basalt-andesite-liparite of Bajocian age; 2) weakly differentiated basalt-andesite of Batonian age. Organic carbon appears in concentrations up to 0.09%. (From the authors' abstract).

BELTRAME, R.J., NORMAN, D.I., ALEXANDER, E.C., Jr., SAWKINS, F.J., 1976, Volatiles released by step-heating a cordierite to 1200°C, (abst.): Amer. Geophys. Union Trans., v. 57, p. 352. First author at Minnesota Geological Survey, St. Paul, MN 55108.

H_2, He, N_2, CH_4, Ar, CO, C_nH_n, H_2S, CO_2 and SO_2, released by heating a cordierite from a 1700 m.y. Front Range gneiss, have been studied on a quadrapole mass spec. These vol. were released by step-heating of the sample for one hour at 100°C intervals over the range 100°-1200°C. The accompanying water was meas. by a freezing and weighing tech. The T-gas % release plots for most of the vol. exhibit a sharply defined release peak with a low T tail. The Ts of max. release for the various vol. are: C_nH_n-400°C; He-500°C; H_2 and H_2O-850°C; H_2S-900°C; and N_2, CH_4, CO_2 and CO-1000°C. SO_2 was det. only at 1100°C and may be spurious. A T of 1100°C was required to dehydrate the sample and degassing was not complete until 1200°C. There are strong similarities in the T-% gas released plots for the pairs H_2O-H_2 and CO_2-CO. This suggests that much of the H_2 and CO may be generated within the exper. system. Myashiro has reported a change in the distortion index of cordierites in the 700-°900°C range. We find changes in the gas-release patterns in the same T range.

BENHAMOU, G. and CLOCCHIATTI, R., 1976, Glass inclusions in quartz and anorthoclase phenocrysts from Pantelleria peralkaline lavas: a thermometric study: Bull. Soc. Fr. Minéral. Cristallogr., v. 99, p. 111-116 (in French). Authors at Laboratoire de Pétrographie, Université Paris Sud, Bâtiment 504, 91405 Orsay, France.

Quartz and anorthoclase phenocrysts from the Pantelleria lavas contain two-phase glassy inclusions characteristic of minerals grown from silicate liquids. Homogenization of shrinkage bubbles in these magmatic inclusions indicates minimum crystallization temperatures of 750-800°C (±20°C) in quartz-bearing samples. Measurements for inclusions in anorthoclase are always about 30-50°C higher than those for quartz from the same sample. Fe, Ti oxides compositions in similar samples suggest formation at 1025°C. In quartz-free and fayalite-bearing samples, homogenization temperatures ranged from 970° to 1020°C. During the heating runs acmite crystals appeared, grew, and were resorbed between 700 and 850°C. In all samples a gaseous phase was sometimes found trapped with glass. These inclusions decrepitated at 950-1000°C in quartz. A comparison is made with homogenization data from other volcanic rocks. (Authors' abstract modified by A. Barabas.)

BENNETT, J.N. and GRANT, J.N., 1976, Qualitative analysis of daughter salt-bearing inclusions by laser microprobe (abst.): Geological Society-Mineralogical Society (Britain) Symposium on fluid inclusions, Univ. of Durham, Abstracts of meeting (unpaginated), to be published in Trans. I.M.M. Sect. B.

The laser microanalyser used was a Carl Zeiss LMA-1 instrument at the Department of Physics, University of St. Andrews, which had a controlled pulse or Q-switched ruby laser that emitted at 694.3 nm through an optical adaptor into a petrological-type microscope. A microplasma is produced in the sample and is excited between carbon electrodes held just below breakdown potential. Emission spectra are resolvable in a Q-24 ultraviolet prism spectrograph in the range 250-500 nm and spectral plates are viewed on an overhead projector. With spectral observation at present limited to the ultraviolet, the light elements, including halogens and alkalis, are poorly differentiated.

Samples studied from the Bolivian sub-volcanic tin province were of quartz containing extremely saline multi-daughter salt inclusions of 20-50 μm diameter. High flashtube voltages are necessary to achieve cratering and crater diameter is controlled by fracture rather than vaporization; craters are shallow, yet up to 10 times the diameter of the target inclusion. Elements identified included (Si), Fe, Ti, Cu, Mg, Mn, B and V, and probably Na, K, Ca, Sn, Al and Mo.

Since quartz and clear-salt solutions are excellent transmitters of visible (ruby) light, application to non-daughter salt-bearing inclusions may not be possible since the absorption by a solid phase seems critical. (Authors' abstract)

BERGLUND, L. and TOURET, J., 1976, Garnet-biotite gneiss in "Système du graphite" (Madagascar): petrology and fluid inclusions: Lithos, v. 9, p. 139-148. First author at Institut de Minéralogie, Palais Rumine, 1005 Lausanne, Switzerland.

Primary 'carbonic' fluid inclusions filled with nearly pure high density CO_2 occur in garnet in a garnet-biotite gneiss from 'Système du Graphite', Komajia, Madagascar (Malagasy). They have been formed during syntectonic growth of the garnet under granulite facies conditions. Most of the biotite appears to have crystallized later than the garnet, under the influence of more water rich fluids. (Authors' abstract).

BERKLEY, J. L., BROWN, H. G., IV, KEIL, Klaus, CARTER, N. L., MERCIER, J-C. C., and HUSS, Glenn, 1976, The Kenna ureilite: an ultramafic rock with evidence for igneous, metamorphic, and shock origin: Geochim. Cosmo. Acta, v. 40, p. 1429-1437. First author at Department of Geology and Institute of Meteoritics, University of New Mexico, Albuquerque, N.M. 87131.

Some thin metalliferous veins penetrating silicate grains contain secondary inc. of melt with high-Ca clinopyroxene (high-Ca, Mg-rich augite to augite), andesine, K-feldspar, chromite, and siliceous CaO- and alkali-rich glasses of variable comp. (p. 1432). (From authors' abstract)

BERTMAN, E.B., 1976, Temperatures of formation of gold ore deposits at Nuratinskiye Mts (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept., 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 29 (in Russian; translation by A. Kozlowski).

Au ore deps. are char. by following T_D* and T_H**:

Assoc.	Ts, °C, at deps.:				
	Charmitan	Kansay	Sarmich	Mardzhan -bulak	Sentiab
Au-rare-metal	280-360* 280-410**		240-380 260-320		320-360 280-320
Au-pyrite-arsenopyrite	200-280 220-290	190-260 200-270	180-240 200-250	200-280 280^a-240	180-260 190-260
Au-polysulfide	100-210 130-205	140-180	80-180 120-170	135-205 110-150	80-180 120-180

a - probably a misprint, 180? (A.K.) (From Authors' abst.)

BERZINA, A.P., SHUGUROVA, N.A., AND SOTNIKOV, V.I., 1976, Gaseous composition of mineral-forming solutions at copper-molybdenum deposits: Akad. Nauk SSSR, Doklady, v. 228, no. 1, p. 188-191 (in Russian). Authors at Inst. Geol. Geophysics Sib. Div. Acad. Sci. USSR, Novosibirsk-90.

Min.-form. sols. of Cu-Mo deps. are G at early stage (origin of K-spar, albite and thick quartz veins); G incs. sometimes bear xls of chlorides and ore mins., T_H = 500-600°C, and at Kal'makyr dep. - 800°C. Later stages are char. by L sols. occasionally boiling, T_H = 450-380°C. Comp. of G in individual incs. (46 quant. anal. from deps.: Sorskoe-Kuznetskiy Alatau, Zhireken - Transbaikalia, Kal'makyr - Middle Asia, Kadzharan, Agarak, Aigedzor, Maralazmi - Caucasus, Erdenituin-Obo, Tsagan-Suburga, Narin-Khuduk - Mongolia), is as follows (vol. %): sum of HCl, HF, H_2S, SO_2, and NH_3, 2 - 100; CO_2, 1.7 - 77.2; CH_4, 2.5 - 100; N_2 + rare gases 0.3 - 63.1. NH_3 was not found in G phase; for Sorskoe dep. presence of HF and absence of HCl was ascertained.

Zhireken dep. is char. by HCl and absence of HF, Kal'makyr - by HCl and HF in G phase. (Abst. by A.K.)

BEULINE, M.V., 1976, Conditions of formation of the Tagarsk iron-ore deposit (central near-Angarsk) according to inclusions in minerals: Soveshch. Molodykh Uchenykh Mineral., Geokhim., i. Metodam Issled. Mineral (Tezis. Dokladov), Primor. Otdel., Vses. Mineralog. Obshch., Dal'nevostoch. Geol. Inst., Vladivostok, p. 30-31 (in Russian; translation courtesy of Michael Fleisher). Author at Inst. of Geol. and Geophys., Sib. Branch, Acad. Sci. USSR, Novosibirsk.

1. The Tagarsk iron-ore dep. is located in the southern limb of the Kodinsk uplift-anticline (zone of Angarsk fold, middle course of the Angara River). In structural relations it is confined to the intersection of two systems of deep tectonic disturbances of north-east and north-west strike. The min. is ellipsoidal in plan, and pipe-like, disappearing at depth. The country rocks are tectonic breccias of carbonate rocks and trap form. that have undergone intense metasom.

2. Among the metasom. form. there are separated two principal min. paragen. assoc: skarn and hydrosilicate. Magnetite min. is confined to the latter.

3. Inc. were studied in garnets, calcites, epidotes, and magnetites from diff. paragenetic assoc.: pyroxene-garnet and garnet skarns, min. and barren calciphyres, calcite-epidote nests, and calcitic veinlets. Magnetite was studied from calcite-chlorite-serpentine-magnetite ore with variable ratios of the components.

4. The study included the forms and types of inc., their orientation, morphology, phase comp., and ratios of phases, aggregate state, T_H in silicate min. and calcites, and decrep. in the magnetites. The studies permitted the separation of the following genetic groups of inc.: in the garnet: (1) P xline; (2) P G-L; (3) PS G-L; and (4) S G-L; in the epidote: (1) P G-L, and (2) S G-L; in the calcite: (1) P xline; (2) P G-L; and (3) S G-L.

5. P xline inc. in garnets consist of pyroxene (diopside with $\gamma = 1.694 \pm 0.002$) of elongated-prismatic habit, forming individual inc. or rosette-like aggregates. In the calcites inc. of this type were small (0.001 mm) equant xlites of magnetite. The P G-L inc. from the inner zone of garnets of pyroxene-garnet skarn homog. in the liquid phase at 610-540°; from the inner zone of garnets of monomin. garnet skarn at 560-520°. The outer zone of garnets xliz. at 540-520-220°. In the barren calciphyres T_H of P G-L occurred at inc. 470-200°. In calcites of min. calciphyres, T_H of P G-L incs. was 450-190°. In coarsely xline calcite and epidote from vugs and veinlets, P G-L inc. T_H was 330-140°. Incs. in calcite showed T_H at 420-380° in one growth zone, both in the gas and in the liquid phase. It is possible that such inc. could have been formed from a two-phase system. This indicates that the P corr. will be minimal and the T_H will be cloe to T_F.

6. The minimum T_D of magnetite, det. on the thermovacuum app., is 380-460°.

7. Det. of the salt content and conc. in the inc. was made from T_{Frz}. It has been found that the predominant salt is NaCl with conc. up to 21-22 wt. % at T_H 420-400° and 8 wt. % at T_H = 250°.

8. The P devel. in inc. in calcite at T_H, det. from T_H and T_{Frz}, was 430-120 atm.

BIGGAR, G.M., 1976, Progress in experimental petrology: London, The Natural Environment Research Council Publication Series D, no. 6, 314 pp.

This report covers research work at Edinburgh and Manchester Universities 1972-1975. It includes many experimental studies involving volatiles (H_2O and CO_2) and various rocks or minerals, at a variety of P-T combinations. Of particular interest are items by N. Hards (p. 88-90) on Distribution of elements between the fluid phase and silicate melt phase of granites and nepheline syenites, and by W.C. Storey (p. 205-206) on The solubility of H_2O in silicate melts. (ER)

BILAL, Ahmad, and TOURET, Jacques, 1976 - Fluid inclusions in catazonal xenoliths from Bournac (Massif Central, France): Bull. Soc. Fr. Minéral. Cristallogr., v. 99, p. 134-139 (in French). Authors at Muséum National d'Histoire Naturelle, 61 rue de Buffon, 75005 Paris, France.

Xenoliths brought up by eruptions of some the neogene volcanos of the Massif Central include a wide compositional range of lower crystal charnockitic and granulite facies rocks. Three types of inclusions (most secondary) are distinguished based on mode of occurrence and microthermometry measurements :

1 - "<u>Carbonic</u>" inclusions : homogenization temperatures of the CO_2-rich fluid allows the definition of three subgroups :

a) Small, early inclusions with homogenization temperatures below -20°C (frequency maxima between -20 and -25°C). The CO_2 is apparently quite pure.

b) Large, late-stage inclusions which homogenize in either the liquid or gas phase at temperatures greater than + 20°C. Melting temperatures of -58 to -60°C indicate the possible presence of hydrocarbons.

c) A poorly defined group of inclusions with intermediate homogenization temperatures (~ -7°C) and fractured cavities suggesting modification by explosion.

2) Aqueous inclusions have only been observed in granitic xenoliths. They have equivalent salinities of about 13 % NaCl.

3) Inclusions of undetermined character in which no phase changes were observed between - 180°C and + 100°C. They probably include single phase gases (air or hydrocarbons ?) or glasses.

The earliest CO_2-rich fluids were the most dense (1.072 gm/cm^3). Extrapolated isochores are consistent with the P - T conditions estimated from mineral stabilities. The succession of fluid types suggest a metamorphic evolution from high pressure granulites (~ 700 - 900°C, 6 - 10 Kb) to low pressure granulites (~ 700 - 800, 1 - 3 Kb) and locally to amphibolite facies. The aqueous fluids typical of amphibolite facies conditions are found in granulite terranes but are notably absent in the granulite xenoliths. This supports the conclusion that the amphibolite facies features were superimposed on granulite facies rocks during slow isostatic ascent to the surface. Abstract by A. BARABAS

BILD, R.W., ROBINSON, K.L., and MÜLLER, O., 1976, On the formation history of silicate inclusions in the Mundrabilla iron meteorite:

investigation of trace elements in coexisting metal, troilite, and silicate phases by neutron activation analysis (abst.) (in German with English abst.) Max-Planck Inst. für Kernphysik, Heidelberg, Jahresbericht, p. 148.

Analyses of trace elements in the metal, sulfide and silicate phases of the Mundrabilla iron meteorite are under way in an attempt to understand the relationship of the phases to each other and the formation history of the meteorite. The silicate inclusions appear to have undifferentiated chondritic ratios of lithophile elements. (Author's abstract).

BOGOYAVLENSKAYA, I.V., 1976, Studies of inclusions of mineral-forming media abroad (1973-1975) (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept., 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 17-18 (in Russian; translation by A. Kozlowski).

A review.

BOLOTOVA, N.Ya. and MANUCHARYANTS, B.O., 1976, Temperatures of precipitation of gold and low-sulfide gold-quartz formations of Yano-Kolyma chain (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept., 1976: Ufa, Bashkir Section, Acad. Sci USSR, Inst. of Geol., p. 21 (in Russian; translation by A. Kozlowski).

During studies of G/L incs. in Au ore deps., a group of S incs. in regenerated quartz was found. This quartz is assoc. with pption of Au. T_H of incs. in regenerated quartz from four deps. (160-230, 210-250, 250-280, 220-280°C) increases from shallow (160-250°C) to moderate-depth (250-280°C), P 650-900 atm to 800-1300 atm, respectively.

BORODIN, V.A., BROVCHUK, I.F., INGOBATOV, A.P. and KOPLUS, A.V., 1976, Conditions of formation of fluorite deposits, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 52-53 (in Russian; translation by A. Kozlowski).

1. G/L inclusions, water leachates and forms of occurrence of Hg in fluorites from 19 deposits of the USSR were studied. Pegmatitic deposits yielded T_H in fluorites equal from 430 to 120°C, rare-metal - greisen from 320 to 90°C, apocarbonate from 300 to 75°C, epithermal from 280 to 60°C.

2. Cl and F prevail in water leachates over CO_2 (probably CO_3^{2-}, A.K.) and other anions. At high-temperature stages of mineral-formation Hg occurs as sulfide and in isomorphous mixtures; at low-temperature stages it is present as fluoride, chloride and oxychloride forms. (From the authors' abstract).

BOULANGER, Dominique, 1976, Growth pictures and intragranular cavities in quartz from Diebilets (Maroc): Bull. Soc. Fr. Minéral. Cristallogr., v. 99, p. 88-90 (in French). Author at Dept. Géol. Université Picardie, 33 rue Saint Leu 80000 Amiens, France.

Scanning electron fractography shows an intricate network of fine-lined striations at the boundary between the crystals. The relationships of these effects of mutual growth in the formation of intergranular cavities are considered. (Author's abstract)

BOULEGUE, Jacques, GENEST, Philippe, and MICHARD, Gil, 1976, Geochemistry of thermal waters from the Dogger (T = 75°C): Acad. Sc. Paris, Compte Rend., v. 282, Série D, p. 145-148 (in French). Authors at Lab. Geoch. des Eaux, Université Paris VII, 2, Place Jussieu, 75221 Paris Cedex 05, France.

A careful analysis of the geothermal waters from the Dogger (drill core from Melun) have been made. A chemical model is calculated. The waters are in equilibrium with calcite and dolomite. Na - K - Ca geothermometers do not give correct results with this type of water (126°C for the Fournier-Truesdell and 45°C for the Pačes geothermometer). The main reduced species of sulphur are polysulphide ions. It is supposed that polyselenide ions may explain the high concentration of selenium. (Authors' abstract slightly modified by M. Pagel.)

BOWDITCH, D.C., EDMOND, C.R., DUNSTAN, P.J. and MCGLYNN, J.A., 1976, Suitability of containers for storage of water samples: Australian Water Resources Council Technical Paper No. 16, 39 pp. First author at The Australian Mineral Devel. Lab., South Australia.

Of pertinence to all wet chemical analyses of fluid inclusions (ER).

BOWMAN, J.R. and ESSENE, E. J., 1976, Contact metamorphism at Elkhorn, Montana, (abst.): Amer. Geophys. Union Trans., v. 57, p. 338. Authors at Department of Geology and Mineralogy, University of Michigan, Ann Arbor, MI 48109).

Microprobe anal. of participating phases in the dolomites indicate that equil. can be treated within the system $CaO\text{-}MgO\text{-}Al_2O_3\text{-}SiO_2\text{-}H_2O\text{-}CO_2$. (From authors' abstract)

BOWMAN, John R. and O'NEIL, James R, 1976, Skarn forming fluids of magmatic origin at Elkhorn, Montana, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 788. First author at Dept of Geol. and Mineralogy, Univ. of Michigan, Ann Arbor, MI.

C, O, and H isotope anal. of min. separates from the gabbro intrusive, contact meta. marble, assoc. Ca-Mg-Al-Si skarns, and modern local meteoric water at Elkhorn, Montana, are summarized:

	δO^{18}	δD	δC^{13}
Intrusive	+6.5 to +7.1(Plag)	-75 to -87(Amph)	
Skarn	+10.2 to+12.2(Cc)	-75 to -85(Amph,Mica)	-5.1to-8.7(Cc)
	+6.0 to +7.1(Cpx)	-56(Epid)	
Marble	+19.6 to+23.5(Cc)	-65 to -93(Amph)	-1.1to-2.8(Cc)
Meteoric H_2O	-19.4	-147	

Applications of P-T-XCO_2 equil. fix main stage skarn form. to P =1.0±.3Kb,T=525±25°C, XCO_2=.05to.25. Mass balance calc. indicate that obs. C^{13} depletions in the skarn are too large to have been due to decarbonation of pre-existing marble, inferring a magmatic source for the skarn C. Calc. δO^{18} and δD ranges for H_2O are respectively: Intrusive (+6.7to+7.3, -50to-67); Skarn (+9.2to+11.2, -55to-70); Marble (+18.7to+22.5). The data clearly indicate that the skarn fluids were dominantly magmatic in origin. The O^{18} enrichment of ∿2‰ in the skarn relative to magmatic fluids is consistent with mixing with O^{18}-rich CO_2 evolved during skarn reaction. If mixing of this CO_2(+28) and magmatic H_2O(+7) occurred, the resultant $XCO_2 \leq .25$ required by the isotopic data is consistent with exper. T-XCO_2 stability fields of the obs. assem. Lighter δD values from later stage replacement micas(-107) and epidote(-75) limit max. meteoric H_2O contents of these late stage fluids to 25-20%. The isotopic-petrologic evidence at Elkhorn indicates that early high T(500-600°C) stages of interaction between intrusive and country rock did not involve significant amounts of meteoric water.

BOYLE, R.W., WANLESS, R.K., and STEVENS R.D., 1976, Sulfur isotope investigation of the barite, manganese, and lead-zinc-copper-silver deposits of the Walton-Cheverie Area, Nova Scotia, Canada: Econ. Geol., v. 71, pp. 749-762.

The sulfur in the sulfates and sulfides of the country rocks and epigenetic deposits exhibits a wide range in $\delta^{34}S$ composition, from +33.6‰ to -42.0‰.

The avg. $\delta^{34}S$ values for the sulfides and sulfosalts in the Magnet Cove mine are all negative, ranging from -0.9‰ to -39.6‰. There is a progressive decrease in ^{34}S with respect to the paragenetic sequence of mins., the last sulfosalts and sulfides to be xlized being significanctly depleted in ^{34}S.

It is concluded that the large massive cryptoxline barite body in the Magnet Cove mine originated mainly by replacement of bedded gypsum and anhydrite (Ba^{2+} for Ca^{2+}) because of similarities in the isotopic comp. of the sulfates in the evaporites and in the resultant barite. Other coarsely xline barite veins and pods appear to have been dep. from deep circulating brines. The sulfides and sulfosalts in the Magnet Cove dep. appear to have been derived from sulfate in the deep circulating brines by reduction processes, the shift in the isotopic constitution to more negative values being due to these processes which may have been partly aided by bacterial activity. (From the author's abstract).

BRADY, J. B., 1976, Models for intergranular diffusion in metamorphic rocks, (abst.): Amer. Geophys. Union Trans., v. 57, p. 338. Author at Department of Geology, Smith College, Northampton, Massachusetts 01060.

BRATUS', M.D., KOVALISHIN, Z.I., and GNILOMEDOV, V.Ye., 1976, Conditions of formation of gold ore mineralizations (Carpathians) (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept., 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol. p. 22-23 (in Russian; translation by A. Kozlowski).

Au is connected with meta. rocks of Rakhovskiy massif; it occurs in veins of quartz, barite, and carbonate, with sulfides of Fe and Pb, T_F = 250-100°C. (...) G phase in incs. contains 40-70 vol. % CO_2; this together with heterog. of sols. were main factors det. pH and migration of Au. (Authors' abst. shortened by A.K.)

BRATUS', M.D., MAMCHUR, G.P., KOVALISHIN, Z.I., et al., 1975, Carbon isotope composition of hydrothermal organic minerals from Transcarpathian ores): Akad. Nauk Ukr. RSR, Dopov., Ser. B, no. 6, p. 490-492 (in Russian with English sum.).

BRATUS', M.D. and VOVK, P.K., 1976, Conditions of formation of calcite, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 41-42 (in Russian; translation by A. Kozlowski).

At the Dal'negorskoe (i.e., Tietiukhe) deposit sphalerite plus galena mineralization overlaps hedenbergite skarns. Calcite formed in cavities during the final stage of formation of the deposit. The sequence of changes of the crystal habits is as follows: $[0001] + [10\bar{1}1] \rightarrow [10\bar{1}1] \rightarrow [21\bar{3}1] \rightarrow [\bar{1}0\bar{1}0] \rightarrow [01\bar{1}2]$, mainly depending on pH and Eh of the parent solution. (Authors' abst.)

BRETT, Robin, 1976, Reduction of mare basalts by sulfur loss: Geochim. Cosmo. Acta, v. 40, p. 997-1004. Author at U.S. Geological Survey, National Center, Stop 959, Reston, VA 22092.

Metallic Fe content and S abundance are inversely correlated in mare basalts. Either S vol. from the melt results in reduction of Fe^{2+} to Fe^0 or else high S content decreases Fe^0 activity in the melt, thus explaining the correlation. All considerations favor the model that metallic iron in mare basalts is due to sulfur loss. The Apollo 11 and 17 mare basalts were probably sat. with S at the time of eruption; the Apollo 12 and 15 basalts were probably not sat. (From the author's abstract)

BREY, G.P. and GREEN, D.H., 1976, Solubility of CO_2 in olivine melilitite at high pressures and role of CO_2 in earths upper mantle: Contrib. Min. Petrol., v. 55, p. 217-230. (See also discussion, ibid., p. 231-237). (ER)

BROWNE, P.R.L., ROEDDER, E. and WODZICKI, A., 1976, Comparison of past and present geothermal waters, from a study of fluid inclusions, Broadlands field, New Zealand: Proc. Internat. Symp. on Water-Rock Interaction, Czechoslovakia, 1974, J. Čadek and T. Pačes, eds: Prague, Geological Survey (CSSR), p. 140-149. First author at N. Zealand Geol. Survey, Box 30368, Lower Hutt, N.Z.

Essentially the full data for the study given by a previous abstract (Browne, Roedder, and Wodzicki, (1974) Fluid Inclusion Research, v. 7, p. 29 (1974)), but with added consideration of the possibility that the presence of CO_2 may be in part responsible for the apparent salinities (from freezing) of up to 13,600 ppm NaCl equivalent. (ER).

BRUMBY, G. and SHEPHERD, T.J., 1976, Sample preparation for fluid inclusion studies: Min. Mag., v. 40, p. 647-648.

The samples are embedded in cold-setting Araldite cylindrical blocks before sawing. (ER)

BURNHAM, C.W., 1976, Thermodynamic properties of aluminosilicate melts (abst.): Geol. Assoc. Canada - Mineral. Assoc. Canada Program with

Abstract, v. 1, p. 57. Author at Department of Geosciences, The Pennsylvania State University, University Park, Pennsylvania 16802.

BURRUSS, R.C., 1976, CO_2±CH_4 fluid inclusions: quantitative measurement of composition, density, and interpretation of isochore P, T paths, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 797-798. Author at Dept. of Geol. and Geophysical Sci., Princeton Univ., Princeton, NJ.

Approx. 380 CO_2-rich fluid inc. (45% with no obs. H_2O-rich phase) have been anal. in 15 samples from graphitic, upper amphibolite facies meta. rocks from Bryant Pond, Maine, and 5 samples of graphitic, lower granulite facies rocks from Khtada Lake, British Columbia. Comp. and d. of the CO_2-rich phase has been det. from obs. T of phase transitions in individual inc. These were interpreted with pub. phase equil. and phys. prop. within the system $CO_2 + CH_4 \pm H_2O \pm NaCl$. Lit. data on vapor sat. CO_2-CH_4 liquids show that increasing mole % CH_4 decreases the liquid d. at constant T_h.

The inc. may be grouped into three classes based on the comp. and d. of the CO_2-rich phase. I: Inc. with high mole % CH_4 (18 to 44 mole % for Khtada Lake, 6 to 16 mole % for Bryant Pond) and low d. of the CO_2-rich phase (near crit. to < crit. d.). II. Inc. with very low d. (invariant point: -138° to -124°C, homog. to gas at $\leq$-101°C) which have an est. bulk mole % $CH_4 \geq 95\%$. III. Inc. with little or no CH_4 (0 to 6 mole %) and moderate apparent d. (T_H to liquid 0° to +17°C).

Isochores for class I and II inc. are consistent with the hypothesis that they entrap fluids which equil. with graphite at 600° to 800°C and 1 to 2 kbar. This suggests high geothermal gradients (>70°C/km) occurred during late (retrograde) meta. of both terrains. Class III inc. have isochores more consistent with max. prograde meta. P and T deduced from silicate petrology by Guidotti, et. al. (1974) for Bryant Pond (650-750°C, 4 kbar) and Hollister (1975) for Khtada Lake (750-850°C, 5-8 kbar). (Author's abstract).

BURT, D.M., 1975, Beryllium mineral stabilities in the model system CaO-BeO-SiO_2-P_2O_5-F_2O_{-1} and the breakdown of beryl: Econ. Geol., v. 70, p. 1279-1292.

Mineral incompatibilites (based on a complete review of natural occurrences), relevant experimental data, and a computer program ("REACTION") have been used to model the probable stabilities of beryllium-bearing minerals in the system CaO-BeO-SiO_2-P_2O_5-F_2O_{-1}, in terms of the chemical potentials of the Lewis acid components P_2O_5 and F_2O_{-1}. (From the author's abstract)

BURT, Donald M., 1976, Generation of high HF fugacities in miarolitic pegmatites and granites: the possible role of topaz, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 798. Author at Dept. of Geol., Arizona State Univ., Tempe, AZ.

BURTON, B.H., 1975, Paragenetic study of the San Martin mine, near Sombrerete, Mexico: M.S. thesis, U. Minn.

The San Martin Mine, situated on the Mesa Central near Sombrerete, Mexico, yields silver, copper, and zinc from replacement orebodies caused by the intrusion of the Oligocene Cerro de la Gloria stock into Lake Cretaceous limestones.

The orebodies exhibit lateral zonation, which consists dominantly of bornite-chalcopyrite mineralization near the intrusive and sphalerite mineralization at a farther distance. The amount of silver present in bornite, chalcopyrite, and tetrahedrite decreases outward from the intrusive. There are three prominent ore mineral associations: 1) bornite-chalcopyrite (-pyrrhotite); 2) chalcopyrite-galena-tetrahedrite; 3) sphalerite (plus exsolved chalcopyrite). The metal ratios Ag/Cu+Zn+Pb, Ag/Cu, and Cu/Zn have been utilized to establish the above order of deposition for the associations.

Studies of fluid inclusions in the gangue minerals show that ore mineralization occurred over a temperature range from 445°C to perhaps 400°C and that gangue deposition continued to about 340°C. The salinity of the primary ore-forming fluids reached as high as 45-48 wt. equivalent percent NaCl but later decreased to values of 5-20 wt. percent.

Assuming hydrostatic conditions, and using a density of 1.2g/cc for the ore-forming fluid, the vapor pressure over primary fluid inclusions in fluorite indicates that the depth of formation of the ore deposit was greater than 1.9 kilometers. If a vertical temperature gradient of 45-65°C/km was present during deposition, then the depth of formation for the deposit was 5-7 kilometers, in which case a correction due to pressure of +42°C-88°C must be applied to the homogenization data. Deposition may therefore have begun at any temperature between 513°C and 467°C. (Author's abstract).

BURTON, Jacqueline C. and TAYLOR, Lawrence A., 1976, Sulfurization of skarn silicates: experimental data on oxygen and sulfur fugacities, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, p. 798. Authors at Univ. of Tennessee, Knoxville, TN.

ČADEK, J. and PAČES, T., eds., 1976, Proceedings International Symposium on Water-Rock Interaction, Czechoslovakia 1974: Prague, Geol. Survey 464 pp. (in English).

Includes many papers on the origin and nature of natural waters, rock-water interaction, active geothermal systems, formation waters, models, kinetics, and experimental studies. The most pertinent of these were abstracted in vol. 7 of COFFI, (1974) when the Abstract Volume was issued. A few of these full papers are cited in this volume of COFFI as well. (ER)

CALAS, G., 1976, Spectrophotometrical evidence of a partial diffusion of fluid inclusion water when heating minerals. Soc. fr. Minéral. Cristallogr., Bull. v. 99, p. 119-120 (in French with very brief English abstract). Author at Univ. Pierre et Marie Curie 75230 Paris Cedex 05, France.

By comparing the UV spectrophotometer absorption traces before and after heating two samples of natural flourite to 295°C, a loss ("diffusion") of water is inferred, and it is stated that this causes "a systematic error in the inclusion analyses" (T_H?). The original (or final) T_H is not given so the internal pressure in the inclusions at 295°C is unknown. (ER)

CALAS, G., HUC, A.Y., and PAJOT, B., 1976, Utilization of infrared spectrometry for fluid inclusion studies in minerals: feasability and limits: Soc. fr. Minéral. Cristallogr., Bull. v. 99, p. 153-161. (In French with English abstract). First author at 75230 Paris Cedex 05 France.

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

CALAS, Georges, HUC, Alain-Yves, and PAJOT, Bernard, 1976, Utilization of infrared spectrometry for fluid inclusion studies in minerals: advantages and limitations: Bull. Soc. Fr. Minéral. Cristallogr., v. 99, p. 153-161 (in French). First author at Laboratoire de Minéralogie Cristallographie, Université Pierre et Marie Curie, 4 Place Jussieu 75230 Paris Cedex 05, France.

In situ chemical analysis of major constituents in fluid inclusions by infrared spectrometry is possible if the host mineral is transparent in the infrared (e.g. halide minerals and sulfides). Analyses of a large number of fluorites from different localities show important compositional variations : high salinity aqueous fluids and CO_2 (Djebel, Kohol, and Hamman Djdidi, Tunisia ; Font d'Arques and Clermont - l'Hérault, France), aqueous fluid, CO_2 and light hydrocarbons, including CH_2 and CH_3 groups of aliphatic compounds and short chain carbonyls (Blue John Fluorite, Derbyshire; Valzergues, Aveyron, France ; Moritz mine, Vosges, France), aqueous fluids with complex organic material including aliphatic and aromatic compounds and organic acids (Clay Center, Ohio) and water, CO_2 and traces of organic matter (White Cloud pegmatite, Colorado). Other halide minerals were studied : halite from New Mexico, Michigan and Strassfurt (CO_2 and saline aqueous fluid saturated with NH_4Cl, sal ammoniac). It is also possible to distinguish OH^- in the crystal structure (e.g. Cumberland fluorite) from water in fluid inclusions. Other information which can be gleaned include compositional variations within individual crystals, relative size of inclusions and calculation of weight percentage of water present in inclusions. (Abstract by A. BARABAS)

CANN, J.R., 1976, Metamorphic processes on the floor, (abst.): Amer. Geophys. Union Trans., v. 57, p. 411. Author at School of Environmental Sciences, Univ. of East Anglia, Norwich NR4 7TJ, England.

(This is just one of many abstracts in this technical session on metamorphism and alteration of oceanic crust and role of hyrothermal circulation). (ER).

CASADEVALL, T., 1976, Sunnyside Mine, Eureka mining district, San Juan County, Colorado; geochemistry of gold and base metal ore formation in the volcanic environment: Ph.D. Dissertation, Penn. State Univ., 146 pp. (Diss. Abstr. Int., v. 37, no. 11, p. 5563B-5564B, 1977).

Identical with IGC abstract of Casadevall and Ohmoto, in Fluid Inclusion Research -- Proceedings of COFFI, v. 8, 1975, p. 32-33.

CASADEVAL, T. and OHMOTO, H., 1976, Sunnyside mine, Eureka Mining District, San Juan County, Colorado: Geochemistry of gold and base metal ore formation in the volcanic environment (abst.): International Geol. Congress, 25th, Abstracts, p. . Abstract published in Fluid Inclusion Research, v. 8, p. 32 (1975).

CHAMBERS, B., 1976, Emeralds - Three for $150: v. 12, no. 12, p. 365-370. Brief mention of three-phase inclusions (ER)

CHAO, E.C.T., 1976, The application of quantitative interference microscopy to mineralogic and petrologic: Amer. Min., v. 61, p. 212-228. Author at U.S. Geol. Survey, Reston, VA 22092.

This paper demonstrates the applicability of quantitative interference microscopy to the study of minerals and rocks in transmitted light. For readers who are not familiar with interference microscopy, the principle, the detectability and measurement of interference fringe shifts, and the precision of its use are discussed. The following are some of its applications: (1) the far superior ease and precision of determination of the refractive indices of minerals over the traditional Becke line method (there is no need to estimate the match point, but instead it measures the difference of the index between the mineral and immersion medium, hence minimizes the operator's error; a precison of ± 0.0002 can be readily obtained); (2) the possible identification of micron-size inclusions; (3) identification of minerals in thin sections by the zero-fringe method; (4) display of chemical variations in minerals; and (5) the study and possible identification of microstructures, such as twinning, zoned crystals, rimmed crystals, exsolution, and various types of lamellar microstructures produced by static or shock deformation. Procedures for measuring interference fringe shifts in various applications are included in an appendix. Complementary use with X-ray diffraction gives the proper perspective of the role of interference microscopy in mineralogic and petrologic investigations. (Author's abstract)

CHEN, C.-H., LO, H.-J., and JUAN, V.C., 1976, Olivine in taiwanite: Geol. Soc. of China, Proc., no. 19, p. 98-106 (in English). Authors at Inst. of Geol., National Taiwan Univ.

A discussion of partition coefficients for Ni, Cr, Mn, Mg, and Fe between olivine and coexisting glasses (natural and after laboratory studies), pertinent to interpretation of silicate melt inclusion analyses. (ER)

CHEPIN, A.I., and DOLOMANOVA, E.I., 1976, Determination of the chemical composition of deposits in opened vacuoles of minerals by the electron microprobe method: Sbornik Nauchn. Trudov, Mosk. Otdel., Vses. Mineralog. Obshch., March 1974, p. 199-201 (in Russian; publ. 1976). (Additional title page reads: New Mineralogical Studies, Ministry of Geol., All-Union Sci. Research Inst. of Min. Resources (VIMS), and Moscow Section, All-Union Mineralogical Soc., Acad. Sci. USSR.) See translations.

CHEPUROV, A.I., BAZAROVA, T. Yu., LAVRENT'YEV, Yu. G., et al., 1974, Composition of inclusions of magmatic melt in minerals of a fergusite porphyry, the eastern Pamirs, and pseudoleucitite, central Aldan: Akad. Nauk SSSR, Dokl., v. 218, no. 5, p. 1185-1188, (in Russian).

CHEPUROV, A. I., LAVRENT'YEV, Yu. G., POKACHALOVA, O. S., et al., 1974, Melt inclusion composition of minerals of pseudoleucitite, central Aldan: Geol. Geofiz. (Akad. Nauk SSSR, Sib. Otd.), no. 4, p. 55-60 (in Russian with English sum.; translated in Sov. Geol. Geophys., v. 15, no. 4, p. 46-50.)

CHERNOV, A.A., TEMKIN, D.E. and MEL'NIKOV, A.M., 1976, A theory of solid inclusion trapping during crystal growth from a melt: Kristallografiya, v. 21, no. 4, p. 652-660 (in Russian).

CHIVAS, Allan R., 1976, Magmatic evolution and porphyry copper mineralization of the Koloula igneous complex, Guadalcanal (abst.): International Geol. Congress, 25th, Abstracts, p. 48. Author at Dept. of Geology & Geophysics, University of Sydney.

Oxidation of the magmatic system can be explained by separation of an aqueous phase from the melt during crystallization and subsequent dissociation and loss of hydrogen (Czamanske & Wones, J. Petrology, 14, 349-80, 1973). Indeed, this aqueous phase is considered to be represented by the early hydrothermal fluids which pervade rocks of the mineralization suite and have introduced at least part of the copper mineralization. Trapped fluids from this event are highly saline and homogenize at temperatures of 500-700°C. The possibility is raised that the conditions of crystallization are different for mineralized and non-mineralized intrusive complexes. (From the author's abstract)

CHOU, I-Ming and EUGSTER, Hans P., 1976, Solubility of magnetite in supercritical chloride solutions, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 811-812. First author at NASA, Houston, TX.

CLOCCHIATTI, R., 1976, Melt inclusions in volcanic minerals: Le Monde et les Minéraux, May-June, 1976 (no. 12), p. 298-299 (in French).

A brief, popular article, featuring six of Clocchiatti's beautiful photomicrographs. (ER)

CLOCCHIATI, Robert, DESNOYERS, Christian, SABROUX, Jean-Christophe, TAZIEFF, Haroun, WILHELM, Serge, 1976, Relationships between glass inclusion and host anorthoclase megacrysts from the Erebus Volcano: Bull. Soc. Fr. Minéral. Cristallogr., v. 99, p. 98-110 (in French). First author at Laboratoire de Géochimie, Université de Paris Sud, 91405 Orsay.

Primary glass inclusions with negative crystal shape are distributed according to monoclinic symmetry in the triclinic host anorthoclase. Microcrystals of apatite, olivine, pyroxene and titaniferous magnetite are often present in the inclusions. Presence of very abundant inclusions visible under the microscope (10's per 0.1 mm^2 surface area in 20 μm thick sections, inclusions 1 - 100 μm long) and submicroscopic inclusions revealed by phase contrast account in part for compositional inhomogeneties as well as for variations in crystallographic orientation (wavy extinction) of the host. Secondary glass inclusions record intermittent dissolution of the host. Microprobe and index of refraction measurements reveal that, regardless of inclusion type and of their position in the host, compositions of the inclusion glasses are uniform and are identical to those of the glass surrounding the megacrysts. Shrinkage bubbles in primary glass inclusions homogenized between 980° and 1030°C. These minimum trapping temperatures agree with the temperature of 990°C determined from the olivine-clinopyroxene geothermometer. Crystallization of the inclusion glasses was studied by holding the samples at 1000°C for variable time periods. After 24 hours, olivine, feldspar and titaniferous magnetite microcrystals identified by ion probe began forming. The infrequent decrepitation of the inclusion suggests that the trapped glass was volatile-poor. The mode of eruption and its influence on the megacrysts are discussed. (Abstract by A. BARABAS)

CLOCCHIATTI, Robert and MERVOYER, Bernard, 1976, Contribution to the study of quartz crystals from Guadeloupé: Bull. du BRGM (deuxième série). Section IV, n°4, p. 311-324 (in French). First author at Lab. Géochimie, Univ. Paris-Sud, 91405 - Orsay, France.

A study of glass inclusions in quartz phenocrysts from volcanic rocks (and laterites) from Guadeloupe. Nuées ardentes, pumice fall, and pumice flow facies are characterized by different types of quartz crystals. In the first type occurrence the magmatic inclusions have bipyramidal, rhombohedral, or irregular forms, attributed to a redeposition of quartz on cavity walls. Feldspar microlites and apatite are present in the cavities. Some evidence for later reheating was found. Fenster quartz from pumice falls contains bipyramidal single-phase glassy inclusions with associated plagioclase, manganiferous ilmenite, apatite, and pyroxene. Finally, in quartz from pumice flows the cavity fillings are multiphase (glass, gas bubble, 2 minerals). Microprobe analyses of glass indicate marked acidic compositions (69.31 to 81.85 wt. % SiO_2). The alkali contents (2.86-3.71 wt. % Na_2O and 2.28-2.59 wt. % K_2O) and that of calcium (1.52-3.07 wt. % CaO) indicate that the glasses have rhyodactitic composition, although it should be noted that crystallization of some minerals preceded that of quartz. Optical thermometry data indicate minimum crystallization temperatures for quartz of 800-900°C. The presence of magmatic quartz in these dacites and andesites is compatible with the elevated pressures invoked for the formation of these island arc magmas. (Abstract by M. Pagel, translated by A. Barabas).

COLE, David R. and OHMOTO, Hiroshi, 1976, Effect of NaCl on the rate of oxygen isotopic exchange reactions between rocks and water, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 817. Authors at Dept. of Geosciences, Pennsylvania State Univ. University Park, PA.

Sol. samples obtained from an exper. circulating geothermal system were anal. for O isotopes. The $\delta^{18}O$ value of pure H_2O (initial $\delta^{18}O_{H_2O} = -10.4‰$) interacted with granite gneiss ($\delta^{18}O(w.r.) = +7.8‰$, $\delta^{18}O(qtz.) = +8.1‰$, $\delta^{18}O(plag.) = +6.6‰$, $\delta^{18}O(Kspar) = +7.51‰$) increased with time and with increasing T at rates of $\Delta_{final - initial} \doteq 0.05‰$/log hr. (0.25‰ after 30 hr) at 300°C, 0.04‰/log hr. (0.20‰ after 30 hr) at 200°C and 0.025‰/log hr. (0.1‰ after 30 hr) at 150°C.

With addition of NaCl, the rate of O isotope exchange increased significantly. For example, with 0.1m NaCl reacted with granite gneiss at 200°C, the $\Delta_{\text{final - initial}}$ increased rapidly to 2.15‰ in the first 30 hr. This $\delta^{18}O$ shift was accompanied by rapid increase in the K^+ conc. in the sol. After 30 hr, the cation conc. in sol. reached steady state equil. and the increase in the $\delta^{18}O_{H_2O}$ values was small. The contrast between the rate curves of the NaCl-sol. and of pure-water reflects a diff. in mech. of O isotopic fract. probably due to cation exchange reactions during alt. of feldspars and biotite as well as to O exchange controlled by diff.

Similar effects of NaCl conc. on the degree of $\delta^{18}O$ shift are also obs. in natural geothermal systems (hot springs; ore-forming fluids).

CORNIDES, I., and KISS, J., 1976, Correlation of the oxygen and carbon isotope ratios of calcite samples from a hydrothermal ore vein: Geochemical Jour., v. 10, p. 181-184. (in English). First author at Dept. Chem., Tokyo, Inst. of Tech., O-okayama, Meguro-ku, Tokyo 152 Japan.

CRAIG, H. and LUPTON, J.E., 1976, Rare gases and volatiles in oceanic basalts, (abst.): Amer. Geophys. Union Trans., v. 57, p. 408. Authors at Geological Res. Div., Scripps Inst. of Oceanography, La Jolla, CA 92093.

CRERAR. D.A. and BARNES, H.L., 1976, Ore solution chemistry, V. Solubilities of chalcopyrite and chalcocite assemblages in hydrothermal solution at 200° to 250°C: Econ. Geol., v. 71, pp. 772-794.

CSIRO, 1976, Fluid inclusions (abst.): CSIRO Minerals Research Laboratories Annual Rept., 1975-1976, p. 24.

The use of infrared spectroscopy for the study of fluid inclusions in minerals has been investigated. Liquid water and carbon dioxide are easily identified by a comparison of 80K and 300K spectra, but the problems involved in quantitative determination of water/carbon dioxide ratios by this method appear to be insuperable at present.

The program of investigation of the fluid inclusions of Australian porphyry copper deposits has continued with the collaboration of A. Chivas and J. Barkas of Sydney University. A study of the fluid inclusions in the Koloula prospect, Guadalcanal, has confirmed another Bingham-type prophyry copper. To establish the "background" fluid inclusions that could be expected in any granite, an extensive study of the unmineralized Lachlan Fold Belt granites has been undertaken. The results show that a wide variety of fluids, unrelated to mineralization, have pervaded these rocks and been trapped within them. It is clear, therefore, that in studying the mineralized granites in this region, care will have to be taken to identify those fluids which are specifically related to processes of mineralization.

Investigation of the fluid inclusions of ore deposits in the New England area of New South Wales continued and at least two contrasting sets of conditions for cassiterite deposition were identified. In the Yankee Lode, Emmaville, cassiterite was deposited from a boiling hydrothermal solution, resulting in a high temperature for cassiterite deposition, minimal wallrock alteration and a small irregular orebody.

By contrast, fluid inclusions show that the Walleroo Lode, Torrington, was formed under less turbulent conditions. The hydrothermal solution was not boiling and a closer approach to equilibrium resulted in extensive alteration and a larger orebody. ("Author's" abstract).

CUNEY, Michel, PAGEL, Maurice, and TOURET, Jacques, 1976, Analysis of gases in fluid inclusions by gas chromatography: Bull. Soc. Fr. Minéral. Cristallogr., v. 99, p. 169-177 (in French): First author at Centre de Recherches Pétrographiques et geochimiques, C.O. n°1, 54500 Vandoeuvre-les-Nancy, France.

A review of liberation and analytical methods for gases in fluid inclusions employed at Nancy and elsewhere. After a discussion of the problems with the existing recovery methods (thermal decrepitation, grinding and crushing under vacuum) a recovery system is proposed combining crushing with simultaneous heating at 400°C to reduce absorption and scavenging with an inert gas. Only inclusions which had not decrepitated at 400°C would be recovered. A gas chromatographic analytical method involving separation of H_2O, CO_2, H_2S, NH_3 and CS_2 from hydrocarbons (CH_4, C_2H_4, etc., up to C_4H_x) has been used in the study of fluids from the Carswell structure, Saskatchewan; from granulite and amphibolite facies rocks from southern Norway, in hydrocarbon-rich inclusions from Alpine cavities and Serifos skarns (Greece), and from the Bois Noirs uranium deposit (France). (Original abstract modified by A. Barabas.)

CUNNINGHAM, C.G., Jr., 1976, Petrogenesis and postmagmatic geochemistry of the Italian Mountain Intrusive Complex, eastern Elk Mountains, Colorado: Geol. Soc. Amer., Bull., v. 86, p. 897-908. Author at U.S. Geol. Survey, Denver, CO 80225.

The Italian Mountain Intrusive Complex lies within the Colorado mineral belt. It consists of Oligocene plutons, dikes, and associated hydorthermal lead-silver deposits. The rocks range in composition from quartz diorite to quartz monzonite. The core of the youngest intrusive mass is porphyritic and contains a central facies characterized by a partly aphanitic groundmass, which was formed by quenching and represents a late-stage venting of the intrusive complex. Upon venting, the youngest plutonic rocks fractured, fluids in the core boiled and were introduced into fractured quartz phenocrysts, and quartz veins were formed.

The evolution of the late magmatic and postmagmatic fluids is inferred from fluid inclusions. Pressure constraints imposed by measured fluid compositions and homogenization temperatures indicate that a pressure of 250 bars existed on the fluids at the time of venting. Depth of emplacement was between 950 and 2,700 m. (Author's abstract).

CZAMANSKE, G.K. and POTTER, Robert W., II, 1976, Fe and Zn concentrations in NH_4Cl solutions for the assemblages Py-Po-Mt-Sph and Cpy+Py+Bn+Sph from 300° to 408°C, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 826. Authors at U.S.G.S., Menlo Park, CA.

DAVIES, G.R., 1976, "Bitumen" in post-burial diagenetic calcite: Can. Geol. Surv., Pap., no. 76-1C, p. 107-114.

DEICHA, Cyril, 1976, Inclusions and metastability of crystals, based on an example of artificial hydrohalite investigated by microcinematography: Bull. Soc. Fr. Mineral. Cristallogr., v. 99, p. 95-97 (in French). Author at Universite P. et M. Curie, 4 Place Jussieu, 75230 Paris Cedex 05 France.

Among the factors able to start the "spontaneous" transformation of a metastable species to a stable one, the presence of inclusions can have a decisive action: with the help of microcinematography this fact is shown using as an example the sodium chloride hydrate, whose crystallization and dehydration have been followed. (Author's abstract)

DEICHA, Georges, 1976, Microscopic intracrystalline cavities in lithosphere materials: Bull. Soc. Fr. Minéral. Cristallogr., v. 99, p. 69-73 (in French). Author at Lab. Géol. Appl., Univ. P. et M. Curie, Tour 16, 4 Place Jussieu, 75230 Paris Cedex 05, France.

Report on a meeting organized by the C.N.R.S. in Dec. 1975. The following seven points were discussed: (1) Theoretical considerations and laboratory experiments on the formation of growth cavities during the building of crystalline structures; (2) Disequilibrium in geochemical fluids and their inclusion in minerals; (3) Variability of the characteristics of the cavities and the incorporation of foreign elements; (4) The relationships between syngenetic and epigenetic cavities; (5) The recrystallization of fissures of microtectonic origin under diverse conditions of metamorphism; (6) The role of microscopic and submicroscopic cavities in deep and superficial alteration by geodynamic agents, and (7) The presence of cavities in detrital materials, their influence or erosion, transport and deposition, and their sedimentological significance. (Abstract by M. Pagel, translated by Chris Eastoe).

DEICHA, Georges, BASSETT, Allen, et al., 1976, Dynamometamorphism and secondary intragranular imbibition of crystalline rocks by mineralizing solutions (abst.): International Geol. Congress, 25th, Abstracts, p. 115. First author at E.R. No 45 du C.N.R.S., 50 rue de Mareil, 78 100 Sante-Germain-en-Laye, France.

Dark field ultramicroscopy and electron fractography are used to show the effects of natural decrepitation of fluid-filled cavities on the behaviour of crystalline rocks, when they are submitted to rise of temperature, and by tectonic crushing. ER

DEINES, Peter, 1976, The consistency of oxygen isotope fractionations among minerals in igneous and metamorphic rocks, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 831. Author at Dept. of Geosciences, Pennsylvania State Univ., University Park, PA.

DELANEY, John R. and MEUNOW, David, 1976, Volatile content of glassy pillow basalts from the Mid Atlantic ridge, (abst): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 832-833. First author at Dept. of Geosciences, Univ. of Arizona, Tucson, AZ.

Mass pyrogram (100°C-1250°C) gas release curves of 7 basaltic glass samples from the quenched rims of tholeiitic pillow basalts dredged from the Mid Atlantic Ridge show consistent patterns; 1, at 730°C ± 15°C - minor H_2O release; 2. at 920°C ± 20°C - major H_2O release, minor CO_2 release; 3. at 1050°C ± 30°C - major CO_2 and SO_2 release. Pyrograms of gas release curves for plagioclase and olivine, containing basaltic glass inc. with a separate vol, phase, also quenched in the pillow rim, show sharp CO_2 release spikes, sporadic SO_2 release, but very little H_2O over the range of degassing 1015°C - 1160°C. Electron microprobe anal. of glass inc. in the phen. and in the glass surrounding the phen. demonstrate a strong chem. similarity of all major elements and S. The CO_2/H_2O ratio in glass surrounding the phen. is distinctly less than 1.0 and the CO_2/H_2O ratio from the inc.-bearing phen. is much larger than 1.0. Explanations of the diff. between the CO_2/H_2O ratio of the two glasses may involve: 1) substantial CO_2-rich vol. degassing from the magma after entrapment of glass inc.; 2) significant influx of ocean water into the magma after entrapment of inc.; or 3) surface chem. or diff. effects during xl growth which strongly enhanced the CO_2 content of entrapped glass.

DEMIN, Yu. I., ZOLOTAREV, V.G., YESIPOV, A.V., KUDRYASHOV, A.M., MERGENOV, B.M., and YUSHKEVICH, I.V., 1976, Types of processes of redeposition of ore substance at Sterzhanskoe deposit (Rudnyi Altai): Geol. Rudn. Mest., v. 18, no. 2, p. 12-22 (in Russian). First author at Moscow State Univ., Moscow.

Zones of injections of liparite porphyry occur in ore-bearing rocks. In central parts of zones with injections T_D of ores increases to 440°C, from 320°C at marginal parts. Sphalerite from veins and nests in polymet. ores contains incs. with T_H = 180-200°C; sphalerite from stratabound ores - rare incs. with T_H = 50-95°C. (Abst. by A.K.).

DENIS, M., 1976, The Sierrita, Arizona, porphyry copper -- hydrothermal alteration and fluid inclusion studies (abst.): Geological Society - Mineralogical Society (Britain) Symposium on fluid inclusions, Univ. of Durham, Abstracts of meeting (unpaginated), to be published in Trans. I.M.M. Sect. B.

At Sierrita the zones of alteration conform closely to the classical pattern of Lowell and Guilbert* with a clearly predominant potassic zone and a late propylitic alteration superimposed on the general pattern. The mineralization (pyrite, chalcopyrite, molybdenite) is essentially concentrated in the zone of potassic alteration and is associated with fracture zones related to the contacts of the different intrusions. Chalcopyrite and molybdenite were deposited by separate generations of fluids which show neither low densities nor very high salinities. Boiling, the characteristic phenomenon of porphyry coppers, has occurred only to a small degree at Sierrita. The maximum homogenization temperatures of fluid inclusions are of the order of 400°C. The pressures, deduced from microthermometric data, varied from 250 to 1500 bars. It is thought that this deposit was emplaced at a greater depth than that normally proposed for porphyry coppers, in an environment of little fracturing.

*Lowell J.D. and Guilbert J.M. Lateral and vertical alteration-mineralization zoning in porphyry ore deposits. Econ. Geol., 65, 1970, 373-408.

A new approach to the study of porphyry copper fluids, the analysis of ions dissolved in the aqueous phase of fluid inclusions, has been tried. More than 50 chemical analyses show the fluid phase contemporaneous with the potassic alteration to have been essentially sodium- and chlorine-rich (K:Na atomic=0.10). (Author's abstract)

DESCHAMPS, N., SABOURAUD, C., BOURRELLY, I.N., et al., 1973, Analysis of the chemical composition of fluid inclusions by neutron activation: J. Radioanal. Chem., v. 18, no. 1-2 (International colloquium on activation analysis of very low amounts of elements, Part 2), p. 45-48 (in French).

DOLGOV, Yu,A., 1976, Atmospheres during melting in inclusions in terrestrial and cosmic impact objects (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept., 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 16 (in Russian; translation by A. Kozlowski).

Impactites bear products of interaction of cosmic solid substance with material of the atm., lithosphere, and hydrosphere. All melt incs. in mins. of meteorites are P, they bring almost no gases from space to Earth's atm. Tektites have various origins. On basis of comp. of atm. of melting, trapped in incs., one may discern: a) terrestial (Darwin glass); b) mixed bearing cosmic H_2 (moldavites, spherules of Tungusskiy phenomenon, Moon soil, Libyañ glass); these gases have very stable comp. and they are similar to a mixture of terrestial atm. with atm. of comet; c) CO_2 - incs. in philippinites, indochinites, australites, etc. Incs. in glasses do not leak and hence preclude the influx of air into vacuole (see also Volokhov 1975, Fluid Inclusion Research - Proceedings of COFFI, v. 8, p. 214-219).

DOLGOV, Yu.A., BAZAROV, L.Sh., BAKUMENKO, I.T., et al., 1976, Gases and fluids in mineral inclusions and their genetic importance, in Internat. Geol. Congress, 25th Session, Reports of Soviet Geologists (Tugarinov, A.I., et al., eds.), p. 251-261: Moscow, Izd. Nauk (in Russian with English summary).

This paper was not given at the 25th I.G.C. and the abstract is not present in the volume of abstracts of the 25th IGC. (E.R.)

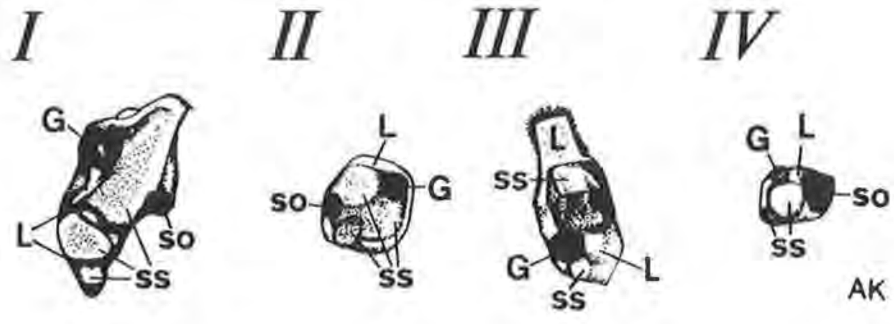
DOLGOV, Yu. A., TOMILENKO, A.A. and CHUPIN, V.P., 1976, Conditions of metamorphism and anatexis on inclusions in minerals, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept., 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 5-6 (in Russian; translation by A. Kozlowski). Authors at Inst. Geol. Geophysics of Sib. Branch Acad. Sci. USSR, Novosibirsk 90.

Incs. in kyanite, sillimanite, andalusite, garnet, diopside, hypersthene, feldspars and quartz, were found to consist of dense, liquified gases, often with an aq. phase. CO_2 prevails, with P_{CO_2} = 6-8 kbar, and $P_{CO_2} \geq 0.8\ P_{tot.}$ in granulite facies. In some regions N_2 at high P is found. In quartzites and granite gneisses of W part of Aldan shield CO_2 = ∿10 times CO (by gas chrom.). On xlized incs. in quartz from migmatites, T of anatexis and xliz. of melts under conds. of granulite and amphibolite facies, are close to upper range of T of meta. (for Aldan shield 900-820 and 830-760°C, respectively). PS, polyphase, NaCl-rich incs. in quartz from migmatite-granites and pegs., are probably the remnant salt melts and melt-sols., separated during xliz. of last portions of anatectic melts. These incs. from Aldan and Baltic shields yield 5-6 kbar and >660°C. These values char. late, regressive stages of meta., proving the xliz. of anatectic melts under high total P. (Abbreviated from the authors' abst.)

DOLGOV, Yu. A., TOMILENKO, A.A. and CHUPIN, V.P., 1976, Inclusions of salt melts-solutions in quartz of deep-seated granites and pegmatites: Akad. Nauk SSSR, Doklady, v. 226, no. 4, p. 938-941 (in Russian). Authors at Inst. Geol. Geoph. Sib. Div. Acad. Sci. USSR, Novosibirsk - 90.

In quartz of anatectites from some complexes of Aldan and Baltic shields and meta. rocks from S. Chuyskiy and Great Mungun-Taiga, both W. Tuva, incs. of essentially salt melts and melt-sols. occur. Such incs. were found in granites, pegs., as well as in wall-rocks: quartzites and gneisses of amphibolite facies, and in some granitoids and pegs. of granulite facies. PS incs. are flat and 1-25 μm long; sol. + G make up only ∿5 vol. % (See Fig. 1). Solids are mainly NaCl, and in addition KCl, ore min. and 2-3 anisotropic mins. (carbonates?). Ore phase doesn't dissolve during heating. T of partial homog. (L+G+xls → L+xls) varies from 90 to 265°C; complete homog. (T_H) at 400-660°C. T_H of incs. in quartz from granitoids from migmatite veins and zonal pegs. are higher ($\leq$ 660°C) than in other rocks ($\leq$ 550°C). T of eutectics equals -45 to -54°C; it testifies to presence chlorides of Na, K, Ca, possibly carbonates, etc. Conc. of NaCl ranges from 55 to 75 wt. %. Gases in incs. permit distinguishing following groups: 1) incs. with CO_2 >"acid gases" (H_2S, SO_2, HCl, HF) + NH_3; 2) same + N_2 and noble gases; 3) same with H_2 and incidentally with CO.P at T_H det. by PT diagram for 30 % NaCl sol. equals 3.5-6.0 kbar; true P values are probably higher for reason of higher concs. P,T and comp. data are for Verkhnealdanian complex, region of Suon-Tiit village. (Abst. by A.K.).

Figure 1. I, II - early xlized and xl-fluid incs. of salt melts-sols; III-IV - late incs. with halite xls. G - gas, L - liquid, ss - solid soluble phase, so - solid ore phase.



DOLISHNIY, B.V., 1976, Accessory mineral-formation in salt rocks, (abst.), Abstracts of Fifth All-Union Conference on Thermobargeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 58-59 (in Russian; translation by A. Kozlowski).

Insoluble part of halite rocks from salt domes of the SE part of Dnepr-Donets depression consists of quartz, calcite, dolomite, dawsonite, pyrite, fluorite, anhydrite, sphalerite, tourmaline, apatite, rutile, muscovite, albite, scapolite, celestite, native sulfur, hematite, and iron hydroxides. Two- (G+L) and three-phase (G+L+halite) inclusions were studied from quartz grains about 1-2 mm long. Inclusions ranged from 0.005 to 0.02 mm. T_H ranged from 200 to 120°C, rarely >200°C. Euhedral mineral habit testifies to their authigenic origin. In the zones of brecciation T_H in quartz, fluorite, dolomite and calcite are high (450-50°C in the Slavyanskaya structure). (Author's abstract).

DOLOMANOVA, E.I., 1976, The chemical composition of gas-liquid inclusions in minerals of tin-ore deposits: Sbornik Nauchn. Trudov, Moskov. Otdel., Vses. Mineral. Obshch., March, 1974, p. 176-177 (in Russian; publ. 1976). (Additional title page reads: New Mineralogical Studies, Ministry of Geol., All-Union Sci. Research Inst. of Min. Resources (VIMS), and Moscow Section, All-Union Mineralogical Soc., Acad. Sci. USSR.) See translations.

DONALSDON, C.H., 1975, A petrographic study of harrisite in the Isle of Rhum pluton, Scotland: PhD Thesis, St. Andrews, Scotland, 138 pp + 3 appendices; Unnumbered report by Experimental Petrology Laboratory, NASA - L.B.J. Space Center, Houston, TX 77058.

Contains much detail on crystallization textures of olivine under various natural and laboratory conditions, and the resultant trapping of silicate melt inclusions. (E.R.)

DONALDSON, C. H., 1976, An experimental investigation of olivine morphology (abst.): Mineralog. Soc. Bull., (London), no. 30, April, 1976, p. 9.

An investigation of the habit of olivine in rock melts as a function of amount of supercooling and of cooling rate. (ER)

DOROGOVIN, B.A., SHATAGIN, N.N., STAROSTIN, V.L., et al., 1975, Dependence of elastic properties of quartz on the pressure existing during its crystallization: Akad. Nauk SSSR, Dokl., v. 222, no. 3, p.669-672. (in Russian).

DOWNS, W.F. and BARNES, H.L., 1976, Geothermal systems: measurements on hydrothermal kinetics, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 842-843. Authors at Dept. of Geosciences, Pennsylvania State Univ., University Park, PA.

An exper. system has been devel. in order to eval. the reaction kinetics of geothermal systems to 350°C and 3500 psi. A hyd. fluid is circulated through rock fragments in a 1.1ℓ reaction vessel which is maintained at a selected T_1. The fluid then passes through a heated connecting tube (at $T>T_1$) to an isothermal heat exchanger (at $T<T_1$) where any ppt is collected. A double valve sampling system is next in line downstream and is followed by a constant V circulating pump which returns the sol. to the reaction vessel. As a sol. sample is removed, the fluid is replaced from a reservoir by a compressed air-driven

piston pump. The circulation path is heated either by immersion in a constant T water bath or by heating coils. Typically the water bath is maintained at 65°C, the min. to which geothermal energy can be extracted economically.

Samples of two rock types, a biotite adamellite and a granitic gneiss, both from the Nacemiento Mountains, N. Mex., have been used as starting materials. These rocks are part of the basement complex being tested by the Los Alamos Sci. Lab. as a dry geothermal reservoir. Prior to use, either these rocks or other min. samples are disaggregated and char. for chem. and isotopic comp., surface area and texture. Both air-sat. distilled water and NaCl brines were used as hyd. sol.

Interp. of the conc. of SiO_2, Na, K, Ca and Al versus time indicates that about 60% of the (H_4SiO_4) in sol. is derived initially from feldspars which dissolve stepwise via the form. of a "protonated feldspar" surface.

DOWTY, E., 1976, Crystal structure and crystal growth: I. The influence of internal structure on morphology; II, Sector zoning in minerals: Amer. Min., v. 61, p. 448-469. Author at Dept. of Geol. and Geophy. Sci., Princeton Univ., Princeton, N.J. 08540.

Of pertinence to studies of the mechanism of trapping of fluid inclusions (ER).

DRIER, J.E., Jr., 1975, Fluid inclusion geothermometry of the Pachuca-Real del Monte silver district, Hidalgo, Mexico [abstr.]: N. M. Geol. Soc., Annu. Field Conf. Guideb., no. 26 (Guidebook of the Las Cruces country), p. 337.

DUDA, R., 1976, Ore occurrences and mineralogic -paragenetic conditions in the Kosicke Hámre - Kosice area (Spissko-gemerské rudohorie Mts.): Mineralia slovaca, v. 8, no. 5, p. 447-468. (in Slovakian with English abstract).

Includes decrepigram for sphalerite (ER).

DUKE, J.M., 1976, Distribution of the period four transition elements among olivine, calcic clinopyroxene and mafic silicate liquid: experimental results: Jour. of Petrology, v. 17, p. 499-521.

DURNEY, D. W., 1976, Recent research on fluid inclusions in Australia: Bull. Soc. Fr. Mineral. Cristallogr., v. 99, p. 128-130 (in French). Author at Macquarie University, Sydney, Australia.

Fluid inclusion research is a comparatively recent field of study in Australia but has been developing notably in the last two years, mainly in connection with analytical techniques and ore deposits.

Fluid inclusions have been described or are being investigated for a variety of ore deposits: tin-fluorite deposits in Tasmania, a scheelite skarn in Tasmania, an auriferous vein in Victoria, Bi, Mo and W pipes in New South Wales, porphyry copper deposits in Australia and Melanesia, and other deposits of Cu, Zn, Pb and U.

Special techniques being used include electron microprobe analysis, vacuum crushing and extraction for gas chromatographic analysis, neutron activation analysis, infrared spectroscopy, transmission electron microscopy and a new apparatus for an accurate temperature measurement.

Regional and time relation studies of fluid inclusions are also being made. (Author's abstract)

DYMNIKOVA, N.G., GNEVUSHEV, M.A., GUBANOV, V.A., UMANETS, V.N., and PETROV, I.P., 1976, Influence of temperature on behaviour of chromium ions during synthesis of pyrope: Zapiski Vses. Mineral. Obshch., v. 105, no. 4, p. 472-475 (in Russian). First author at All-Union Sci. -Research Geol. Inst. (VSEGEI), Leningrad.

Of pertinence to evaluation of approximate T of formation. (A.K.)

DYUFUR, M.S. and SEDOVA, I.S., 1975, The evolution of the P-T parameters during the formation of the metamorphic zoning of the Muzkol Complex (central Pamirs), based on a study of fluid inclusions: Akad. Nauk SSSR, Izv., Ser. Geol., no. 10, p. 49-58 (in Russian).

EADINGTON, P.J., 1976, Fluid inclusions in the minerals of an intrusive quartz-topaz rock near Glen Innes, New South Wales (abst.): International Geol. Congress, 25th, Abstracts, p. 806. Abstract published in Fluid Inclusion Research, vol. 8, p. 52-53 (1975).

EADINGTON, P.J., SMITH, J.W., and WILKINS, R.W.T., 1974, Fluid inclusion and sulphur isotope research, Mount Morgan, Queensland: Papers presented at the Aus. I.M.M. Conference, Southern & Central Queensland, July, 1974, p. 441-444, Australasian Inst. Mining & Metallurgy, Victoria, Australia. First author at CSIRO Div. of Mineralogy, North Ryde NSW, Australia.

This paper is a preliminary report of research on the Mount Morgan gold-copper deposit being done at the Division of Mineralogy, CSIRO. Fluid inclusion and sulphur isotope measurements were made on a suite of 11 samples collected by the staff of Geopeko Ltd. This suite contained representatives of the main ore and rock types of the deposit.

Homogenization temperatures of fluid inclusions measured on quartz from 8 of the 11 samples, ranged from 172°C to 276°C and to this must be added a pressure correction (in this case, up to 50°C) to obtain the formation temperature of the mineral.

Sulphur isotope measurements were made on sulphides from 8 of the 11 samples. The δS^{34} values form a well defined group ranging from -0.5 ‰ to +3.6 ‰ with a mean of +2.4 ‰.

Although the preliminary data do not indicate unequivocally the origin of the deposit they do impose restraints on the wide ranging suggestions that have been put forward.

This work is complementary to the paper of Dr. G. Gibbons who has described other mineralogical aspects of the Mount Morgan deposit, based on a more extensive suite of samples. (Authors' abstract).

EASTOE, C.J., 1976, Fluid inclusion studies of the Panguna and Frieda porphyry coppers, Papua, New Guinea (abst.): International Geol. Congress, 25th, Abstracts, p. 806-807. Abstract published in Fluid

Inclusion Research, v. 8, p. 53-54 (1975).

EDGAR, A.D., and FYFE, W.S., eds., 1976, Water and Magma Genesis: Canadian Mineral., v. 14, pt. 3, p. 225-290.

A series of 5 papers on the subject, including both deep-seated magma genesis and sea-water/basalt interaction. (ER)

EGANHOUSE, R. P. and CALDER, J. A., 1976, The solubility of medium molecular weight aromatic hydrocarbons and the effects of hydrocarbon co-solutes and salinity: Geochim. Cosmo. Acta, v. 40, p. 555. First author at Southern California Coastal Water Research Project, 1500 East Imperial Highway, El Segundo, CA 90245.

The soly. of several medium molecular weight aromatic HCs were det. at 25°C in aq. binary, ternary, and quaternary systems. (From the authors' abstract)

EGGLER, D.H., 1976, Does CO_2 cause partial melting in the low-velocity layer of the mantle?: Geology, v. 4, p. 69-72. Author at Geophys. Lab., Carnegie Inst. Wash., Washington, D.C. 20008.

Recent analyses of fluid inclusions in peridotite minerals suggest that CO_2 is a dominant volatile species in the upper mantle. In a CO_2-bearing oceanic mantle, the low-velocity zone (LVZ) can be explained by a large decrease in the peridotite solidus temperature at a depth of about 90 km, causing melting by intersection with a geotherm. This decrease in the solidus temperature has been found in the system $CaO-MgO-SiO_2-CO_2$ and results from a change in partial melt composition along the solidus from enstatite-normative at pressures less than 26 kb to larnite-normative (melilititic) at greater pressure. Although these liquids dissolve up to 20 wt percent CO_2, they are silicate liquids containing at least 30 percent SiO_2. These silica levels are appropriate for kimberlitic liquids, but the liquids are more calcic than typical kimberlites.

At depths of less than 90 km in suboceanic mantle, CO_2 may be present in carbonate minerals or in vapor, depending upon the geotherm, but cannot be in solution in silicate peridotite minerals. Beneath continents, CO_2 will be present in carbonate minerals, and the mantle will not melt at least to depths of 120 km. (Author's abstract).

EGGLER, D.H. and MYSEN, B.O., 1976, The role of CO_2 in the genesis of olivine melilitite: discussion: Contrib. Mineral. Petrol. v. 55, p. 231-236.

EICHELBERGER, J.C. and GOOLEY, R., 1976, Interaction of basalt and rhyolite magmas (abst.): Geol. Soc. Amer. Abstracts with Programs, v. 8, p. 851-852. Authors at Geosciences Group, Univ. of Cal., Los Alamos Sci. Lab., Los Alamos, NM 87545.

The authors propose a model in which basalt intrudes a rhyolite magma body, breaks into globules, and mixing occurs at the interfaces. (as opposed to immiscibility). (ER)

ELLIS, David E., 1976, Compositions and physical properties of scapolite synthesized at 750°C and 4000 bars, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 853. Author at Dept. of Geol. and Geophysics, Yale Univ., New Haven, CT.

Scapolites of equiv. albite content (eqAb$_X$) from eqAb$_{75}$ to eqAb$_{13}$ are stable relative to plagioclase plus calcite in NaCl-sat. fluid. Scapolites in the range eqAb$_{47}$ are stable relative to plagioclase plus calcite in NaCl-free fluid. The Cl/Cl+CO_3 ratio of syn. scapolite is controlled primarily by the NaCl/NaCl+H_2O ratio of coexisting fluid and secondarily by eqAb content. Variation of Cl/Cl+CO_3 in syn. scapolite is much larger than in natural scapolite. For example, the Cl/Cl+CO_3 ratio in eqAb$_{40}$ scapolite changes from 0.5 to 0.0 as the coexisting fluid changes from NaCl-sat. to NaCl-free. Most natural scapolites have apparently equil. with fluids with low NaCl contents.

Syn. scapolite shows large increases in n_o and a-axis length as its Cl/Cl+CO_3 ratio increases. Decrease in eqAb causes small increases in both. Changes in n_e and c-axis length are small. No combination of unit cell dim. and refractive indices allows det. of both eqAb and Cl/Cl+CO_3 of scapolite. If one comp. variable is known, however, the other may be det. from either a-axis length or n_o.

ENJOJI, M. and TAKENOUCHI, S., 1976, Present and future researches of fluid inclusions from vein-type deposits, in Genesis of vein-type deposits in Japan, Nakamura, T., ed., Mining Geology, Special Issue no. 7, p. 85-100 (in Japanese with English abstract).

The homogenization temperature and salinity of fluid inclusions from the vein-type deposits in Japan are summarized in tables for the convenience of the future study. The data on the homogenization temperatures are obtained from more than 68 mines and the salinity from 22 mines. Some of the decrepitation temperatures are also shown. The chemical compositions of fluid inclusions and the depth of ore formation inferred from the temperature of formation and the thermal gradient are summarized from references.

In general, the homogenization temperatures of gold-silver veins, manganese veins, lead-zinc veins and copper veins of Miocene age are in the range of 240-180°C, 230-150°C, 250-180°C and 270-190°C, respectively, whereas, those of the tungsten and molybdenum veins of ~ late Cretaceous age are generally in the range of 320-250°C. When a copper-lead-zinc-manganese vein shows zoning, the general ranges of temperature of the uppermost manganese zone, upper lead-zinc zone, intermediate copper zone and the lowermost pyrite zone are 200-150°C, 250-170°C, 300-200°C and above 300°C, respectively.

The salinities of fluid inclusions distribute in the range between 12 and 0 wt. % of NaCl equivalent concentration. Highly saline inclusions are reported only from the lowermost barren quartz zone of the Taishu lead-zinc veins, Kyushu. CO_2-rich inclusions are generally found in the late-stage quartz of the tungsten-quartz veins.

Problems encountered in the fluid inclusion study are discussed. They are the indentification of primary and secondary inclusions, accuracy of measurements of temperature and salinity, presentation of data, origin of ore-forming fluids and the inclusion study of artificial crystals. (Authors' abstract).

EPEL'BAUM, M.B., CHEKHMIR, A.S. and LYUTOV, V.S., 1976, Coefficients of diffusion of SiO_2, MgO and CaO in water-albite melt at P_{H_2O} = 500 atm and T = 1000-1100°C: Akad. Nauk SSSR, Doklady, v. 231, no. 4, p. 965 (in Russian). Authors at Inst. Exper. Mineral., Acad. Sci. USSR, Chernogolovka.

ERMAKOV, N.P. (ed.), 1976, Fifth All-Union Meeting on Thermobarogeochemistry (Abstracts of papers), September 20-23, 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geology, 206 pp. (in Russian).

Translated abstracts (given under individual authors in this volume) are arranged in agreement with itinerary of meeting: 1. Papers of plenary sessions, p. 5-18; 2. Section I: Thdy. geochemistry of hyd. and pneu. min.-form. from incs., a. Au-ore and polymet. deps., p. 21-43; b. Non-metals, p. 43-64; c. Rare-metal deps., p. 64-84; d. Pyrite deps., p. 84-94. Section II: Petrology of magmatism and meta. on basis of data of thermobarogeochemistry, a. Magmatic rocks, p. 97-114; b. Peg. (this title missing in text, A.K.), p. 114-117; c. Meta. rocks (title missing in text, A.K.), p. 117-123; d. Various questions (title missing in text, A.K.), p. 123-129. Section III: Practical application of geochem. systems of incs, in mins, a. Prospecting evaluation, geology of deps. (title missing in text, A.K.), p. 131-155; b. Synthesis, p. 155 (154 in Table of contents) - 163. Section IV: Chemistry, and methods and techniques of invest. of incs. of min.-form. media, a. Methods and techniques of invest., p. 167-178; b. Chemistry of min.-form. media, 179-205. Table of contents, p. 206. (Abstract by A.K.) The emblem of the meeting is given below; ӨФӨ refers to Ufa in the Bashkir language.

ТЕРМОБАРОГЕОХИМИЯ

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ESLINGER, E.V. and SAVIN, S.M., 1976, Oxygen isotope geothermometry of diagenetically altered shales, (abst.): Geol. Soc. Smer., Abstracts with Programs, v. 8, no. 2, p. 168. First author at Dept. of Geol., West Georgia College, Carrollton, Georgia, 30117.

ETHIER, V.G., CAMPBELL, F.A., BOTH, R.A., and KROUSE, H.R., 1976, Geological setting of the Sullivan orebody and estimates of temperatures and pressure of metamorphism: Econ. Geol. v. 71, p. 1570-1588.

Various mineralogical and isotopic thermometers are used, but not fluid inclusions. (ER)

FAIZIYEV, A.R., 1976, Conditions of formation of fluorite in Central Kazakhstan, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 54 (in Russian; translation by A. Kozlowski).

1. The fluorite deposits at Kuli-Kolon, Kaznok, Pushnevat, Dzhushkar, Marguzor and Akhmatsai occur in the Zeravshan-Gissar Range in carbonate beds of the Upper-Silurian calcareous shale complex. The deposits are connected with alkaline intrusions.

2. Minerals formed during three stages: I - T_H 350-240°C, P 700-300 atm, II - 300-120°C, P 600-200 atm, III -230-60°C, 400-50 atm. Fluorite, barite, quartz, calcite and dolomite are the main minerals.

3. Quartz crystallized at optical fluorite deposits at T 350-130°C and P 700-250 atm from $Cl-SO_4-HCO_3$ solutions. Calcite formed from $SO_4-Cl-HCO_3$ solutions at 270-60°C and 350-50 atm, siderite at 255-240°C and 320-300 atm, barite - 240-110°C and 300-160 atm, dolomite - 150-130°C and 250-220 atm.

4. Ordinary fluorite crystallized at 230-70°C and 290-100 atm; optical fluorite at 150-80°C and 280-120 atm. Fluorine-bearing solutions forming optical fluorite were of $Cl-SO_4-HCO_3$ type with major Ca and subordinate Na and K concentration.

5. Fluorites bear hydrocarbons, oils and resins in ranges 0.0006 to 0.0016% (average 0.0011%). (Author's abstract).

FAIZIEV, A.R. and ALIDODOV, B.A., 1976, On thermometry of minerals with perfect cleavage: Akad. Nauk SSSR, Sibirsk. Otdel., Geol. Geofiz., 1976, no. 8, p. 140-144 (in Russian with English abstract).

Some ⌒ phenomena observed in thermometric studies of minerals with perfect cleavage such as fluorite, calcite, barite, scheelite, and sphalerite are discussed. This involves the phase relations in the inclusions and hence, temperatures of their homogenization on repeated heating to form anomalous inclusions as a result of natural thermal and mechanical effects. It was found that fissuring of minerals with perfect cleavage occurs in the case when they contain gaseous-fluid inclusions. (Authors' abstract).

FATTAKHUTDINOV, S.G. and VAKHRUSHEV, V.G., 1976, Thermobaric conditions of origin of the Lower Permain rocks, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., P. 56 (in Russian; translation by A. Kozlowski).

A comparison of the reflectivity index, R, of vitrinite particles with T_H of inclusions in anhydrites and gypsums from the Predural'ie. (A.K.)

FAT'YANOV, I.I., 1976, Hydrothermal process during formation of gold ore deposits (abst), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept., 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 23-24 (in Russian; translation by A. Kozlowski).

Au ore deps. formed by alk.-HCO_3 sols., with gases consisting of mainly CO_2, H_2, N_2, CH_4, CO. During the ore stage the buffering props. of hyd. sols. are based on HCO_3 the main anion, whose amount increases from early to late stage. Cl usually is present, SO_4 is found at early stages, $K \approx Na$ at early stage, at ore stage, $K < Na$. At final stage $K + Na < Mg + Ca$. At 250 and 165°C water sols. of electrolytes have structural changes, influencing the stability of metal complexes and causing their decomp. At most deps. early stages (400-200°C) form ores poor in Au; commercial ores xlize at 300-150°C; and late ores (200-50°C) are usually carbonate-rich. Galena, sphalerite, tetrahedrite, Au ppt. at 250-150°C after decomp. of chloride and thiosulfate complexes. Dispersed Au forms probably at 230-280°C. The quality of Au increases with increasing conc. of Na in total alk. and Cl in total anions.

FEHN, Udo and CATHLES, L.M., 1976, Potential hydrothermal convection near abnormally radioactive plutons, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 861-862. First author at Dept. of Geol., Harvard Univ., Cambridge, MA.

FERRY, John M., 1976a, Fluid interaction between granite and sediment during metamorphism, south-central Maine, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 863-864. Author at Geop. Lab., Washington, DC.

Min. comp. indicate that feldspar alt. occurred at 415°C ± 20° due to CO_2-H_2O fluids with $XCO_2 = <0.03-0.13$. The reaction an + cc + H_2O = zo + CO_2 is obs. in metacarbonate rocks to proceed from left to right with increasing proximity to the stocks (increasing T). The circ. of fluids between granites and sed. may have been terminated by the consumption of CO_2 and H_2O by feldspar alt. reactions in the granites. (From the author's abstract)

FERRY, J.M., 1976b, P, T, $^{f}CO_2$, and $^{f}H_2O$ during metamorphism of calcareous sediments in Waterville-Vassalboro area, south-central Maine: Contrib. Min. and Pet., v. 57, p. 119-144. (See previous abstract).

FEVES, Michael and SIMMONS, Gene, 1976, Effects of stress on cracks in Westerly granite: Bull. Seism. Soc. Amer., v. 66. Authors of Dept. Earth and Plan. Sci., Mass. Inst. of Tech., Cambridge, MA 02139.

FIELD, C. W. and GUSTAFSON, L. B., 1976, Sulfur isotopes in the porphyry copper deposit at El Salvador, Chile: Econ. Geol., v. 71, p. 1533-1548.

Sulfur isotope analyses have been performed on 64 monomineralic concentrates from 37 samples that are representative of mineralization in time and space at El Salvador. The isotopic data do not show any consistent trends of ^{34}S depletion with either paragenesis or zoning that would suggest a restricted reservoir of sulfur in the hydrothermal system. More questions than answers are provided by these data. (From the authors' abstract).

FISHER, J.R., 1976, The volumetric properties of H_2O - A graphical portrayal: Jour. Research U.S. Geol. Survey, v. 4, no. 2, p. 189-193. Author at U.S. Geol. Survey, Reston, VA 22092.

A graphical display of the volumetric properties of H_2O is presented as density (0.01 to 1.0 $g\cdot cm^3$) contoured on pressure-temperature coordinates and pressure (1-10,000 bars) contoured on density-temperature coordinates over the temperature range 0-1,000 °C. Data were obtained from sources published during 1964-1969; several minor inconsistencies are observed and attributed to inadequacies in the equations of state used to describe experimental data obtained above 1,000 bars. (Author's abstract).

FLYNN, Ronald T. and BURNHAM, C. Wayne, 1976, Aqueous chloride complexes of the rare earths at magmatic temperatures, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 870. First author at Dept. of Geosciences, Pennsylvanis S. Unit., University Park, PA.

FORD, T.D., 1976, The ores of the South Pennines and Mendip Hills, England - A comparative study, in Handbook of strata-bound and stratiform ore deposits, K.H. Wolf, ed.: Amsterdam, Elsevier Sci. Pub. Co., p. 161-195.

Deposits of both regions are thought to have formed from deep formation waters. Quotes fluid inclusion data from various literature sources and unpublished T_H and salinity data of Roedder on various samples from South Pennines. (ER)

FORESTER, R.W. and TAYLOR, H.P., JR., 1976, ^{18}O-depleted igneous rocks from the Tertiary complex of the Isle of Mull, Scotland: Earth and Plan. Sci. Lett., v. 32, p. 11-17. First author at Dep. of Geol. Sci., Univ. of Saskatchewan, Saskatoon, Sask. S7N OWO Canada.

New oxygen isotope analyses have been obtained on 31 rocks and minerals from the Tertiary ring-dike complex on the Isle of Mull, Scotland. Whole-rock $\delta^{18}O$ values (SMOW) of basalts range from +9.1 to -6.5 ‰, and systematically decrease toward the central plutonic complex. The $\delta^{18}O$ values of the intrusive igneous rocks systematically increase with successively younger ages of emplacement, presumably because the meteoric-hydrothermal systems decreased in intensity with time, as a result of waning igneous activity and mineral deposition within the conduit fractures. Whole-rock $\delta^{18}O$ values of intrusions around the Beinn Chaisgidle center show a narrow range from -3.9 to -1.5, whereas those about the later Lock Ba center can be divided into two groups, the earliest with $\delta^{18}O = -3.3$ to +0.5, and the latest with $\delta^{18}O = +1.0$ to +3.4. All of the rocks within the "limit of pneumatolysis", a zone of hydrothermal contact metamorphism that lies 4-6 km outward from the central intrusions, are depleted in ^{18}O, some by as much as 13‰. These effects are observed over an area of 500 km^2, and were produced by meteoric-hydrothermal convective circulation of early Tertiary ground waters, which apparently had initial $\delta^{18}O$ values of about -11 to -12. (Authors' abstract).

FOURNIER, R. O., 1976a, Estimates of temperatures and salinities of aquifers in the geothermal system at Cerro Prieto, Mexico from hot-spring data, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 873-874. Author at U.S.G.S., Menlo Park, CA.

A comparison of geochemically est. and actual underground Ts can be made at Cerro Prieto, Mexico using pub. info. on Ts and comp. of hot springs and waters discharged from geothermal production wells. (From the author's abstract.)

FOURNIER, R. O., 1976b, Exchange of Na^+ and K^+ between water vapor and feldspar phases at high temperature and low vapor pressure: Geochim.

Cosmo. Acta, v. 40, p. 1553-1561. Author at Branch of Experimental Geochemistry and Mineralogy, U.S. Geological Survey, 345 Middlefield Road, Menlo park, California 94025.

In order to det. whether gas (steam) containing a small amount of dissolved alkali chloride is effective in promoting base exchange of Na^+ and K^+ among alkali feldspars and coexisting brine or brine plus solid salt, exper. were carried out at 400-700°C+steam d. ranging down to less than 0.05. For bulk comps. rich in K, the low P results are close to previous high-P results in comp. of the fluid and coexisting solid phase. However, when bulk comp. is more sodic, alkali feldspars are relatively richer in K at low P than at high P. This behaviour corresponds to enrichment of K in the gas phase relative to coexisting brine and pption of solid NaCl when the brine plus gas comp. becomes moderately sodic.

The gas phase is very effective in promoting base exchange between coexisting alkali feldspars at high T and low water P. This suggests that those ign. rocks which contain coexisting alkali feldspars out of chemical equil. either remained very dry during the high-T part of their cooling history or that the pore fluid was a gas containing very little K relative to Na. (Author's abstract)

FRANTZ, J.D., RUMBLE, D. III, and VIDALE, R.J., 1976, Transport models and their application in geochemistry: Amer. Geophy. Union, Trans. (EOS), v. 57, p. 465-467.

A summary of the numerous papers given at a series of three conferences on transport models and their application to natural rocks ore deposits. (ER)

FREIER, R.K., 1976, Aqueous solutions: Data for inorganic and organic compounds, vol. 1: Berlin, Walter de Gruyter, 440 pp.

FUGE, R., 1976, The automated colorimetric determination of fluorine and chlorine in geological samples: Chemical Geology, v. 17, p. 37-44.

FUJISAKI, Yukio, 1976, Inclusions in emerald from Muzo, Colombia: Jour. Gemm. Soc. Jap., v. 3, no. 4, p. 157-164. (in Japanese with English abstract).

Inclusions observed in an emerald cut stone from Muzo, Colombia were studied by means of microscopic observations and electron probe microanalyses. Physical properties of the stone are summarized in Table 1. Solid inclusions are identified to be pyrite, pyrrhotite, pentlandite and rutile, whose EMPA results are shown in Table 3. Their descriptions and mutual relations are described in some detail, with photomicrographs (Fig. 5-10). Two-phase or three phase inclusions are also observed, but they are much smaller in size than common emeralds from Columbia (Fig. 11-15). How to identify species of solid inclusions under the gemmological microscope is briefly described. (Author's abstract).

GAMBLE, Robert P., 1976, The sulfidation of andradite and hedenbergite and the formation of skarn sulfides, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 879. Author at Dept. of Geol. and Geophysics, Yale Univ., New Haven, CT.

GANEEV, I. G., 1976a, Forms of migration of substance in hydrotherms, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept., 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 9-10 (in Russian; translation by A. Kozlowski).

Differentiation of electrolytes under hyd. conds. in systems under T gradients was invest., especially the final differences of pH, as given in following table:

T of lower auto-clave °C	T decrease in upper auto clave °C	F of auto-clave %	Sol.	molarity	pH of sol. after run		Difference of pH
					upper auto-clave	lower auto-clave	
300	50	83	NaCl	0.25	5.69	5.97	0.28
400	50	25	do.	0.10	6.98	8.86	1.88
400	100	25	do.	0.10	6.48	8.98	2.50
500	200	58	do.	0.10	3.07	6.63	3.56
300	100	80	$CaCl_2$	0.25	5.54	8.54	3.00
300	100	80	NaF	0.50	5.21	6.90	1.69
300	100	80	do.	0.50	6.35	7.50	1.15
400	100	75	$CaCO_3$	0.40	7.25	7.70	0.45
400	100	75	do.	0.05	6.55	7.90	1.35
350	50	75	Na_2CO_3	1.00	10.48	10.80	0.32
350	100	78	do.	1.00	10.40	11.10	0.70
350	250	86	do.	1.00	10.24	13.24	3.00
350	50	73	$NaHCO_3$	0.10	8.08	8.44	0.36
400	50	64	do.	0.50	7.13	9.37	2.24
450	225	86	K_2CO_3	1.00	6.10	13.90	7.80
500	88	56	$KHCO_3$	0.50	10.35	13.05	2.70

GANEEV, I.G., 1976b, Features of hydrothermal solutions and form of migration of mineral substance: Akad. Nauk SSSR, Doklady, v. 227, no. 2, p. 458-460 (in Russian). Author at All-Union Sci.-Research Inst. of Mineral Raw Mat., Moscow.

Essentially same as in preceding abstract (AK).

GANSTER, M. W., 1976, Evidence for the localized accumulation of hydrothermal fluids at the Henderson molybdenum deposit, Empire, Colorado, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 880. Author at Climax Molybdenum Co., Empire, CO.

GARCIA-IGLESIAS, Jésus, 1976, Morphology of corrosion cavities in fluorite: Bull. Soc. Fr. Minéral. Cristallogr., v. 99, p. 85-87 (in French). Author at Escuella Técnica Superior de Ingenieros de Minas de Oviedo, Spain.

From study of natural and artificial corrosion features on (100) and (111) planes in fluorite, genesis by corrosion phenomena of some intercrystalline cavities is suggested. This formation can occur in two cases: (1) when solutions flow through open fractures and (2) when there is a solution corrosion of a mineral before a new crystallization due to modifications of some parameter of the deposit environment. (Abstract M. Pagel)

GARCIA-IGLESIAS, Jésus, and TOURAY, Jean-Claude, 1976, Liquid hydrocarbons in inclusions in the Asturies fluorite from the "La Cabaña" deposit. (Berbés, Spain): Bull. Soc. franç. de Min. et de Crist., v. 99, p. 117-118 (in French). First author at the Oviedo School of Mines, (Lab. of Metallogeny), Oviedo, Spain.

One type of aqueous inclusion is described in "early" (sic.) fluorite and three types in "late" fluorite (2-phase aqueous inclusions, gas inclusions, and liquid hydrocarbon inclusions). For primary inclusions P lies between 220 and 580 bars and T between 148 and 176°C. For secondary inclusions, P lies between 190 and 500 bars and T between 136 and 160°C. (Abstract by M. Pagel, translated by Chris Eastoe).

GAY, M.J. and LATHAM, J., 1976, The freezing behavior of supercooled water drops: Journal of Glaciology, v. 17, n. 75, p. 99.

An electrodynamic containment system was used to study the behavior of supercooled water drops, of radius range 25 to 90 μm. Of interest in freezing studies on inclusions (ER).

GÉLINAS, L., 1976, Archaean variolites -- quench immiscible glasses (abst.): International Geol. Congress, 25th, Abstracts, p. 9. Author at Ecole Polytechnique, Universite de Montreal, Case Postale 6079, Succursale 'A', Montreal, Quebec, Canada H3C 3A7.

Pertinent to the problem of trapping of immiscible silicate melt inclusions. (ER)

GÉLINAS, L., BROOKS, C. and TRZCIENSKI, JR., 1976, Archean variolites-quenched immiscible liquids: Canadian Journal of Earth Sciences, v. 13, p. 210-230.

GENKIN, A.D. and SHADLUN, T.N., 1976, First general book on native gold: Geol. Rudn. Mest., v. 18, no. 4, p. 120-123 (in Russian).

Review of book "Native gold" by N.V. Petrovskaya, "Nauka", Moscow, 1973, (in Russian) with citation on G/L incs. in native gold. (A.K.).

GERRILD, P.M., 1976, A geochemical study of oil in metalliferous veins, Idarado mine, San Juan Mountains, Colorado: Jour. Research U.S. Geol. Survey, v. 4, no. 5, p. 593-599. Author at U.S. Geol. Survey, Denver, Colorado.

A tarry, benzene-soluble material is present in metal-rich veins in the Idarado mine, Ouray County, Colo., in an area not known to have petroleum resources. The material was compared chemically, spectrometrically, and chromatographically with oils from four fields in the nearby Paradox basin. Each of these oil fields contains reservoir rocks equivalent to rock units known to extend beneath volcanic rocks near the mine. Carbon and sulfur isotope data and gas chromotographic data indicate a similarity between the oil from the nearby Sierra field and the oil from the mine. Thus, it seems both geologically and chemically possible that oil in the mine originated in Cretaceous sediments. Variations in the composition of oil from the mine and differences between the mine oil and Sierra oil, notably in the distributions of hydrocarbons, are attributed to bacterial degradation. (Author's abstract).

GHENT, E.D., 1976, Problems in zeolite facies geothermometry, geobarometry and fluid compositions, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 2, p. 179. Author at Dept. of Geol., Univ. of Calgary, Calgary, Alberta, Canada.

GIARDINI, A.A. and MELTON, Charles, 1976, The significance of gases released from natural diamonds by crushing and by graphitization (abst.): International Geol. Congress, 25th, Abstracts, p. 807. Abstract published in Fluid Inclusion Research, v. 8, p. 61-62 (1975).

GIBSHER, N.A. and SHOKHONOVA, L.A., 1976, Behaviour of gases during sulfide formation, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 41 (in Russian; translation by A. Kozlowski).

1. Deposits of the Rudnyi Altai were formed by pneumo-hydrotherms, hydrotherms and colloid-hydrotherms (Rubtsovskoe deposit) during a general T decrease (maximum T_H 550°C at Vavilonskoe, 420°C at Zyryanovskoe, 380°C at Tishinskoe, 300-270°C at Rubtsovskoe); P dropped from 1550 to 50 atm.

2. Hydrotherms were of composition: SO_4-HCO_3 plus some Cl at Rubtsovskoe deposit.

3. CO_2 is the main gas; concentration of sulfur-bearing gases decreased from the pre-ore to the ore stage and then increased in the post-ore stage. Certain regional features of distribution of gases are also apparent. (Authors' abstr.)

GIBSON, E. K., Jr., 1976, Nature of the carbon and sulfur phases and inorganic gases in the Kenna ureilite: Geochim. Cosmo. Acta, v. 40, p. 1459-1464. Author at Geochemistry Branch, TN7, NASA Johnson Space Center, Houston, Texas 77058.

GIGGENBACH, W.F., 1976, Variations in the carbon, sulfur and chlorine contents of volcanic gas discharges from White Island, New Zealand: Bull. volcanologique, v. 39, no. 1, Special issue (Geochemistry of volcanic gases), p. 15-27. Author at Chem. Div., Dept. of Scientific and Industrial Research, Wellington, New Zealand.

On six occasions, from July 1971 to June 1973, discharge samples from twelve selected fumaroles on White Island in the Bay of Plenty, New Zealand, were collected and analysed. The large variations in the absolute and relative proportions of carbon, sulfur, and chlorine containing species, occurring simultaneously over the entire active area of the volcano, suggest that all fumaroles are essentially supplied with one common type of gas made up of at least three components. During quiet periods, with low fumarolic outlet temperatures ($\leq$ 300°), the component with ratios C:S:Cl of 92:3:5 predominates; during heating up periods the relative carbon contents decrease, considered to be due to admixture of a component with C:S:Cl ratios of 44:26:30. Coinciding with maximum outlet temperatures ($\sim$800°C), however, the component with the ratio S:Cl from unity to above ten. The latter component with low ratios of C:S of around 2.5 and ratios of S:Cl of above ten is considered to be most closely related to the primary magmatic gas phase. (Author's abstract).

GIGGENBACH, W. F. and LE GUERN, F. , 1976, The chemistry of magmatic gases from Erta'Ale, Ethiopia: Geochim. Cosmo Acta, v. 40, p. 25-30. First author at Chemistry Division, Department of Scientific and Industrial Research, Petone, New Zealand.

The chem. comp. of the gases emitted from a hornito close to the active lava lake of Erta'Ale, Ethiopia, as derived from chem. anal. on 18 samples collected on 23 January 1974, was found to be (in mol-%): H_2O: 79•4, CO_2: 10•4, total S: 7•36, HCl: 0•42, H_2: 1•49, N_2: 0•18, Ar: 0•001, CO: 0•46, and COS: 0•009. Thdy. considerations, based on the equil. $CO_2 + H_2 \rightleftarrows CO + H_2O$ and $CO_2 + 3H_2 + SO_2 \rightleftarrows COS + 3H_2O$ show that the anal. values represent the equil. comp. of a gas mixture at the meas. T of ~1130°C under close to the surface P conds. Comparison of the Erta'Ale gas emissions with those from other volcanoes suggests a close similarity in their chem. comp. This similarity is considered to be due to common processes governing the release of gaseous species from a magma. (Authors' abstract)

GIORDANO, T. H. and BARNES, H. L., 1976, Galena solubilities in bisulfide solutions to 300°C, (abst.): Amer. Geophys. Union Trans., v. 57, p. 341. Authors at Ore Deposits Research Section, Pennsylvania State University, University Park, PA 16802.

Lead chloride complexes are likely to be dominant in most hyd. ore sol. (From the authors' abstract)

GOLDSMITH, J.R., 1976, Scapolites, granulites, and volatiles in the lower crust: Geol. Soc. Amer., Bull., v. 87, p. 161-168. Author at Dept. Geophys. Sci., Univ. of Chic., Chicago, IL 60637.

GOLOVCHENKO, N.G., GRIGORCHUK, G.Yu. and IVASIV, S.M., 1976, Endogene mineralization at E. Zabaikal'ye (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept., 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 25-26 (in Russian; from authors' abstract, translated by A. Kozlowski).

In Darasuno-Mogochinskaya zone (Au, molybdenite) ore stages formed at Ts (°C): quartz-magnetite (no det.), quartz-molybdenite (440-290), quartz-tourmaline (420-280), quartz-bismuthinite (400-270), Au-quartz-pyrite-chalcopyrite (440-260), Au-quartz-polymetal (330-210), quartz-carbonate-stibnite (210-180); main near-vein alter.: sericitization, K-spar form., albitiz., carbonatiz., chloritiz.; in Ingodino-Shilkinskaya zone (Au, scheelite, cassiterite): quartz-scheelite (350-250), Au-quartz-pyrite-arsenopyrite (390-250), Au-quartz, bismuthinite (380-270), quartz-tourmaline (370-250), Au-quartz-polymet. (320-230), quartz-carbonate-stibnite (270-100);main near-vein alter.: sericitiz., chloritiz., carbonatiz., albitiz.; in Undino-Zolinskaya zone (molybdenite, galena, sphalerite, Au): quartz-tourmaline (440-290), quartz-magnetite (450-330), quartz-scheelite (no det.), quartz-molybdenite (490-300); near vein alter. same as in the first zone. Incs. in mins. usually are 2-phase G/L, sometimes G or 3-phase with L_{CO_2} or halite dm.

GOLUBEV, V.S., 1976, Physico-chemical models of evolution of solutions forming endogene deposits of raw materials: Akad. Nauk SSSR, Doklady, v. 228, no. 1, p. 195-198 (in Russian). Author at All-Union Sci.-Research Inst. of Raw Materials, Moscow.

Theor. calcs. of evolution of hyd. sol. connected with juvenile sources, role of chem. active barriers, kinetics of ore-form., and difference between two boundaries of chem. ppt. are presented. (A.K.)

GOLUBEV, V.S. and SHMARIOVICH, Ye. M., 1976, Dynamics of ore formation on mobile geochemical barrier during mobilisation of ore substance from wall-rocks: Acad. Nauk SSSR, Doklady, v. 226, no. 2, p. 437-439 (in Russian).

Theor. calc. including mass balance, kinetics of transport, time of ore form. and possible conc. of metal in sols. (Abst. by A.K.).

GOMELAURI, A.I., 1976, Temperatures of formation of barite-polymetallic deposits of Western Georgia, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 39-40 (in Russian; translation by A. Kozlowski).

1. Barite-polymetallic deposits occur in calcalkaline volcanogenic-sedimentary complex of Bajocien age, in zones of fracturing.

2. T_H of fluid inclusions was 280-220°C; these results are different than those reported by Bagratishvili (1960) and Uchameyshvili (1967) who reported 130°C and less.

3. According to new thermodynamic data, barite is stable up to 300°C.

4. At 250°C barite in association with anhydrite was grown from solution of pH = 4.

5. Barite deposits formed from sulfate-chloride solutions; the higher the HCO_3 concentration, the lower the amount of barite in assocciation. (Author's abst.)

GOODING, J. L. and MUENOW, D.W., 1976, Activated release of alkalis during the vesiculation of molten basalts under high vacuum: implications for lunar volcanism: Geochim. Cosmo. Acta, v. 40, p. 675. First author at Department of Geology, University of New Mexico, Albuquerque, N.M. 87131.

Knudsen cell-quadrupole mass spect. was used to study the high-T vaporization of Hawaiian basalts, plagioclase, tektites, and samples from the Allende meteorite. Procedures are described by which mass loss rates and vapor Ps of Na and K were meas. quan. (From the authors' abstract)

GOUMA, K., 1976, Epigenetic cavities as elements of the microstructure of tectonized quartz (abst.): 4ème Réunion Annuelle des Sciences de la Terre, Paris, p. 207 (in French). Author at Dept. Geol. Struc., Univ. Pierre et Marie Curie, 4 Place Jussieu, 75230 - Paris Cedex 05, France.

A discussion of the importance of the epigenetic cavities in rocks, in particular those in quartz from the noses of folds in the Jujols series (eastern Pyrenees) and their study with the scanning electron microscope. (Author's abstract abridged by M. Pagel, translated by A. Barabas).

GRABEZHEV, A.I., POKROVSKIY, P.V. and DEMINA, N.Ye., 1976, Isothermic conditions of formation of Urals gold ore and rare metal deposits (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept., 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 30 (in Russian; translation by A. Kozlowski).

At Au (Kochkarskoe, Berezovskoe, Byn'govskoe) and rare metal (Shameyskoe, Zenkovskoe) deps. pre-ore alk. metasomatism and vein form. took place at 700-350°C. Berezites, listvenites (Au deps.) and greisens (rare metal deps.) formed at 380-270°C; quartz ore veins - at 400-250°C. Concs. of F, Cl and CO_2 in incs. are variable.

GRACHEV, V.S., 1976, High-temperature fluorite in the rare-earth metasomatites, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 52 (in Russian; translation by A. Kozlowski).

At fluorite-bertrandite-phenakite deposits fluorite forms several generations. Early fluorite often is the main mineral of ores and it is earlier than K-spar, quartz, phenakite and bertrandite. That fluorite bears inclusions filled by: a) L = 90 to 98% plus xls = 2 to 10%; b) L = 88 to 95%, G = 2 to 9%, xls - 1 to 6%. T of gas dissolution equal 100 to 120°C, T_H - 540 to 600°C. Above 270°C most inclusions decrepitate. At deposits of other types than the named one such inclusions were not found. (From author's abstract).

GRANT, J.N., WILKINSON, N., and HALLS C., 1976, Analysis of fluid inclusion daughter salts by use of a scanning electron microscope (abst.): Geological Society-Mineralogical Society (Britain) Symposium on fluid inclusions, Univ. of Durham, Abstracts of meeting (unpaginated), to be published in Trans. I.M.M. Sect. B.

Daughter salt-bearing fluid inclusions are common in minerals from certain types of ore deposit, especially the high temperature magmatic-hydrothermal deposits. The highly saline fluids preserved in these inclusions are samples of the ore-bearing fluid at an early stage in its evolution, and their analysis is a potentially important source of information on the chemistry of ore transport and deposition.

Most methods of fluid inclusion analysis are beset by problems of contamination of the very small volume of sample involved. The common presence of a number of different generations of inclusions in a given mineral grain leads to serious uncertainties in the analysis of large sample volumes.

The scanning electron microscope (SEM), equipped with solid-state X-ray detector and multichannel analyser, offers a simple and rapid method for acquisition of qualitative data on the composition of selected groups of inclusions. A Cambridge Instruments Stereoscan 2A is used at Imperial College, London, for the study of high-salinity inclusion fluids from a number of mineral deposits, which include tin ores from Bolivia and Malaysia. The inclusions are opened by mechanical fracturing to expose the contained daughter salts. Qualitative information on the major elements present can be rapidly obtained by point analysis of individual visible grains, or by area scan over the whole inclusion cavity. The method can be used as an aid to identification of individual daughter-salt species and, if the volume of these and of the inclusion cavity can be measured in an optical microscope, a semi-quantitative estimate of concentration can be calculated.

For high-temperature early-stage hydrothermal fluids from some Bolivian deposits the method has been used to confirm high concentrations of Na, K and Cl and has revealed very high Fe concentrations and led to the identification of the $FeCl_2 \cdot 2H_2O$ daughter salt. Other elements that have been identified include S, Ca, Al, Mn and P. Because of the irregular shape of the sample surface the sensitivity is low and the method is not suitable for the investigation of trace-metal contents of inclusion fluids.

A major problem that was encountered is that many daughter salts were deliquescent on exposure to air and so lost their crystal form when the inclusion was opened. They could recrystallize in new forms, or simply appear as amorphous blobs on vacuum pumping in the SEM. This can make it difficult or impossible to relate SEM imagery and composition data to what is seen in the optical microscope, although it does not invalidate the chemical data that can be obtained. (Authors' abstract)

GRAVES, M.C., 1976, The formation of gold-bearing quartz veins in Nova Scotia: Hydraulic fracturing under conditions of greenschist regional metamorphism during early stages of deformation: Master's Thesis, Dalhousie Univ., Halifax, Nova Scotia, 80 pp.

Fluid inclusions in quartz of the veins are two-phase (water as a liquid and carbon dioxide as a vapour). No solid phases were observed. They fall into two populations: one with a very constant vapour-to-liquid ratio (pseudosecondary), which homogenize at 262 ± 10°C and a second population which mainly occur in groups and along planes with varying vapour-to-liquid ratios (secondary) and homogenization temperatures of 210 ± 6°C. If the arsenopyrite crystallized together with the vein quartz at 432 ± 60°C and the pseudosecondary population of inclusions represents the crystallizing fluid, a pressure of 2.3 ± 1.0 kilobars can be estimated. (From the author's abstract; see also next abstract).

GRAVES, M. C. and ZENTILLI, M., 1976, Gold-bearing quartz veins formed during Continental collision (abst.): Geol. Assoc. Canada - Mineral. Assoc. Canada Program with Abstract, v. 1, p. 57. Authors at Department of Geology, Dalhousie University, Halifax, Nova Scotia, Canada, B3H 3J5.

Au-bearing quartz-carbonate-arsenopyrite vein systems occur in folded, greenschist-grade metasediments of the Cambro-Ordovician Meguma group of southwestern Nova Scotia. Arsenopyrite geothermometry and fluid inc. geobarometry indicate that the vein min. assemb. xlized under the same cond. as those of the regional meta. assemb. of the country rocks. The veins were formed in sets parallel to the bedding of the

Meguma turbidite sequence during the early stages of deformation and meta., which culminated in upright folds and pervasive axial-plane slaty cleavage.

The gold- (and/or scheelite-) bearing quartz veins, whose formation clearly preceded the intrusion of the post-orogenic Nova Scotia batholith, resulted from the action of meta. pore-fluids and the differential stress field that affected the thick turbidite sequence during collision.

Collision environments are generally considered as metallogenetic provinces mainly in terms of their post-orogenic granitoid plutons. However, these Au dep. of Nova Scotia, a distinct metallogenetic unit, were generated during a syn-orogenic, pre-batholithic, continent-continent collision, metallogenetic epoch. (From the authors' abstract) (see also previous abstract).

GREEN, H.W., II, 1976, Plasticity of olivine in peridotites, in Electron microscopy in mineralogy, H.-R. Wenk, ed.: Berlin, Springer-Verlag, p. 443-464.

Some discussion of "bubbles" of CO_2 on deformation features and dislocations in olivine (pp. 458-462) (ER)

GREW, Priscilla C., 1976, Mineralization in microfractures by stress corrosion cracking, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 894. Author at Institute of Geophysics and Planetary Physics, Univ. of California, Los Angeles, CA 90024.

GRIGORCHUK, G.Yu., and IVASIV, S.M., 1976, Types of metasomatic columns bordering veins of various gold content and thermobaric conditions (at a certain deposit at Transbaikal'ye) (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept., 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 31 (in Russian; translation by A. Kozlowski).

First type of high Au content veins is char. by near-vein zone of K-feldspathization (often K-spar occurs in vein), passing at larger distance from vein into sericitiz. and silification. Second type, with low Au content, has reverse sequence from vein to outside: quartz-sericite to K-spar zones. Vein quartz of first type bears PS G incs. (F up to 10%) and G/L incs. (F = 60-70%), T_H = 415-400°C and 390-350°C respectively. At 390-380°C sols. boiled. Quartz of second type also bears G incs. (F = 10-15%) and rarer PS G/L incs. (F = 50-70%), T_H = 420-380°C and 380-330°C, respectively. Critical phenomena were noted at 390-380°C.

GROSS, W.H., 1975, New ore discovery and source of silver-gold veins, Guanajuato, Mexico: Econ. Geol., v. 70, pp. 1175-1189.

Evidence is presented to show that the vein material did not have its source in hydrothermal vein material from nearby granites, from lateral secretion by meteoric waters through Tertiary lavas, or from solutions emanating from the mantle. The source is believed to be the Mesozoic sedimentary rocks that underlie the area. Alkaline ground water in these rocks was heated to temperatures above 350°C (based on fluid inclusion T_H) during the period of volcanism in the middle Oligocene. The hot solution leached vein-forming materials from the surrounding rocks and escaped along faults formed by crustal subsidence following volcanism. The solutions moved upward along the faults, and the disposition of vein material during the upper Oligocene was caused primarily by a decrease in temperature estimated to be approximately 10°C/100 m. (From the author's abstract). The fluid inclusion data were useful in exploration (ER).

GRUSHKIN, G.G., KHEL'VAS, I.G, and NIKULIN, N.N., 1976, Alterations of wall-rocks of tin ore deposit Khingan: Zapiski Vses. Mineral. Obshch., v. 105, no. 4, p. 438-448 (in Russian). Authors at Blagoveshchenskiy Polytechnic School, Far-East Division of All-Union Sci.-Research Inst. of Mineral Raw Materials, Khabarovsk.

Mean value of T_H of incs. in fluorite and quartz was 323°C; the earliest mins. in veinlets formed at 470°C and 570 bar. Also lit. data on incs. and role of halogens in min. form. are discussed. (A.K.)

GÜBELIN, E.J., 1976, Notes on mono- and bi-phase inclusions in amethyst: The Jour. of Gemmology, v. 15, no. 4, p. 165-171.

A discussion of freezing and heating data on inclusions in amethyst (unspecified location) and their interpretation (low salinity water solution and methane gas). (ER)

GUHA, J. and KOO, J., 1975, Role of fluid state mobilization during metamorphism of the Henderson ore bodies, Chibougamau, Quebec, Canada: Canadian Jour. Earth Sci., v. 12, no. 9, p. 1516-1523. Authors at Sciences de la Terre, Univ. du Québec à Chicoutimi, Chicoutimi, Québec G7H 2B1.

Highly saline fluid inclusion were found (p. 1521). (ER)

GUILHAUMOU, Nicole, LECOLLE, Michel, ROGER, Guy, TOURAY, Jean-Claude, and VETO, Evan, 1976, The conditions of formation of late Hercynian veins in Huelva province, Spain, from a study of fluid inclusions in quartz: C.R. Acad. Sci. Paris, v. 282, ser. D, p. 589-592. First author at Lab. Geol. Ecole Normale Supérieure, 16 rue d'Ulm, 75005 Paris, France.

About 1000 microthermometric measurements were made on automorphic quartzes representing late episodes of vein-filling, or manganiferous jaspers. T_H lies between 90°C and 180°C and T_M between 0°C and -23°C. For certain inclusions containing halite cubes, the temperature of solution, T_S (120-190°C) is greater than T_H. The variation in T_M is attributed to boiling of the mineralizing solutions after an abrupt fall in P. These veins were deposited at a depth of 2-5 km and are associated with the last stages of the regional metamorphism which affected this area. (Abstract by M. Pagel, translated by Chrie Eastoe).

GUILLOU, J.J. and ZIMMERMANN, J.L., 1974, Fluid inclusions in the regional metamorphic rocks of Aracena, Sierra Morena, Spain [abstr.]: Reun. Annu. Sci. Terre, [Programme Resumes], no. 2, p. 204, (in French).

GUSEL'NIKOV, V.N., 1976, Ferruginous quartzites and volcanism: Geol.

Rudn. Mest., v. 18, no. 5, p. 110-116 (in Russian). Author at Sci. - Research Inst. of Problems of Kursk Magnetic Anomaly, Zheleznogorsk.

A reply to critical paper of Ya. N. Belevtsev and Yu. P. Mel'nik (Geol. Rudn. Mest., v. 16, no. 5, 1974), supporting the present author's idea of a "polyvolcanic", i.e., magm. origin of ferruginous quartzites of Kursk Magn. Anomaly; T_D of quartz of meta. and mag. origin from ferruginous quartzites was 400° ± 50°C (300-400°C in taconites) and 600-800°C, respectively. T_D of magnetites were 750-800°C. (Abst. by A.K.).

GUSTAFSON, L.B. and HUNT, J.P., 1975, The porphyry copper deposit at El Salvador, Chile: Econ. Geol., v. 70, p. 857-912. First author at Australian Nat. Univ., Canberra, A.C.T., Australia.

A summary of over 80 man-years of detailed geologic mapping and study on the property. Two coexisting types of fluid inclusions were found in Early and Transitional quartz veins but never in Late pyritic veins. Type I contains high-salinity fluid with NaCl and KCl (?) daughter crystals (35-40% NaCl and <12% KCl) plus hematite (?) and chalcopyrite (?), with small bubbles at low pressure. Type II has large bubbles (40-80%) with 1/8 to 8 atm. CO_2 and a small opaque daughter (hematite?). T_H for both types ranges from 360° to >600°C. Type III is found in all veins; it contains low-salinity fluid and homogenizes at <350°C. (ER)

HAAS, J.L., Jr., 1976a, Physical properties of the coexisting phases and thermochemical properties of the H_2O component in boiling NaCl solutions. (Preliminary steam tables for NaCl solutions.): U.S. Geol. Surv., Bull. 1421-A, 73 pp.

From first principles and parametric equations of state for the H_2O-NaCl system, the following preliminary data were tabulated between 80° and 325°C and up to saturation in halite: vapor pressure, density, specific volume of the liquid and the gas, partial molal volume of H_2O in the liquid, partial molal enthalpy of H_2O in the liquid and the gas, and partial molal entropy of H_2O in the liquid and the gas. (Author's abstract).

HAAS, J.L., Jr., 1976b, Thermodynamic properties of the coexisting phases and thermochemical properties of the NaCl component in boiling NaCl solutions. (Preliminary steam tables for NaCl solutions.) U.S. Geol. Surv., Bull. 1421-B, 71 pp.

From first principles and parametric equations of state for the H_2O-NaCl system, the following preliminary data were tabulated between 80° and 325°C and up to saturation in halite: vapor pressure, density, molal volume of the liquid, molal enthalpy of the coexisting liquid and gas, molal entropy of the coexisting liquid and gas, partial molal volume of NaCl in the liquid, partial molal entropy of NaCl in the liquid, and partial molal enthalpy of NaCl in the liquid. (Author's abstract).

HAJASH, Andrew and TIEH, Thomas, T., 1976, Experimental seawater/basalt reactions, 200-500°C, 500-2000 bars: additional mineralogical data, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 899-900. Authors at Dept. of Geol., Texas A&M Univ., College Station, TX.

HALLAM, M., and EUGSTER, H.P., 1976, Ammonium silicate stability relations: Contrib. Min. and Pet., v. 57, p. 227-244.

Of pertinence to NH_3 in inclusions (ER).

HARDIE, Lawrence A., 1976, Origin of $CaCl_2$-rich geothermal brines by basalt seawater interaction beneath mid-ocean ridges: some simple mass balance calculations, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 903. Author at Johns Hopkins Univ., Baltimore, MD.

The calc. gives a seawater/basalt mass ratio of 3/1 (vol/vol ratio of 9/1) for the interaction. While simple basalt-seawater reaction obviously works well for mid-ocean ridge geothermal systems it will not account for the Pb-Zn-Fe-Mn-rich $CaCl_2$ geothermal brines of continental rift systems like the Salton Sea or Red Sea. (From the author's abstract).

HARDS, N.J., 1976, The role of fluorine and chlorine in late-stage magmatic processes: an experimental study (abst.): Mineralogy Soc. Bull., (London), no. 30, April, 1976, p. 4. Author at Dept. of Geol., Manchester Univ.

The importance of F and Cl in acid and alkaline magma differentiation is considered. Experimental results show that Cl tends to concentrate in an aqueous 'vapour' phase, while F remains preferentially in the melt and causes a considerable lowering of the liquidus and solidus temperatures.

Distribution coefficients between melt and 'vapour' phase have been determined for various elements for melts of granite and nepheline syenite compositions in the presence of F and Cl at 1 kb pressure near the liquidus, and also, in the presence of F, as the solidus is approached. It was found that alkalis and base metals may concentrate quite strongly in a Cl-bearing 'vapour' phase, while alkaline earth elements, Al, rare earths, Sn, and transition metals such as Zr and Nb, tend to remain in the melt. Most elements show little tendency to enter the 'vapour' phase in the presence of F, even as the solidus is approached, although Be may begin to concentrate in the 'vapour' phase near the solidus.

The influence of F and Cl on late-stage magmatic processes may be considered in the light of these results. In particular, the importance of various crystalline phases which may remove F and Cl from the melt is discussed. It is concluded that F-rich melts may be very important in the final stages of magma differentiation, and examples from nature are cited to support this conclusion. (Author's abstract)

HARMAND, Christian, and ZIMMERMANN, Jean-Louis, 1976, A study of volatile elements in some acid volcanic glasses: Acad. Sc. Paris, Compte Rend., v. 282, série D, p. 1391-1394 (in French). First author at Dépt. Géol. et Minéral., Université de Clermont-Ferrand, 5 rue Kessler 63000 Clermont Ferrand, France.

Analyses by mass spectrometry of volatile elements in different acid volcanic glasses have shown the water content to be 85.90%, CO_2 is the next most abundant component, there are also a few organic compounds and traces of HF, H_2S. A study of the liberation curves of H_2O and CO_2 seems to indicate that fluids were trapped during quenching of these glasses. In an obsidian from Lipari the little water present must be of juvenile origin. (Author's abstract)

HARMON, Russel, THOMPSON, Peter, SCHWARCZ, Henry, and FORD, Derek, 1976, Late Pleistocene paleotemperatures from stable isotope analysis of fluid inclusions in speleothems (abst.): International Geol. Congress, 25th, Abstracts, p. 807-808. Abstract published in Fluid Inclusion Research, v. 8, p. 69-70 (1975).

HART, Stanley R., DAVIS, Karleen E., KUSHIRO, Ikuo, WATSON, E. Bruce, 1976, Partitioning of nickel between olivine and silicate liquid, (abst): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 906-907. First author at M.I.T., Cambridge, MA 02139.

HATCH, J.R., GLUSKOTER, H.J., and LINDAHL, P.C., 1976, Sphalerite in coals from the Illinois Basin: Econ. Geol., v. 71, pp. 613-624.

Chem. anal. of 81 samples of coal from the Illinois Basin suggested the occurrence, in many instances, of a separate zinc sulfide phase. Field invest. proved this. The sphalerite is generally Cd rich; ratios of Zn to Cd in the sphalerite samples extr. from coals range from 48/1 to 358/1. The Zn/Cd for sphalerite samples from Illinois and Kentucky that were collected from strata other than coal range from 29/1 to 1,050/1.

Sphalerite occurs in coal principally as fillings in cleats (vertical fractures). Pyrite, quartz, kaolinite, and calcite are assoc. with the sphalerite. The paragenetic sequence began with a sulfide stage, continued with a silicate stage, and concluded with a carbonate stage. The sphalerite is epigenetic and was dep. slowly under cond. near equil. The cleats provided channels in the coal along which the min. sol. could move, and the coal in turn provided a suitable substrate for the bacterial reduction of sulfate to sulfide and/or a source of reduced sulfur.

A Zn content as high as 5,350 ppm and Cd content as high as 65 ppm, both on a whole coal basis, were obs. (Modified from the authors' abstract).

HAUG, J., and FARQUHARSON, R.B., 1976, Detailed textural and mineralogical study related to genesis of the Merry Widow and Kingfisher skarn deposits, Northern Vancouver Island (abst.): Geol. Assoc. Canada - Mineral. Assoc. Canada Program with Abstract, v. 1, p. 57. Authors at Department of Geology, The University of Calgary, Calgary, Alberta, T2N 1N4.

The arsenopyrite geothermometer yields a T of ∿440°C for stage 2, and fluid inc. T_H are ∿250°C for quartz of stage 3. The process of min. is considered in the light of textural and mineralogical details. From the authors' abstract.

HAVETTE, Andrée, and WEISS, Jacqueline, 1976, Identification of solid inclusions in lava phenocrysts by ion analyser: Soc. fr. Minéral. Cristallogr., Bull., v. 99, p. 165-168 (in French with English abstract). First author at Lab. de Pétrog., Univ. Paris XI, 91405 Orsay, France.

The study of solid inclusions within phenocrysts requires in situ analysis. The mass spectra obtained by ion analyzer (i.e., ion microprobe) permit rapid determination of minerals of dimensions greater than 20μm while smaller inclusions are determined by ion images.

HEATHCOTE, Richard C., 1976, Fenitization of the Arkansas novaculite, Garland County, Arkansas, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 910. Author at Dept. of Geol., Univ. of Iowa, Iowa City, IA. 52242.

HELGESON, H.C., and KIRKHAM, D.H., 1976, Theoretical prediction of the thermodynamic properties of aqueous electrolytes at high pressures and temperatures. III. Equation of state for aqueous species at infinite dilution: Amer. Jour. Sci., v. 276, no. 2, p. 97-240.

HEMLEY, J.J., 1976, Stability relations of anthophyllite and antigorite (abst): U.S. Geol. Survey Prof. Paper 1000, p. 177.

HENLEY, R.W., NORRIS, R.J., and PATERSON, C.J., 1976, Multistage ore genesis in the New Zealand geosyncline, a history of post-metamorphic lode emplacement: Mineralium Deposita (Berl.), v. 11, p. 180-196. Authors at Dept. Geol., Univ. of Otago. Dunedin, N.Z.

Epigenetic gold-quartz and scheelite-quartz lodes in Otago and other parts of the New Zealand geosynchline crosscut quartzofeldspathic and metavolcanic rocks of the pumpellyite-actinolite and greenschist facies. The lodes, which commonly strike north-west, are spatially associated with a 30 km wide belt of metavolcanic schists, with associated piemontite and sideritic schists, which parallels the axis of the geosyncline. Oxygen isotope and uncorrected fluid inclusion data for Glenorchy and Bendigo material give the range 230-350°C for lode formation, over 100°C lower than the metamorphic temperature of the country rock, and this indicates that substantial uplift and unloading had occurred prior to the hydrothermal emplacement of the lodes. A model is developed to account for the origin of the lode mineralization. A recent oxygen isotope study of the Glenorchy lodes suggested that the ore-bearing fluid was derived from rocks at depth over 150°C hotter than the lode formation temperature, and this is consistent with an origin by dehydration reactions at the greenschist to amphibolite transition. Hydraulic fracturing, induced by rapid uplift and unloading of the pile, allowed fluid migration to higher crustal levels where ore deposition occurred. The spatial association of the lodes with the metavolcanic suite suggests that metals were derived by trace-leaching from the volcanic suite at the water source, or during migration, whilst tungsten may have been leached from associated manganiferous metasediments which commonly contain high anomalous concentrations of tungsten. Ore deposition occurred in response to lowering of temperature and pressure during fluid migration, and wall-rock interactions, particularly where lower oxygen fugacities were imposed by wall-rocks on the hydrothermal phase. (Author's abstract).

HERR, Frank L. and HELZ, George R., 1976, Activity coefficient of NaHS in water and brines; implications for sulfide mineral solubility, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 914-915. First author at Dept. of Chemistry, Univ. of Maryland, College Park, MD 20742.

HESS, P.C., 1976, Equations of state for "ideal" silicate melts (abst):

Geol. Assoc. Canada/Min. Assoc. Canada Meeting Program with Abstracts, v. 1, p. 57. Author at Brown Univ., Providence, Rhode Island.

HOAGLAND, James Robert, 1976, Petrology and geochemistry of hydrothermal alteration in borehole Mesa 6-2, East Mesa geothermal area, Imperial Valley, California, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 919. Author at Univ. of California, Riverside, CA 92502.

HOEFS, J. and FREY, M., 1976, The isotopic composition of carbonaceous matter in a metamorphic profile from the Swiss Alps: Geochim. Cosmo. Acta, v. 40, p. 945. First author at Geochemisches Institut, Goldschmidtstr. 1, D-34 Göttingen, Germany.

44 $\delta^{13}C$-values for carbonaceous matter in a meta. profile from the Swiss Alps have been det. The anal. samples range from unmeta. sed. to staurolite schists. The C isotopic comp. is more-or-less constant with δ-values around -25‰ in the unmeta. sed. but shifts towards higher ^{13}C-content with increasing grade of meta. $\delta^{13}C$ values of around -11‰ were meas. in the rocks of the highest meta. grade. (Authors' abstract)

HOENIG, Alan, 1976, Workshop on cracks in rocks: Amer. Geophy. Union. Trans. (EOS), v. 57, no. 1, p. 9-12.

A review of a workshop held at Harvard Univ., 1975. Cracks and microcracks have gross effects on many rock properties, and particularly fluid flow (ER).

HOLLISTER, L. S. and BURRUSS, R. C., 1976, Phase equilibria in fluid inclusions from the Khtada Lake metamorphic complex: Geochim. Cosmo. Acta, v. 40, p. 163-175. Authors at Dept. of Geological and Geophysical Sciences, Princeton University, Princeton, New Jersey 08540.

The Khtada Lake, British Columbia, meta. complex consists of high grade amphibolite and metased. units with devel. of gneiss, migmatite, and homog. autochthonous plutons. Max. meta. cond. are estim. to have exceeded 5 kbar and 700°C.

Fluid inc. in matrix quartz are highly variable in d. and comp. ranging from apparently pure CO_2 (G or L or both at room T) through $CO_2 + H_2O \pm CH_4$ mixtures to inc. which are entirely aq. They occur along cracks, in groups without planar features, and as isolated incs. The latter, and some which occur in groups, are interpreted to most nearly approx., in d. and comp., the fluids present during the peak of meta.

The d. and fluid comp. data are derived from direct obs. of phase changes between -180 and +380°C, and from the application of pub. exper. data in the system CH_2-CO_2-H_2O-NaCl. The most dense, pure CO_2 incs. indicate a P of entrapment at 5 kbar, if a T of 700°C is assumed. This is in close agreement with the min. P-T est. from the min. assemb. Methane was positively identified in incs. in graphite-bearing specimens. Salt content is concluded to be about 5-6 wt% NaCl equiv. in the aq. phase in both aq. and $CO_2 + H_2O$ incs. There is evidence of immiscible separation of CO_2-rich and H_2O-rich fluids at Ts at least as high as 375°C. (Authors' abstract)

HOLLOWAY, J.R., 1976, Fluids in the evolution of granitic magmas:

Consequences of finite CO_2 solubility: Geol. Soc. of Amer. Bull., v. 87, p. 1513-1518. Author at Div. of Geochem., Dept. of Chem., Arizona State Univ., Tempe, AZ 85281.

The small but finite solubility of CO_2 in granitic magmas under crustal conditions, together with the common occurrence of CO_2 in likely magma source materials, suggests that granitic magmas will often be accompanied by a CO_2-H_2O fluid phase during their ascent in the crust.

Polybaric and isobaric calculations have been made for model systems with varying total volatile content, initial CO_2/H_2O ratios, crystallization rates, and closed-system or open-system conditions. The calculations demonstrate the presence of CO_2 in an evolving magma system can result in greatly differing values of H_2O activity (and hence H_2O content, phase equilibria, and physical properties of the magma). Specifically, if the mass ratio CO_2/H_2O is $\gtrsim 0.4$ and the initial mass ratio of total volatiles to silicate magma is $\gtrsim 0.05$, then, if little or no loss of the fluid phase occurs during magma evolution, the activity of H_2O will remain nearly constant. This is in strong contrast to all other possible cases in which the activity of H_2O increases rapidly with decreasing pressure and (or) anhydrous phase crystallization, invariably reaching a value of unity.

It is also demonstrated that if CO_2 is present in a fluid phase in the magma source region, then there will be a fluid present throughout the evolutionary history of the magma. The presence of fluid bubbles in the magma should considerably alter many properties of the magma system such as heat transfer, mass transfer, and viscosity. (Author's abstract).

HOLLOWAY, J.R. and EGGLER, D.H., 1976a, Solubility of CO_2 in haplokimberlite liquids at high pressures on the join Ca_2SiO_4-Mg_2SiO_4-CO_2, (abst.): Amer. Geophys. Union Trans., v. 57, p. 340. Authors at Geophysical Laboratory, 2801 Upton St., N.W., Washington, D.C.

HOLLOWAY, John R. and EGGLER, David H., 1976b, "Fluid-absent melting of peridotite containing phlogopite and dolomite", (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 922-923. First author at Arizona State Univ., Tempe, AZ 20008.

Recent exper. work suggests that at Ps above 28 kbar there is no separate fluid phase in the mantle--that all H_2O is bound in phlogopite (ph) and all CO_2 is bound in dolomite (dol). The dol and ph are phases in garnet-lherzolite (garnet + olivine + Ca-rich pyroxene + Ca-poor pyroxene). Fluid-absent melting exper. were performed at 30 kbar on garnet-lherzolite assemb. containing ph or ph + dol in the system H_2O-K_2O-CaO-MgO-CoO-Al_2O_3-SiO_2. All H_2O was added as ph, and all CO_2 was added as dol. In the ph-garnet-lherzolite, ph began to melt at 1235°C ± 15°C and was completely melted at 1260° ± 15°C. In the dol-ph-garnet-lherzolite, the solidus is at 1125°C ± 25°C, regardless of the ratio of dol to ph. For a wide range of H_2O/CO_2 ratios, dol melts at the solidus but ph persists over a short super-solidus T interval. Over that interval a wide comp. range of liquids can be produced whose trace-element pattern will reflect partitioning with ph. For at least 200°C above that interval, a small amount of liquid will coexist in equil. with garnet-lherzolite assemb., but ph will be absent. (Author's abst.)

HOWER, John, 1976, The determination of diagenetic and metamorphic temperatures using clay mineral assemblages, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 2, p. 201. Author at Dept. of Earth Science, Case Western Reserve Univ., Cleveland, OH 44106.

HUANG, Chi-I, 1976, An isotopic and petrologic study of the contact metamorphism and metasomatism related to copper deposits at Ely, Nevada: PhD dissertation, Penn. State Univ., Nov., 1976

The ore deposits at Ely, Nevada are associated with intrusions of mid-Cretaceous quartz monzonite into Paleozoic limestone and minor shale and sandstone. Five concentric zones of alteration in limestone show the effect of contact metamorphism and metasomatism (the tactite stage), as well as a subsequent hydrothermal event (the clay-sulfide stage). These zones are the garnet-rich tactite, the pyroxene-rich tactite, the wollastonite, the silica-pyrite, and the peripheral zones in order of increasing distance from the contact. During the tactite stage, biotite, garnet and pyroxene were formed near the contact, while further away wollastonite and marble mark contact metamorphism. During the clay-sulfide stage, the assemblages quartz-calcite-magnetite-pyrite-clay and quartz-calcite-actinolite-epidote-clay-sulfides are common in and adjacent to veins in the tactite.

Heating of fluid inclusions allows estimates of the salinity and temperature of ore-forming fluids. Most inclusions in garnet, pyroxene and quartz of the tactite stage are of moderate to high density with one or no daughter mineral, and give homogenization temperatures of 450 to 600°C. Inclusions in the clay-sulfide stage quartz contain up to 42 wt. %NaCl equivalent and have wide range of densities. Most of them homogenize between 250 and 500°C but a few did not homogenize when the heating experiment terminated at 500°C. Trapping of a boiling fluid during the mineral deposition may have been responsible for the dispersion of homogenization temperatures to erroneously high values. Based on this assumption, the range of 315 to 445°C is suggested for the temperature of the clay-sulfide stage and copper mineralization in the tactite zone. Quartz from the silica-pyrite zone has inclusions similar to those of the clay-sulfide stage in both filling temperatures and salinities.

$\delta^{18}O$ values of hydrothermal calcite and marble increase outward systematically from the tactite zone to the peripheral zone, but most of the calcites are richer in ^{18}O than the coexisting quartz, suggesting isotopic disequilibrium. On the other hand, excluding calcite, minerals of different stages and zones have $\delta^{18}O$ values corresponding to the tendency to concentrate ^{18}O under equilibrium conditions. $\delta^{18}O$ values of quartz are 9.1 to 12.8‰ (vs. SMOW); of pyroxene, 8.3 to 12.4‰; of garnet, 5.3 to 8.5‰; of two actinolites, 7.2 and 7.8‰; of magnetite, 3.7 to -0.3‰. Quartz-magnetite pairs give isotopic temperature estimates between 680 and 355°C. Seven pyrites have $\delta^{34}S$ values from -5.9 to 2.6‰ (vs. CDT). Ten hydrous minerals have δD values of -109 to -46‰ (vs. SMOW).

The calculated oxygen isotopic composition of waters associated with quartz of the clay-sulfide stage in the tactite zone within the Veteran pit shows a regular outward decrease from 10.5 to 7‰. Mixing of the ore-forming fluid with groundwater may be responsible for this pattern.

The maximum CO_2 content of the ore-forming fluid is estimated at about 6 mole %, and the total dissolved sulfur (predominantly H_2S)

about 0.01 molal at 327°C. The minimum fluid pressure during the mineralization was about 200 to 320 atm based on the fluid inclusion study. Construction of isobaric (500 atm) T-X_{CO_2} and f_{S_2}-f_{O_2} diagrams at 527, 427 and 327°C provides estimates of physiocochemical conditions of the ore deposit based on the stability of andradite, epidote, wollastonite, quartz + sericite ± calcite, quartz + calcite + tremolite, anhydrite, hedenbergite, magnetite and sulfides. An increase in f_{CO_2} and/or decrease in the temperature is suggested as the cause for outward zoning from the garnet to the silica-pyrite zone. f_{S_2} and f_{O_2} during the clay-sulfide stage are principally buffered by pyrite-magnetite. (Author's abstract).

HUANG, Wuu-Liang and WYLLIE, P. J., 1976, Melting relationships in the systems $CaO-CO_2$ and $MgO-CO_2$ to 33 kilobars: Geochim. Cosmo. Acta, v. 40, p. 129-132. First author at Department of Geology, National Taiwan University, Taipei, Taiwan, Republic of China.

HUNTINGDON, A. T., 1976, Chemical aspects of volatile transfer in magmas (abst.): Mineralog. Soc. Bull., (London), no. 30, April, 1976, p. 4-5. Author at Dept. of Geol., Reading University.

The aspects of magmatic volatile transfer which have been studied are deposition from volcanic gases (sublimates) and deposition from the vapour phase in lava vesicles. These will be reviewed and exemplified by chemical studies of Etnaean sublimates and Ugandan vesicle deposits. Sublimates are temperature controlled, the halides of sodium and potassium dominating the high-temperature deposits, with sulphur contents increasing with lowering of temperature. Micas, as vesicle deposits, appear to be controlled by silicate-melt composition as they are most commonly found with alkaline lavas. (Author's abstract)

ILDEFONSE, Jean-Pierre and VICTOR, Gabis, 1976, Experimental study of silica diffusion during metasomatic reactions in the presence of water at 550°C and 1000 bars: Geochim. Cosmo. Acta, v. 40, p. 297-303. Authors at Institut de Recherche sur les Ressources et Matériaux Minéraux, Université d'Orléans, 45100 Orléans, France.

IMAI, Naoya, 1976, Genesis of the fluorspar deposits of the Igashima mine, Niigata Prefecture, Japan: Dept. Geol. and Mineral., Niigata Univ., no. 4, p. 285-290 (Nishida Memorial Volume) (in Japanese with English abstract).

The fluorspar deposits of the Igashima mine, Niigata Prefecture have long been believed to be of contact-metasomatic origin, connected genetically with granitic rocks of pre-Neogene in age. In this paper, summarizing their geologic environments, characteristic features of wall rock alteration and the results of the fluid-inclusion geothermometry of fluorspars, the present writer argues against such a genetic view. He believes that the ore deposits are of hydrothermal-metasomatic origin, related genetically to rhyolite of mid-Miocene age, having been formed at the place further away from the center of the eruption, and that the environment of ore-formation was relatively low-temperature and low-pressure. (Author's abstract).

IMAI, H., LEE, M.S., IIDA, K., FUJIKI, Y., and TAKENOUCHI, S., 1976, Geologic structure and mineralization of the xenothermal vein-type deposits in Japan: Problems of Ore Deposition vol. 1, B. Bogdanov, ed.: Sofia, Bulgarian Acad. Sci., p. 241-246 (in English).

Brief mention of inclusion data from Ashio and Akenobe mines on p. 246 (ER).

IMAI, Hideki, TAKENOUCHI, Sukune, and NAGANO, Ken'ichi, 1976, Fluid inclusion study of the Mamut porphyry copper deposit, Sabah, Malaysia (abst.): International Geol. Congress, 25th, Abstracts, p. 809. Abstract published in Fluid Inclusion Research, v. 8, p. 77-78 (1975).

INSTITUTE OF GEOLOGICAL SCIENCES, (London), 1976, Annual Report for 1975, p. 86.

A new ultra-high vacuum bakeable stainless steel system for the analysis of gas from fluid inclusions was designed and built. This development allows the background for residual gases to be considerably reduced thus making it possible to analyse smaller samples. For more conventional thermometric analyses a new hot stage is being designed which will permit samples to be examined over the entire temperature range of -100°C to +500°C without changing specimen chambers. The stage will be coupled to a programmable temperature controller and will greatly simplify the thermometric analysis procedure.

Fluid inclusion studies continued on the Carrock Fell wolframite mineralisation and was expanded to include potassium-argon age determinations, which established a temporal framework for the spatially related processes of greisenisation and mineralisation, and a limited geochemical survey of tungsten variation in the Skiddaw granite.

Work continued on the Dolgellau gold and copper mineralisation. Preliminary optical and thermometric analyses of fluid inclusions in quartz veins associated with disseminated copper sulphides indicated deposition from fluids cooler than those responsible for the formation of the auriferous quartz veins. Using similar techniques, it also seems possible to distinguish between geochemical copper anomalies related to disseminated as opposed to vein-type deposits.

Fluid inclusion studies were initiated on the quartz pebbles from the Witwatersrand conglomerates. The results to date indicate differences in the pre-depositional inclusions within and between reefs in the Witwatersrand basin which reflect differences in the provenance. ("Author's" abstract).

IRVINE, T.F., JR., and HARTNETT, J.P., 1976, Steam and air tables in SI units, including data for other substances and a separate Mollier chart for steam: Washington, Hemisphere Pub. Corp., 127 pp. First author at State University of New York, Stony Brook, NY.

ISUK, Edet E., and CARMAN, John H., 1976, Remarkable molybdenite solubility in hydrous sodium disilicate liquids, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 937. First author at Univ. of Iowa, Iowa City, IA 52242.

Phase relations in the system $Na_2Si_2O_5 - MoS_2 - H_2O$ reveal remarkably high sol. ($\leq$ 12.5 wt. %) of molybdenite in hydrous sodium disilicate liquids. (From the authors' abstract.)

IVASIV, S.M. and POZDEEV, K.M., 1976, Temperature zoning at deposits of the Sadon group, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol. p. 36 (in Russian; translation by A. Kozlowski).

1) At the Arkhonskoe and Kholstinskoe polymetallic deposits (NW part of the Sadono-Unal'kiy anticlinorium) the ore-forming process is divided into 3 stages: quartz-pyrite (370 - 240°C), quartz-galena-sphalerite (320 - 200°C) and quartz-carbonate (140 - 100°C). Abrupt T changes of 80 - 100°C are typical for the beginning of each stage. Mineral-forming solutions were of hydrosilicate-chloride-Na-K composition.

2) Quartz-galena-sphalerite stage formed $\leq$ 800 atm.

3) Vertical section has T gradient 20 - $\overline{10}$ to 40 - 30°C per 100 m; horizontally, T_H decreases with increasing distance from the Sadono-Unal'skiy fault.

4) Vertical gradient is applicable for evaluation of the degree of denudation of veins of the Arkhon-Kholstinskoe ore field (...). (Authors' abstract).

JACKSON, N.J., 1976, The Levant mine Carbona, A fluid inclusion study: Ussher Soc., Proc., v. 3, pt. 3, p. 427-429. Author at Dept. Geology, Kings College, London.

Fluid inclusions were studied in quartz and fluorite from an intense, disseminated and massive cassiterite-arsenopyrite-chalcopyrite-pyrite replacement and vein mineralization, occurring within a granite sheet complex on the 180 fanthom (329 m) level of the Levant mine.

The data suggest that: 1) the main phase of alteration (albitisation) developed at 270-370°C, probably from 15-30 wt. % NaCl equiv. solutions; 2) the probable temperature of main phase ore deposition was between 270-330°C, although cassiterite may have been deposited at slightly higher temperatures. Salinities are similar to the above, and anhydrite (?) daughter crystals are present along with NaCl; and 3) quartz pegmatites containing inclusions of arsenopyrite, pyrite and chalcopyrite formed between 250-310°C from dilute (<10%) solutions. A zoned quartz-fluorite pegmatite shows a continuous temperature decrease from quartz (270°C) to purple fluorite (114°C). These are all uncorrected for pressure. (ER).

JACOBSEN, J.B.E. and McCARTHY, T.S., 1976, An unusual hydrothermal copper deposit at Messina, South Africa: Econ. Geol., v. 71, p. 117-130.

Fluid inclusions in late quartz and calcite have T_H 210-130°C (p. 128-129). (ER)

JAHNKE, F.M., 1976, Structure and vein development at the Al gold mine, Victoria: Unpublished thesis for M. Sc., Melbourne University, Victoria, Australia.

The early vein minerals were probably precipitated at temperatures of 345-385 ± 50°C, the later minerals at 295-315 ± 50°C. Pressures probably varied between 200 bars and 1260 bars. Fluid inclusions within vein quartz were moderately saline and contained at least CO_2, Na, Cl and probably HCO_3 with minor amounts of Ca, K, Al, Br and possibly H_2S. Decreases in pressure and reaction between the hydrothermal solutions and the vein wall rocks are suggested as likely precipitation mechanisms for the gold which was transported as thio, chloro and/or carbonate complexes. (From the author's abstract).

JEHL, V., POTY, B., and WEISBROD, A., 1976, Hydrothermal metamorphism of the oceanic crust in the North Atlantic Ocean, (abst.): Amer. Geophys. Union Trans., v. 57, p. 597-598. Authors at Centre de Rech. Petrogr. et Geoch. 54500, Vandoeuvre, France.

Fluid inc. and min. have been anal. in meta. tholeites from the Atlantic crust. The most important new-formed min. are: smectites, chlorites, albite, adularia, zeolites, analcite, prehnite, wairakite, quartz, actinolite, epidote, calcite. Those min. are formed by incongruent dissolution of the former rock-forming min. and glass, or by direct pption from the sol. in a close network of veinlets and vesicles. The meta. cond. range from the zeolite facies to the low-grade amphibolite facies. The fluid phase, studied in inc. from quartz, feldspars and calcite, is essentially a chloride-bearing aq. sol., the d of which is moderately high (0.6 to 1.0 g/cc); the sal. varies from 2 to 15 wt. % eq. NaCl. CO_2, CH_4, etc. are absent. With the aid of the microthermometry data, the P and T cond. of the meta. can be est.: rather low Ps (250 to 2000 bars) and low to moderate Ts (140 to 460°C). The avg. thermal gradient is about 150 ± 50°C/km. In fact several generations of fluid are suspected, although they hardly can be dist. from the microthermometry data. For instance, it seems that analcite-bearing assoc. and calcite in serpentinites are related to late low-T sol. It is believed that the convective flow of the fluid phase, which originates from sea water, is the major direct cause of the meta. Besides the thermal effect (convective heat transfer), the infiltration of the aq. sol. leads to an important transfer of components, with the addition of (mainly) H_2O and Na to rock, and the leaching of (mainly) Ca. Such an oceanic hyd. meta. acts upon the oceanic crust to a depth of more than 3 km. (Authors' abstract).

JOSHI, M.S., and KOTRU, P.N., 1976, Role of microcrystals in the growth and development of prism faces of cultured quartz (I). attached microcrystals: Kristall und Technik, v. 11, no. 9, p. 913-925. (In English with German abstract). First author at Sardar Patel Univ., Dept. of Physics, India.

Detailed examination of the processes involved in the nucleation and growth of spurious nuclei in synthetic quartz crystals. (ER)

KADIK, A.A., EGGLER, D.H., 1976, The behavior of water and carbon dioxide during formation and gas release acidic magmas: Geokhimiya, 1976, no. 8, p. 1167-1175 (in Russian).

KALOUSTIAN, J., ROSSO, J.C., CARANONI, C., CARBONNEL, L., 1976, The clathrate-hydrates of chlorine derivatives of methane. Phase diagrams of the systems H_2O-CH_2Cl_2; H_2O-$CHCl_3$; H_2O-CCl_4: Revue de Chimie Minerale, v. 13, p. 334-342 (in French with English abstract). First author at Lab. de Chimie Physique Minerale et macromoleculaire, U.E.R. Scientifique de Luminy, 70, route Leon-Lachamp, 13288 Marseille Cedex 2, France.

Phase diagrams of the systems H_2O-CH_2Cl_2,H_2O-$CHCl_3$,H_2O-CCl_4 were studied by thermal analysis (increasing temperature method). In the three cases a clathrate hydrate is met, peritectic decompositions and monotectic reactions are observed. Calorimetric study of the invariants shows that clathrate formulas are X.34 H_2O and not X.17 H_2O. In the host cubic structure Fd3m the occupancy factor of the largest voids is 0.5 and not 1. Results are controlled by radiocrystallography. (Author's abstract).

KALYUZHNYI, V. A., 1976, Thermobaric parameters of mineralogenesis based on inclusions of H_2O-NaCl type, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept., 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 10-11 (in Russian; translation by A. Kozlowski). Authors at Inst. Geol. Geochem. of Fuels, Acad. Sci. of Ukrainian SSR, L'vov.

1. NaCl conc. in incs. of postmagm. fluids usually is higher than total conc. of other water-sol. cpds., thus the interpretation of data obtained during studies of incs. is possible by use of P-V-T-X diagrams for the system NaCl - H_2O.

2. From data on specific volumes of L and G phases under conds. of three-phase (B+L+G) and two-phase (L+G) equil. from 0° to 725°C, and calc., a V-T-X diagram was made for H_2O-NaCl. (B = solid dms, here NaCl).

3. The curve of V_L in equil. with G and solid (B) phases has a max. on the V-axis, first found by the author; for H_2O-KCl this max. is absent. Comp. of G at Ts = 0-725°C is very low in NaCl and hence the curve V_G is in the area of fresh H_2O.

4. Anal. of XTV diagrams proves that: (a) during homog. trapping of incs. the penultimate phase change in incs. during heating testifies to phase state of the whole system of min.-form. in relation to H_2O and NaCl phases; type of final homog. testifies to phase state of inc. in moment of homog., e.g., incs. homog. by schemes: (B+L+G) → (B+L) → L show that system during trapping consisted of sol. and xls of NaCl, and T_H is the true T of xliz; (b) for conds. of boiling sol. or heterog. trapping, one may present the peculiarities of each inc. of all the group of syngenetic incs. - this permits finding incs. formed during homog. trapping and det. the true Ts of xliz.; (c) regime of homog. of H_2O+NaCℓ incs. in G phase has very complicated nature due to the discontinuity of fields of sol. and melt for high values of V. During heating of such incs. the following phase transitions are possible: (B+L+G) → (L+G) → (B+L+G) → (B+G) → (B+L+G) → (L+G) → G, where L of first three expressions is sol. and of remaining - melt. A critical point exists, beyond which, with decrease of V, the change of sol. into melt during T increase goes by steps.

5. A three-dim. PTX diagram of system H_2O-NaCl permits evaluation of real value of P in incs. in moment of their homog. by scheme: (B+L+G) → (B+L) → L.

KAMSHILINA, Ye. M., 1976, Chronicle. In scientific board on oreformation: Geol. Rudn. Mest., v. 18, no. 3, p. 107-110 (in Russian).

Paper includes short summary of activity of Soviet Section of Commission on Ore-Forming Fluids in Inclusions. (A.K.).

KANO, S. and NAMBU, M., 1976 A thermochemical view concerning the sequential genesis of Fe-S-O minerals observed in Shin-Yama pyrometasomatic iron-copper ore deposit, northeastern Japan: J. Japan. Assoc. Min. Petr. Econ. Geol., v. 71, p. 61-78 (in English). Authors at Research Inst. of Min.-Dressing and Metal., Tohoku Univ., Katahira, Sendai.

On the basis of published mineralogical and physicochemical (inclusion and other) data on the deposit, it is assumed that the mineralizing solution responsible for ore deposition was a 2.0 molal NaCl acidic hydrothermal solution. A predominant aqueous sulfur species is shown to have been H_2S. Sulfur concentration and oxygen fugacity of the solution are estimated at $10^{-2.35}$-$10^{-2.49}$ molality and at $10^{-29.76}$-$10^{-31.14}$ atmospheres respectively. (From the author's abstract).

KAPUSTIN, Yu. L., 1976, On origin of carbonatites: Zapiski Vses. Mineral. Obshch., v. 105, no. 3, p. 329-343 (in Russian). Author at Inst. Mineral., Geochem., Crystallochem. Rare Elements, Moscow.

Paper contains an evaluation of role of volatiles (CO, CO_2, C_nH_m, P, H, H_2O, and F) in the process of form. of carbonatites. (A.K.)

KAPUSTIN, Yu.P., 1976, Certain essential petrogenetic peculiarities of alkaline rocks: Akad. Nauk SSSR, Doklady, v. 231, no. 5, p. 1214-1217 (in Russian). Author at Inst. Mineral. Geochem. and Crystallochem. of Rare Elements, Moscow.

Paper bears discussion of role of volatiles from system: H - O - C, pertinent to G components of fluid inclusions. (A.K.).

KARSKIY, B. Ye., ZORIN, B.I., and DEVYATOV, V. Ye., 1975, Application of maps of decrepitometric anomalies during prospecting for muscovite pegmatites (Mama region), in Muscovite pegmatites of the USSR: Leningrad, Lenigrad Div. of "Nauka" Publ. House, p. 117-120 (in Russian).

676 samples of gneiss from Kedrovyi Mt were taken at 10m intervals along lines spaced ∿ 40 m, and then decrep. meas. made at T < 540°C. Histograms of number of impulses vs number of samples both for wall rocks and for pegs. are unimodal and have positive asymmetry. Authors assumed that 0-50 imp. is a negative anomaly, 50-250 is background, and > 250 is a positive anomaly. Decrep. data drawn as isotherms on a map 1:1000), and as lines of equal decrep. activity, permitted prediction of the possible localisation of muscovite-bearing zones. See also Zorin, Karskiy, and Devyatov, Fluid Inc. Res. - Proc. of COFFI, v. 7, 1974, p. 248-249 (Abst by A.K.)

KARSKIY, B. Ye., ZORIN, B.I., and FORTUNATOV, S.P., 1974, Decrepitation studies of structural varieties of the Mama micaceous pegmatites: Vyssh. Uchebn. Zaved., Izv., Geol. Razved., no. 3, p. 43-51, (in Russian).

KARZHAVIN, V.K., 1976, Investigation of kinetic pecularities of gas liberation from minerals during heating: Geokhimiya, 1976, no. 11, p. 1701-1713 (in Russian).

KASHAEV, N.I., NOSOV, S.F., and KHAKIMOV, A.Kh., 1976, Conditions of formation of emeralds as indicated by inclusions in minerals, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 54-55 (in Russian; translation by A. Kozlowski).

Inclusions in emerald, beryl, chrysoberyl, apatite, fluorite, quartz and feldspar from pegmatites, micaceous rocks and quartz-feldspathic veins of Ural, were studied. The inclusions were mainly two-phase gas-liquid. P three-phase inclusions bear either L CO_2 or solids (mainly chlorides). (From the authors' abstract).

KESLER, S.E., ISSIGONIS, M.J., BROWNLOW, A.H., DAMON, P.E., MOORE, W.J., NORTHCOTE, K.E., and PRETO, V.A., 1975, Geochemistry of biotites from mineralized and barren intrusive systems: Econ. Geol., v. 70, p. 559-567.

Ninety-two biotite separates from 35 different igneous systems in western North America and the Caribbean region have been analyzed for Cl, F, H_2O, Cu, Zn, Fe, and Mg. Biotites in fresh magmatic samples from igneous systems genetically related to significant mineralization (dominantly porphyry copper type) form a population with average chlorine and fluorine contents greater than and average copper content less than the average of the remaining barren intrusive systems (at the 90 percent confidence level). However, the magnitude of this halogen enrichment is too small to permit its use as a routine exploration tool. There are no systematic differences in Cl:F,F:H_2O or other multicomponent ratios of biotite compositions that can be used to distinguish between mineralized and barren host intrusions with a high degree of confidence. Although the average halogen content of biotites from both mineralized and barren potassium-rich intrusions is higher than that for potassium-poor intrusions, biotites from mineralized potassium-rich intrusions are slightly enriched in halogens with respect to their barren counterparts. Magmatic biotites from the Boulder batholith do not exhibit systematic spatial variations in halogen abundance related to known areas of mineralization, although biotites from altered rocks around Butte exhibit chlorine depletion. The copper content of biotites from the same samples indicates the location of mineralization at Butte more reliably, however. (Authors' abstract).

KESLER, S.E., ISSIGONIS, M.J., and Van LOON, J.C., 1975, An evaluation of the use of halogen and water abundances in efforts to distinguish mineralized and barren intrusive rocks: J. Geochem. Explor., v. 4, no. 2, p. 235-246.

KHAYRETDINOV, I.A., BELIKOVA, G.I. and ANDRYANOVA, N.A., 1976, New possibilities in thermobarogeochemistry connected with diagrams, (abst.), Abstracts of Fifth All-union conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 11-12 (in Russian; translation by A. Kozlowski).

Information on paragenetic assoc. is necessary in thermobarogeochemistry, since data on incs. in transparent mins. are applied also for opaque ones. Important additional data may be obtained from Purbe diagrams. Nonstoichiometric comp. of mins. permits application of this method to each cpd. Coincidence of pH and Eh features of surfaces of contemporaneously xlized mins. is the basis of the method. Evaluation of Eh and pH char. under cond. of xliz. is performed by meas. of T, P, and comp. of sols., Eh and pH potentials - exper. under standard conds. and in electrolyte with comp. close to comp. of sol. in incs. Diff. of potentials between mins. of various P-T-char. is det. by Purbe diagrams, comparing respective Purbe diagrams and measur. of distance between areas of pH and Eh of compared mins. If the above invest. were performed for one specimen of dep., only meas. of the diff. of potentials for probable parageneses is sufficient for other specimens. Significant diff. of potentials proves form. of mins. under various T and, maybe, from hyd. sols. of various comp. (...) (Authors' abst. shortened by A.K.)

KHITAROV, D.N., 1976, Methods of study of composition of liquid phase of inclusions of mineral-forming media in minerals (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept., 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 16 (in Russian; translation by A. Kozlowski).

Errors, imperfections, and possibilities of methods of study are discussed. Role of the methods is evaluated. Data on these subjects are presented, collected by V.A. Kormushin under sponsorship of All-Union Commission on Methods of Studies of Inclusions, especially on the water leachate method, used by various research groups in USSR. Perspectives of following devel. of methods of det. of comp. of L phase in incs. were evaluated, especially of more universal application, accuracy etc.

KHOLIEF, M.M. and HAMED, H.A., 1976, Effective method for correlation between some hydrocarbon productive horizons of Miocene age in the Gulf of Suez with the help of inclusions in quartz: Bull. Centre Rech. Pau - SNPA, v. 10, no. 1, p. 53-65 (in English).

The present study was carried out on about 150 quartz preparations selected from subsurface clastic sections in the western side of the Gulf of Suez. These sections belong to the Miocene and represent the productive horizons of some oil fields. This study describes the significance of solid and fluid inclusions as a tool for correlation of sediments. It also gives a brief account of the petrographic features of the examined quartz. (Author's abstract).

KIGAY, I.N., 1976, Chronicle. Meeting on endogene ore-formation: Geol. Rudn. Mest., v. 18, no. 3, p. 103-104 (in Russian).

Paper contains a concise abstract of article presented by G.B. Naumov and V.B. Naumov on Nov. 25, 1975: "Phys.-chem. nature of sequence of endogene ore-formation". In this article the authors discuss on, the basis of fluid inc. data, the influence of T, P, and pH on hyd. alt. of rocks and origin of ores. KCl sol. during T increase, ought to be at first weakly acid and then highly alk.; this is the possible way of explanation of changes of pH of ore-forming sols. This last supposition was widely discussed by those with opposing views. (Abst. by A.K.).

KIRKPATRICK, R.J., 1976, Towards a kinetic model for the crystallization of magma bodies: Jour. Geophy. Research, v. 81, p. 2565-2571. Author at Dept. of Geol. Sci., Harvard Univ., Cambridge, MA 02138.

Equations describing nucleation and growth of crystals (and their effect on crystal morphology and probably the trapping of inclusions). (ER).

KOGARKO, L.N., 1976, Physical-chemical conditions of the formation of the Khibina apatite deposits (abst.): International Geol. Congress, 25th, Abstracts, p. 418-419. Author at Institute of Geochemistry and Analytical Chemistry Academy of Sciences USSR.

Apatite deposits of the Khibina alkaline massive are the largest in the world and are important from the commercial point of view.

The investigations of the thermometry of primary inclusions in rock-forming minerals of apatite-nepheline rocks shows that apatite ores of Khibina massif were formed at the magmatic stage. The homogenization temperatures of the order of 1000-700°C are characteristic of the apatite and nepheline of apatite ores and underlying urtites. Silicate-phosphate immiscibility was not involved. (From the author's abstract)

KOGARKO, L.N. and ROMANCHEV, B.P., 1976a,Physico-chemical conditions of eudialyte mineralization of agpaite-nepheline syenites: Akad. Nauk SSSR, Doklady, v. 229, no. 2, p. 455-458 (in Russian). Authors at Inst. Geochem. Anal. Chem. of Acad. Sci. USSR, Moscow.

Eudialyte xls from eudialyte lujavrites and eudialytites from Lovozero and from Ilimaussaq contain magm. P xlized incs (see Figure). The incs. homog. in melt at 800-860°C; same T_H are for nepheline, microcline and aegirine. See also same authors, Ufa abstract.

Figure 2b. Magm. xlized inc. in eudialyte from eudialytite, Lovozero, 640x.

KOGARKO, L. N. and ROMANCHEV, B. P., 1976b,Complex studies of inclusions and genesis of alkaline rocks, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept., 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 8-9 (in Russian; translation by A. Kozlowski).

Agpaitic nepheline syenites of Lovozero massif xlized under low P_{O_2} (buffer: quartz-fayalite-magnetite) over a 300-degree T interval, at the initial stage of xliz. P_{H_2O} was ∿100 bar and such "dry" magma has a high T (980-1000°C) during intrusion. Xliz. began for nepheline (980-800°C), apatite (900-800°C), microcline, aegirine and eudialite and then the remnant melt enriched in halogens to form sodalite bodies and by way of liquation (liquid immiscibility) - villiaumite. The liquation was evidenced by studies of incs.

KOKORIN, A.M. and KOKORINA, D.K., 1976, Temperature zoning of tin-ore deposits of the cassiterite-silicate formation, in Prognozirovaniye skrytogo orudeneniya na osnove zonal'nosti gidrotermal'nykh mestorozhdeniy (Sokolov, G.A., editor), p. 110-112 (in Russian) Izd. Nauka, Moscow, Union of Soviet Socialist Republics.

KOL'KOVSKIY, B.C., MEL'NIKOV, F.P., and PETROV, P.P., 1976, Temperatures of formation of polymetallic deposits of the Madan ore field (Bulgaria), (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 35-36 (in Russian; translation by A. Kozlowski). First author at Sofia, Bulgaria.

Ore field consists of about 30 vein and metasomatic Zn-Pb deposits of Miocene age. Hypogene mineralization is divided into six stages: 1) quartz-sericite and johannsenite-rhodonite aureoles in gneiss and marble, 2) quartz-pyrite, 3) quartz-sphalerite-galena (commercial), 4) rhodochrosite-ankerite, 5) quartz-arsenopyrite, 6) calcite. Studies of fluid inclusions showed that: 1) mineral formation began at 420-400 and finished $\leq$ 100°C; from one stage to the other T changed abruptly 60-70°C; 2) in minerals of the commercial stage T_H varies from 360 -350 to 260 - 250°C; vertical gradient equals about 10°C (per 100 m? A.K.); and T_H increases from N toward the S part of the ore field; 3) Fe content in sphalerite of the commercial stage reaches 12%, i.e., the sphalerite geothermometer is not applicable. (Authors' abstract).

KOLTUN, L.N., 1976, Comparative evaluation of conditions of formation of polymetallic deposits of Transbaikalia, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 39 (in Russian; translation by A. Kozlowski).

Polymetallic deposits are connected with Pz_1 (Lower Paleozoic? or Permian - Zechstein? - A.K.) limestones, and more rarely with sandstones, granites or effusives.

1. Ore formed during frequent tectonic events, dividing mineralization into stages. Most of polymetallic deposits have similar mineral compositions and sequences. (...)

2. T_H for deposits in limestones: 380 to 5-10°C (sic); at deposit Savinskoe-5 pre-ore skarn formation was at 400°C. Axinite stage is pneumatolytic. At vein Novo-Shirikinskoe polymetallic deposit T_H reached 300°C.

3. T_H for productive stages was 230 - 140°C, T decreased over a range 20-90°C.

4. Deposits with high T_H have arsenopyrite-pyrite-pyrrhotite associations; those with low T_H - galena-sphalerite-carbonate-quartz and galena-sphalerite-chalcopyrite-pyrite-quartz associations, occassionally with Hg and As mineralizations.

5. Water leachates gave a HCO_3 - Ca composition, with subordinate Na, K, Cl and $HSiO_3$. (Author's abst.)

KONOVALOV, I.V., 1975, The contact metamorphism of Konkudero-Mamakan granites and the gold ore mineralization, Lena region: Geol. Geofiz. (Akad. Nauk SSSR Sib. Otd), no. 5, p. 45-53 (in Russian with English sum).

See Konovalov, 1975 in Fluid Inclusion Research, v. 8, p. 93, 1975.

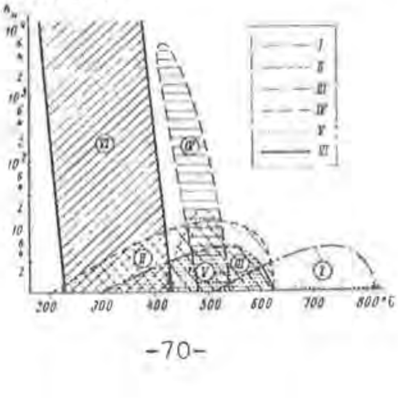
KOPLUS, A.V., KHITAROV, D.N., MISHINA, N.B. and BOLOKHONTSEVA, S.V., 1976, Conditions of formation of fluorite mineralization in Kazakhstan, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 51 (in Russian; translation by A. Kozlowski).

Late Caledonian and late Variscan fluorine-bearing volcanogenic-hydrothermal ore mineralization is associated with effusive rocks of the Central Kazakhstan, Forebalkhash-Illiiskiy and Wester-Talasskiy belts. There are no distinct differences between T_H of inclusions at deposits connected with volcanic rocks of acid and basic to alkaline composition. Late Caledonian fluorite ores have the lowest T_H for the whole process (190-55°C) as well as the lowest for the commercial ores (135-55°C). Late Variscan mineralization has T_H 205-55°C and 200-60°C, respectively. Higher T_H values appeared in fluorites from the Solnechnoe deposit of skarn-carbonate-greisen type, (280-80°C and 280-175°C, respectively. Solutions changed from early Na-Cl-F type late Ca-Mg-Cl type (Authors' abstract).

KORMUSHIN, V.A., SHARIPOV, R.K. and IBRAYEVA, N.Zh., 1974, Chemical analysis of the gaseous phase of inclusions in quartz: Akad. Nauk Kaz. SSR, Izv., Ser. Geol., no. 6, p. 84-86 (in Russian).

KOROBEYNIKOV, A.F., 1976, Contribution to geochemistry of gold in contact-metasomatic processes of granitoid intrusions: Akad. Nauk SSSR, Doklady, v. 227, no. 5, p. 1224-1227 (in Russian). Author at Tomsk Polytech. Inst., Tomsk, USSR.

Ts of form. of gold ore deps. are presented on Fig. 1: Diagram of coefficient of conc. of gold (K_n; = conc. in ore/conc. in wallrock) in min. of contact-metasom. zones of granitoids and traps of various regions of Siberia and Middle Asia versus Ts of their form. (from T_H of incs.). I - field of devel. of mins. of Mg skarns of granitoid intrusions of Sayano-Altai region and Chatkal'skaya zone, Middle Asia; II - lime skarns of granitoids of same regions; III - lime skarns of trap intrusions of Siberian platform; IV - skarn-magnetite ores of Lower Palaeozoic granitoid formation of Sayano-Altai region (max. of low-grade metasom. Au conc.); V - contact-metasom. magnetite ores of Fe ore deps. of Siberia; VI - mins. of Au ores in skarns and hydrothermalites (main high-grade Au deps.). K_n = Au conc. in ore: Au conc. in parent rocks. (A.K.)



KORONOVSKIY, N.V., BYKOV, M.B., SAPARIN, G.V., and SLUEV, V.I., 1976, Microliquation in acid volcanic rocks: Akad. Nauk SSSR, Doklady, v. 230, no. 1, p. 190-193 (in Russian). Authors at Moscow State University, Moscow.

Pertinent to melt immiscibility in magm. incs. (A.K.)

KOSUKHIN, O.N., 1976, Conditions of formation of chambered pegmatites (from inclusions of the mineral-forming medium): Soveshch. Molodykh Uchenykh Mineral., Geokhim., i Metodam Issled. Mineral (Tezis. Dokladov), Primor. Otdel., Vses. Mineralog. Obshch., Dal'nevostoch. Geol. Inst., Vladivostok, p. 32-33 (in Russian; translation courtesy of Michael Fleischer). Author at Inst. of Geol. and Geophy., Sib. Branch, Acad. Sci. USSR.

The ambiguities of the treatment of geol.-min. data obtained during studies of granites and peg. make difficult the sol. of many problems of the origin of these rocks. Hypotheses on the genetic features of the form. of granites and peg. can be made more accurate in many cases by study of inc. of the min.-form. medium in min., because the presence of P inc. of a specific min.-form. medium indicates unambiguously the xliz. of the min. from the given medium (melt, sol, or gas). Nevertheless, study of inc. of the min.-form. medium in min. of granites and peg. encounters significant difficulties for many reasons.

Chambered peg. bodies of granitic intrusives of eastern Transbaikal (Kyrinskii granitic massif) and Kazakhstan (Dzheltan and Dungalinskii massifs) were studied. In the quartz grains from diff. zones of peg. bodies and in quartz of the granite enclosing the peg. body there were found rexlized inc. of magmatic melts. At room T the inc. consist of a xlin. of quartz-feldspar aggregate and an inhomog. fluid, (aq. sol. and gas). The arrangement of the largest group of inc. is azonal. In the quartz, graphic aggregates were obs. of a series of melt inc., confined to the zone of its growth.

It has been found that reliable T_H can be obtained only by the study of a group of small (1-2 microns) inc., because of the high d. of the fluid constituting the melt inc.

Study of the rexlized melt inc. indicates the form. of peg.-granitic, aplitic, graphic, and peg. zones of chambered peg. from viscous silicates melts.

T_H, det. on azonal groups of inc., which appear to be undoubtedly P, and which reflect the cond. of min. form., indicate a low T for the peg.-forming melt. Thus, for a chambered peg. of the Dzhel'tan massif T_H of quartz of the aplitic zone is 580-600°C. The appearance of the first indication of melting in the inc. when heated were det. to be ∿ 500°C.

It has been det. that the form. of each of the structural-material zones of the peg. body occurs in a narrow T interval. The form. of peg. bodies from the peripheral zone to the zone of coarse-grained peg. (Dzhel'tan massif, Kyrinskii massif) occurs with gradual T decrease. T_H of P melt inc. in quartz of the granite enclosing the peg. body indicates that their xliz. is completed at Ts close to Tf of the outer zone of the chambered peg.

KOVAL, V.B., ZHUKOV, F.I., TERESHCHENKO, S.I., 1976, Geochemical stability of nickle-cobalt relations under conditions of regional metamorphism:

Dopov. Akad. Nauk Ukr. RSR, Ser. B., 1976, no. 2, p. 108-110 (in Ukranian). Authors at Inst. Geokhim. Fiz. Miner., Kiev, USSR).

The spectral anal. of pyrite from the Urup deposit and from the Krivoi Rog deposit were made to det. the Ni:Co ratio which together with the results of the study of gas-liq. inclusions in quartz and other minerals of the region provide data on the genesis of the ore deposits. The Ni:Co ratio in the majority of the specimens of the 2 deposits is about the same ($3x10^{-3}/6x10^{-4}$%). The study of the gas-liq. inclusions show that the Ni:Co ratio remains unchanged over a wide range of temp. and pressure during the formation of the ore deposits. (C.A., v. 84, no. 13, 182582f).

KOVALENKO, N.I., 1976, Experimental investigation of a possible way of transfer from granitic melt and ongonite melt: Ezhegodnik Sibirsk Inst. Geokhim. (Yearbook Siberian Inst. Geochemistry) for 1975, p. 221-226 (publ. 1976; in Russian).

A discussion of experimental work in the "system" granite - H_2O-HF with 0.8-1.7 wt. % F. (ER).

KOVALEVICH, V.M., 1976, Halite of the salt deposits of Miocene age from the Forecarpathians, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 58 (in Russian; translation by A. Kozlowski).

T_H, P, Eh, and pH were measured in individual inclusions in halite crystals artificially crystallized at T 20 to 100°C. In granular natural halite only liquid, one-phase inclusions were found. Daughter minerals (sylvite) were found only in other halite varieties. Solutions are of SO_4-Mg composition and they are similar to concentrated marine water. Coarse-crystalline halite bears one-, two-, three-, and polyphase inclusions, saturated with gases of P>P atmospheric; chemical composition of solution in these inclusions ranges from SO_4-Mg to Cl-Ca, i.e., the solution was formed catagenetically at T ~70°C. (Author's abst.)

KOVALISHIN, Z.I., 1976, Carbon-bearing compounds in hydrothermal deposits (abst.), Abstracts of Fifth All-Union Conference of Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 60-61 (in Russian; translation by A. Kozlowski).

Both sedimentary and igneous rocks of Carpathians and Transcarpathians bear carbon compounds; in effusives CO_2- and CH_4-bearing melt inclusions were found. CH_4 is the main hydrocarbon in inclusions, especially in vein quartz from the Vyshkovskoe ore field. In inclusions in minerals of the Beregovo-Veganskoe Au-polymetallic ore field (sphalerite, galena, quartz) CO_2 compromises 39.54 vol. %; at the Beregovskoe deposit its content increases from sphalerite to galena and quartz (to 68.00 vol.%). In barite-forming solutions the role of CO_2 and CH_4 decreases. Inclusions in quartz and quartz-carbonate veins of Hg ore deposits of Vyshkovskoe field bear up to 76.30 vol.% of CO_2 and 21-28 to 56.81 vol.% of CH_4- - presumably transport of metals is possible as hydrocarbon complexes. Inclusions in quartz of the Rakhov ore region bear CO_2 up to 69.18 vol.% and CH_4 up to 56.60 vol. % (Authors' abstract).

KOZYRIN, N.A. and GORBACHEVA, M.I., 1976, One of possible causes of changes of pH or of ore-forming solutions (experimental data): Geol. Rudn. Mest., v. 18, no. 4, p. 92-96 (in Russian). Authors at Mendeleev's Moscow Chem. - Technolog. Inst., Novomoscow Div.

Neutral, weakly alk. and alk. sols. (NaOH and H_2SO_4 added) change pH-value during contact with silicate rocks. Especially strong decrease of pH occurs during interaction of sols. with quartz and silicate glasses. In quartz-ore veins barren pre-ore quartz ppts first. It changes conc. and comp. of ore-forming sols, and also absorbs OH ions, decreasing pH, and causing more intensive pption of ores. (Abst. by A.K.).

KRAFFT, Katia and CHAIGNEAU, Marcel, 1976, On the ratios between chlorine and bromine in volcanic gases of twelve Indonesian volcanos (Sumatra, Java, Flores and Sulawesi): Acad. Sc. Paris, Compte Rend., v. 282, Série D, p. 341-343 (in French). Authors at Service d'Analyse des Gaz du C.N.R.S., 4, Avenue de l'Observatoire 75270 Paris Cedex 06, France.

The chlorine/bromine ratios of volcanic gases examined are quite variable according to sample location, without correlation with temperature, the altitude, or the distance from the sea. However, the relatively high amounts of bromine might be used in forecasting of eruptions. These ratios lies between 10 and 1000 but the majority are between 10 and 200. The mean values for each volcano are 134 (Marapi) 32 (Krakatau) 75 (Papandajan) 100 (Kawah Idjen) 98 (Merapi) 210 (Elulobo) 139 (Ija) 1000 (Egon) 203 (Lewotobi-Laki) 225 (Lewotobi-Perempiran) 62 (Soputan) 10 (Api-Sian). (Authors' abstract modified by M. Pagel)

KRAVTSOV, A.I. and ONIKIYENKO, S.K., 1975, Comparative data on the volatile component composition of magma: Vyssh. Ucheb. Zavedeniy Izv., Geologiya i Razvedka, 1975, no. 8, p. 58-65 (in Russian; translated in Internat. Geology Rev., v. 18, no. 7 (1976), p. 766-772. Authors at S. Ordzhonikidze Moscow Geologic Prospecting Institute, Moscow, USSR.

KRAVTSOV, A.I., VOITOV, G.I., IVANOV. V.A. and KROPOTOVA. O.I., 1976, Gases and bitumens in rocks of "Udachnaya" pipe: Akad. Nauk SSSR, Doklady, v. 228, no. 5, p. 1204-1207 (in Russian). Authors at Moscow Geol.-Prospect. Inst.

Kimberlites contain bitumens and gases, including HCs, with different isotopic comp. than HCs from sed. wall rocks: $\delta^{13}C$ (PDB) = -5.0 ‰ for eclogite and -16.4‰ for vein kimberlite, -28.5 to -25.4‰ for CH_4 from kimberlite, depth 362.9 m, in contrast with lower $\delta^{13}C$ values for organic matter from sed. rocks, -40 ‰. (Abst. by A.K.)

KREULEN, R., 1974, Fluid inclusions; the problem of successive generations of quartz in progressive regional metamorphism [abstr.]: Reun. Annu. Sci. Terre, [Programme Resumes], no. 2, p. 236, (in French).

KRISTMANNSDOTTIR, H. and TOMASSON, J., 1976, Sea-water influx in Icelandic groundwater and geothermal systems, (abst.): Amer. Geophys. Union Trans., v. 57, p. 160. Authors at National Energy Authority

Dept. of Natural Heat, Laugavegur 116, Reykjavik, Iceland.

KUO, Say-Lee and MORTON, R. D., 1976, Conditions of stratiform ore deposition in the Anvil Range District, Yukon -- Fluid inclusion and sulfur isotope studies (abst.): Geol. Assoc. Canada - Mineral. Assoc. Canada Program with Abstract, v. 1, p. 56. Authors at Department of Geology, University of Alberta.

T_H and T_{Frz} and CO_2 wt% in barite, quartz and sphalerite from stratiform ores of the Anvil Range district, together with S isotope comp. in coexisting pyrite, sphalerite, galena and barite, elucidate ore dep. cond. Dep. included in the studies are the Faro, Doal Lake (Grum), Vangorda and Swim Lake dep. Ore form. Ts were $\sim$170-250°C; sal. of the ore sol.: 5-9% NaCl; immiscible CO_2 percent (in barite) was $\sim$5%; the depth below sea level during ore dep. was $\sim$400 meters ($\equiv$0.12 to 0.30 Kb). The ore sol. probably represents a "dilute" connate brine recycled through Helikian basement and/or equil. with Lower Paleozoic volcanic rocks and which apparently rose to the sea floor without boiling. The source of S was sea water sulfate in partial equil. with other sulfide species; reduction of the initial sulfate in a hyd. system prevented significant isotope fract. and provided most of the S for sulfide form. Prelim. thermochemical considerations show that the initial S isotope comp. of total dissolved S in the ore sol. was around $\sim$25%; the major S bearing species were $SO_4^=$, H_2S, and HS^-; fugacity of O during ore dep. was $\sim 10^{-33}$ to 10^{-37}, (avg. 10^{-35}); the pH of ore sol. ranged from 4.5 - 5.5; the ionic strength of the ore sol. was $\sim$1.0; molarity of the total dissolved S in ore sol. was $\sim$.01 - .001/Kg H_2O. Mixing of sulfide species (mainly H_2S) in the "vent" fluid with sea water sulfate appears to be a possible mechanism for fixing the "final" isotope comp. of the total dissolved S prior to ore dep.; the mixing proportion of "vent" S to sea water was about 1:5. S isotope frac. T_S of sphalerite-galena pairs agree well with T_H of P fluid inc. in sphalerite, quartz and barite. (Authors' abstract)

KUZ'MINA, T.M., ZAGORSKII, V.E., and MAKAGON, V.M., 1976, Temperatures of formation of zones of exocontact alteration around veins of rare-metal pegmatites: Ezhegodnik Sibirsk Inst. Geokhimii (Year Book Siberian Inst. Geochemistry) for 1975, p. 78-82 (publ. 1976; in Russian; see translations).

KUZNESOVA, S.V., IVANTISHINA, O.M., 1976, Temperature conditions for mercury mineralization formation in the Mountain Crimea: Akad. Nauk UkRSR, Dopovidi, Ser. B, no. 7, p. 592-595 (in Ukranian with English abstract).

The paper deals with temperature data of mineralization in mercury manifestations within the Moutain Crimea. The results of chemical analyses of two water extracts from quartz, for Na, K, Li, Ca, Al, Cl, HCO_3, CO_3, SO_4, and Si, are presented. Mineralization of mercury is of the intermediate and low-temperature type; cinnabar is deposited at a temperature of about 100°C. (Modified from author's abstract). (ER)

KUŹNIARSKI, M., 1976, Contact transformation temperatures of roof pendants in the Kłodzko-Złoty Stok granitoid massif, Chwalisław area in the Sudeten Mts.: Polska Akad. Nauk Archiwum Mineralogiczne, v. 32, part 1, p. 59-78 (in Polish with English abstract and summary). Author at Inst. Geochem., Min. and Pet. Warsaw Univ., Warsaw, Poland.

A variety of mineralogical geothermometers were used, including "rough and equivocal" data on decrepitation of feldspar and quartz. (ER)

KYLE, J.R., 1976, Brecciation, alteration, and mineralization in the Central Tennessee zinc district: Econ. Geol., v. 71, p. 892-903.

In Central Tennessee sulfide-depositing solutions were in equilibrium with calcite and could not have been responsible for dissolution and subsequent collapse of overlying dolostone beds to form ore-hosting breccias. Stratigraphic relationships suggest that secondary dolomitization and dissolution were related processes and that the dominance of limestone dissolution in preference to volume-for-volume dolomitization controlled the development of the breccia systems. Precipitation of coarse crystals of ore and gangue minerals may have resulted from slow mixing of separate fluids containing reduced sulfur and metals or by gradual reduction of sulfate present in a metal-bearing brine. (From the author's abstract).

KYLE, P. R., 1976, Petrology of volcanic ejecta from Mt. Erebus, Antarctica, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 966. Author at Institute of Polar Studies, and Dept. of Geol. and Mineralogy, The Ohio State Univ., Columbus, OH 43210.

Glass inc. in some phen. were anal. by broad beam microprobe tech. They show small and systematic variations in chem., which represent changes with time and therefore indicate the evol. of the residual liquid. Whole rock-groundmass trends are opposite to the glass inc. and may indicate a cumulus origin for anorthoclase in the whole rock samples. (From the author's abstract)

LAHIRY, Ashoke, 1976, Observations on fluorspar mineralization at Amba Dungar, Gujarat, based on fluid inclusion data: Indian Jour. of Earth Sci., v. 3, no. 1, p. 37-43. Author at Dept. Geol., Univ. of Rajasthan, Udaipur.

The fluorspar deposit of Amba Dungar has gained significance for its association and possible genetic relation with the carbonatites. A genetic link of the mineralization with the carbonatites is not borne out by the present studies on the fluid inclusions in the fluorite. Thermometric and cryometric studies of fluid inclusions in the fluorite and the chemical analysis of the fluid content of the inclusions point to the extremely dilute nature and low temperature of the mineralizing solution. The mineralization of fluorite-quartz type occurred when calcium-rich descending waters encountered the ascending solutions containing fluoride complexes. This resulted in a lowering of temperature and extreme dilution of the mineralizing solution. A deep source of the fluorine is consistent with the geology and tectonics of the area. (Author's abstract)

LANGE, I.M. and MURRAY, R.C., 1976, Evaporite brine reflux as a mechanism for moving deep warm brines upward in the formation of Mississippi valley type base metal deposits [abstr.]: Geol. Soc.

Am., Abstr. Programs, v. 8, no. 5, (Rocky Mountain Section 29th annual meeting), p. 597-598.

LAPIN, A. V., 1976, Geological examples of limited miscibility in ore-silicate-carbonate melts: Akad. Nauk SSSR, Doklady, v. 231, no. 3, p. 694-697 (in Russian). Author at Inst. Mineral., Geochem. and Crystallochem. of Rare Elements, Moscow.

In kamaforites and calcite carbonatites from Vuorijarvi (Kola Peninsula) spherolitic and orbicular structures, consisting of forsterite and magnetite, were found. These spherolites, surrounded by calcite with phlogopite and apatite, are interpreted as structures caused by melt immiscibility; pertinent to melt inclusions. (A.K.)

LATIL, Catherine and MAURY, Roger, 1976, Study of the substitution of F^-, Cl^- and OH^- in apatite: Application to apatites from the Caledonian granites of Ecosse (abst.): Mineralog. Soc. Bull., (London), no. 30, April, 1976, p. 11. Authors at Laboratoire de Minéralogie et Cristallographie, Université Pierre et Marie Curie, 4 Place Jussieu - PARIS Cedex 230. (In French)

LAZARENKO, E. E., 1976, The formation of the miarolitic quartz from the granites of Emelianovsky Quarry on the Volhynia: Min. Sbornik, v. 2, no. 30, p. 95-97 (in Russian).

During the formation of miarolites from granites, the mineralogenesis regime was unstable and often changed. It was distinguished by two varieties of quartz: 1) low-temperature smoky quartz (primary inclusions have T_H 160°C); 2) higher-temperature morion (T_H of the secondary inclusions 330°). (Author's abstract)

LAZARENKO, E.K., VOZNYAK, D.K., PAVLISHIN, V.I., and SHELUKHIM, V.I., 1976, Typomorphic peculiarities of quartz crystals with inclusions of methane solutions (Donets basin): Akad. Nauk SSSR, Doklady, v. 231, no. 6, p. 1446-1449 (in Russian). First author at Inst. Geochem. and Physics of Minerals of Acad. Sci. Ukrainian SSR, Kiev.

Quartz crystals from a quartz vein cutting sandstones of Carboniferous age bear fluid inclusions from 0.0n to 5-6 mm long filled by adqueous and methane solutions. Types of filling are as follows: $L_2(G_2) + L_1$, $L_1 = 2\text{-}5\%$; $L_2(G_2)$; $L + L_2(G_2)$, $L = 20\text{-}70\%$; where L = aqueous solution, salt concentration low, last crystal of ice disappears at -1°C, L_1 = liquid hydrocarbons(?), $L_2(G_2)$ - methane solution under supercritical state. Inclusions L_2 are filled, based on data from mass spectrometry, by CH_4 (90.81%), N_2 (5.61%), CO_2 (1.89%) and H_2O (1.69%). T_H of $L_2(G_2)$ inclusions (100 measurements) varies from -71 to -81°C; chemical nature of phases A and B precipitating during freezing was not defined, but A probably is $CO_2 \cdot 5\text{-}3/4\ H_2O$; B precipitates at T -116 to -139°C. Solution after precipitation of A and B is almost pure methane, since T_{Frz} = 180-182°C (for methane T_{Frz} at 1 atm is -182.49°C). Aqueous inclusions have pH = 7.8 ± 0.2, T_H = 125-160°C, highest P 350-400 atm. (Abst. by A.K.)

LAZARENKO, Ye.Ye., 1976, Comparison of T_H of quartz from the commercial and barren pegmatites of the Ukrainian shield, (abst.), Abstracts of

Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 45-46 (in Russian; translation by A. Kozlowski).

In contrast with the commercial pegmatites, the barren pegmatites often do not contain reticulate and laminated quartz and high-temp. polyphase fluid inclusions. In the barren pegmatites of Viktorinka, reticulate quartz yielded a low T_H (210°C, in L). The commercial pegmatites bear fluid inclusions in reticulate fractures with high T_H (380°C in G). Other inclusions have similar T_H. Inclusions in quartz from the barren pegmatites of the Usolusy region homogenize at 336-120°C. In the commercial pegmatites, however, quartz is characterized by inclusions with T_H 400-350°C (excluding the regenerated quartz).

In the reticulate quartz the gas phase consists mainly of F and Cl; in the liquid phase Na is low. Polyphase inclusions in commercial pegmatites bear concentrated brines (chlorides and sulfates of Na, Ca, Mg and K). (Author's abst.)

LAZ´KO, Ye. Ye. and AFANAS´YEV, V.I., 1974, Mineral inclusions in olivines from kimberlites from pipe "Udachnaya," Yakutia: Vses. Miner. Obshch. Zapiski, v. 103, no. 1, p. 77-84 (in Russian). Authors at Diamond Lab. of Central Sci.-Research Geol.-Prospect. Inst., Mirnyi, Yakutian Autonomic SSR.

Monoclinic pyroxene, Cr-spinel and garnet are most common incs. in olivine; orthorhombic pyroxene as individuals or in intergrowths with clinopyroxene, graphite and ore minerals are rarer incs. The incs. in olivines from kimberlites are ten times more frequent than in olivine from peridotite xenoliths. By goniometric and X-ray studies authors found that these min. incs. are primary and that they are very similar to incs. in diamonds, proving the close similarity of origin of olivines and diamonds in kimberlites. (Authors' abstract, transl. by A.K.)

LAZ'KO, E.M., DOROSHENKO, Yu. P., KOLTUN, L.I., Lyakhov, Yu.V., MYAZ, N.I., PIZNYUR, A.V., 1976, Processes of hydrothermal minerogenesis in the east Transbaikalian deposits, from a study of gas-liquid inclusions in minerals (abst.): International Geol. Congress, 25th, Abstracts, p. 809-810. Abstract published in Fluid Inclusion Research, v. 8, p. 102-103 (1975).

LAZ'KO, Ye. M., LYAKHOV, Yu. V. and PIZNYUR, A. V., 1976, Some most important trends of development of thermobarogeochemistry, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept., 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 6-7 (in Russian; translation by A. Kozlowski). Authors at L'vov Univ., L'vov.

Authors propose the all-union coordination of studies of fluid incs., and for post-magmatic deps. they suggest: 1) construction of dynamic models of individual ore bodies, 2) studies of state of ore metal complexes and stabilities under high P and T, (...), and 3) organization of thermobarogeochemical divisions at mining ore enterprises.

LEACH, D.L., NELSON, R.C. and WILLIAMS, D., 1975, Fluid inclusion studies in the northern Arkansas zinc district: Econ. Geol., v. 70, p. 1084-1091.

Many zinc-lead deposits of the Mississippi Valley type occur in northern Arkansas along the southern flank of the Ozark uplift. Geologically the deposits are similar to the much larger deposits in the Tri-State region 200 kilometers to the northwest. Studies of freezing and homogenization temperatures of fluid inclusions in minerals from the Arkansas deposits have been made to see if the ore fluids were also similar. Primary inclusions in sphalerite, quartz, and dolomite homogenized in the range 80° to 132°C. Pressure corrections to be added probably do not exceed 10°C. Most of the primary inclusions in calcite were single phase, suggesting temperature of formation of less than approximately 50°C. The majority of the freezing temperatures for sphalerite and quartz were in the range -20° to -23.6°C, corresponding to salinities greater than 22 weight percent salts; the highest freezing temperature for sphalerite was -10.8°C, corresponding to approximately 15 weight percent salts. The freezing data for calcite show that calcite was deposited from solutions having salinities from less than 4 weight percent salts to nearly fresh water.

The close similarity of the mineralogy, geology, and fluid inclusion data for the two districts suggests that they represent the same period of mineralization. The origin of the ore deposits may be explained by the movement of heated, saline, formational waters out of the Arkoma or Anadarko basins. (Authors' abstract)

LeBEL, L., 1976, Fluid inclusion study of the porphyry copper deposit of Cerro Verde--Santa Rosa, southern Peru. Part I: The quartz--sericite alteration (abst.): Geological Society-Mineralogical Society (Britain) Symposium on fluid inclusions, Univ. of Durham, Abstracts of meeting (unpaginated), to be published in Trans. I.M.M. Sect. B.

The porphyry copper type deposit of Cerro Verde-Santa Rosa is near the city of Arequipa, southern Peru. It is genetically related to a stock of porphyritic dacite to quartz-monzonite intruding the igneous rocks of the Caldera complex (50 m.y.) and some Precambrian gneiss. Breccias are widely developed.

The study of the fluid inclusions has been carried out on the quartz phenocrysts of the intrusive rocks in the quartz-sericite(phyllic) alteration zone of the Santa Rosa deposit. By use of morphological and physicochemical properties, five types of fluid inclusion were selected. The corresponding fluids were located by their isochore lines on an NaCl-H_2O diagram.

To identify the daughter minerals included in one type of multiphase inclusion a separate study by means of micro-beam techniques was undertaken. Those minerals were silicates, chlorides, sulphates, phosphates, sulphides and oxides. The interpretations cover the fields of thermodynamics (barometry, exsolution and boiling phenomena), petrology (origin of acidic magmas) and metallogeny (sulphate and sulphide relationships). (Author's abstract)

LE BEL, Laurent, 1976, Preliminary note on the mineralogy of solid phases in quartz phenocryst inclusions in the porphyry copper from Cerro Verde/Santa Rosa, S. Peru: Soc. Sc. Nat., no. 350, v. 73, p. 201-208 (Lab. de Geol., Min., Geophy., et du Musée Geol. de L'Univ. de Lausanne, Bull. 220) (in French; see translations).

LELEU, Michel, MAUREL, Colette, MICHARD, Gil, POTY, Bernard, SCHOTT, Jacques, and WEISBROD, Alain, 1976, Experimental metallogeny: Soc. Géol. France, Mém. h, Série n°7, p. 245-264. First author at B.R.G.M. Orleans, France.

The contribution of laboratory work to genetic understanding of ore deposits is described; the origin of metal and sulfur, the transport, the mechanisms and conditions of deposition, and the transformations of the ore bodies, are successively considered. Special attention is given to the sulfate-reducing processes, the transport by thermogravitational effect, the transport and deposit conditions of uranium, the act played by unmixing in the genesis of ore deposits related to granitoids, the processes of the separation of Fe and Mn, and the chemical reactions which occur in the cementation zone. (Authors' abstract)

LETERRIER, Jacques and ZIMMERMANN, Jean-Louis, 1976, The behavior of the fluid phase in the acid-basic plutonic association of the Quérigut massif, Ariége (abst.): Sciences de la Terre, Paris, 4th annual meeting, p. 270 (in French). Authors at Centre de Recherches Pét. et Géoch., C.O. no. 1, 54500 Vandoeuvre-lès-Nancy, France.

Granites, on approaching bodies of basic composition, undergo an evolution towards granodiorites and then tonalites by means of interaction and the exchange of elements between synchronous acid and basic magmas. According to analyses of loss on ignition, mass spectrometry on whole rock samples and on min. separates, and fluid inclusions in the quartz, (1) the tonalites are deficient in fluids compared with the other rocks, (2) the granites and granodiorites are poorer in in CO_2 and organic compounds but richer in water than the diorites, (3) the composition of the fluid phase of the tonalite is intermediate between those of the two preceding groups, except for fluids from biotite, (4) the aqueous inclusions in quartz from all facies are characterized by a very high salinity.

The following model is presented: crystallization of the diorites, first giving an anhydrous paragenesis (plagioclase and pyroxene), then a paragenesis rich in OH-bearing minerals (hornblende and biotite). The fluid phase is then pumped into the neighboring granitoid magma, causing the clear fluid deficit in the tonalites. The high salinity of the inclusions indicates that the circulating fluids have very likely acted as transporting agents during the exchange of elements between the two magmas. (Author's abstract, modified and abridged by M. Pagel, and translated by Chris Eastoe).

LETNIKOV, F.A. and GANTIMUROV, A.A., 1976, Interaction of hydrogen with gabbro-diorite: Akad. Nauk SSSR, Doklady, v. 227, no. 4, p. 965-967 (in Russian). Authors at Inst. Earth's Crust of Sib. Div. Acad. Sci. USSR, Irkutsk.

Gabbro-diorite from Birkhinskiy massif (NW Baikal'ye) with FeO/Fe_2O_3 = 1.35 in incs. bears gases (vol. %): CO 63, CH_4 28, H_2 8.3, CO_2 0.6, H_2O 0.1. This rock, ground to 0.5 mm, was interacted with 1 atm. H_2 at 700, 800 and 900°C. At 700°C the oxidation of H_2 was not obs., but significant amounts of water formed from H_2 at 800 (FeO/Fe_2O_3 after reaction 2.89) and 900°C (FeO/Fe_2O_3 = 6.48). In each exper., a vol. of 4800 cm^3 was passed through rock, giving at 800°C - 24.41 cm^3 of G_{H_2O}, and at 900°C - 36.96 cm^3. The expers. prove oxid. of H_2 during migration of G from mantle. (Abst. by A.K.)

LEVINE, S.L., 1975, Chemical remanent magnetization in iron ores and wall rocks of Cerro de Mercado, Durango, Mexico: M.S. thesis, Univ. of Minn.

Cerro de Mercado, which is situated on the eastern flank of the Sierra Madre Occidental in Durango, Mexico, is Mexico's largest and oldest operating iron mine. The iron oxide ores of Cerro de Mercado are volcanogenic, and they are associated with thick sequence of Tertiary felsic volcanics and intrusives.

A brief study of fluid inclusions in fluorapatite from oxidized ore and altered footwall rhyolite indicates that the emplacement of the apatite accompanied a hydrothermal event of moderate temperature (greater than 350°C) at a crustal depth in excess of 400 meters. The oxidation of the iron ores and the alteration of the footwall are interpreted as having taken place during the thermal event. (From the author's abstract). (See also Rosasco, Roedder, and Simmons, 1975 in Fluid Inclusion Research, v. 8, p. 156 for daughter minerals).

LEVINE, S.L., 1975, Chemical remanent magnetization in iron ores and wall rocks of Cerro de Mercado, Durango, Mexico: Univ. Minn. MS thesis.

LIVNAT, Alexander, RYE, R.O., and KELLY, W.C., 1976, Stable-isotope and fluid-inclusion studies of the Keweenawan copper district, northern Michigan, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 980-987. First author at Dept. of Geol. and Mineralogy, Univ. of Michigan, Ann Arbor, MI 48104.

δD and $\delta^{18}O$ data have been obtained on over 270 samples of whole rocks and min. in the Keweenawan copper district assoc. with (1) native copper min., (2) cross-cutting sulfide veins, and (3) late-stage veins at White Pine. The "fresh" (0.6 to 1.4 wt % H_2O) interiors of basalt flows in the native-copper country have very low (-170 ± 10 permil) δD and very large (11.3 ± 0.8 permil) $\delta^{18}O$ values while Keweenawan basalts in Minnesota have values more typical of normal basalts. Evidently the basalts in the copper country underwent some hydration and extensive exchange with low-T meteoric waters prior to min. $\delta^{18}O$ values of amygdaloidal chlorite, K-feldspar, quartz, and calcite assoc. with native copper show an apparent systematic decrease with stratigraphic depth, which probably reflects the burial meta. gradient. Whole-rock δD and $\delta^{18}O$ values of assoc. chloritized, pumpellyitized, and epidotized basalts are greatly diff. from those of "fresh" basalts and appear to be compatible with those for the amygdule phases. $\delta^{18}O_{H_2O}$ and δD_{H_2O} values of the min. fluids calc. from whole-rock, anygdule-phase, and sulfide-vein data are 6 ± 3 permil and 0 ± 10 permil respectively through the area, implying that a non-magmatic fluid external to the Keweenawan system was responsible for the native-copper and vein min. Calc. $\delta^{18}O_{H_2O}$ values of <-6 permil indicate that diff. fluids must have been involved in the late veins at White Pine. Fluid inc. in quartz and calcite in amygdules and veins from the area are usually fracture controlled, even in undeformed xls, and give little useful info. on Ts or fluid comp. (Authors' abstract)

LKHAMSUREN, J., 1976, Fluid inclusion data on the fluorite occurrences in Eastern Mongolia (abst.): International Geol. Congress, 25th, Abstracts, p. 810-811. Abstract published in Fluid Inclusion Research, v. 8, p. 105-106 (1975).

LUDINGTON, S.D., 1976, Melting experiments in the system K_2O-Na_2O-Al_2O_3-SiO_2-H_2O-F_2 (abst.): U.S. Geol. Survey Prof. Paper 1000, p. 166. Author at U.S. Geol. Survey, Reston, VA. 22092.

Hydrothermal experiments were conducted at temperatures between 585° and 800°C at a total pressure of 1,000 bars. Cationic composition is that of the 1-kbar "granite" minimum in the fluorine-free system; fluorine contents are 1.8 ± 0.1 percent by weight. The work is aimed at quantitatively determining the fluorine fractionation between crystals, melt, and aqueous fluid. Preliminary results indicate that fluorine is concentrated strongly in the melt; fluorine contents of the quenched melts produced at low temperatures are as high as 7 percent by weight. Thus, if a fluorine-rich (greisen-producing?) aqueous fluid is to be produced by a crystallizing granitic magma, it must come when the last melt crystallizes and volatiles, including fluorine, are driven from the system, to be incorporated later in F-OH minerals, pegmatites, and (or) hydrothermal fluids. (Author's abstract)

LUPTON, J.E. and CRAIG, H., 1976, Primordial helium in oceanic basalts, (abst.): Amer. Geophys. Union Trans., v. 57, p. 408. Authors at Geological Research Div., Scripps Inst. of Oceanography, La Jolla, CA 92093.

LUTTS, B.G., PETERSIL'YE, I.A. and KARZHAVIN, V.K., 1976, Composition of gaseous substance in rocks of upper mantle of the Earth: Akad. Nauk SSSR, Doklady, v. 226, no. 2, p. 440-443 (in Russian). Authors at Inst. of Earth's Physics of Acad. Sci. USSR, Moscow.

Garnet peridotites from kimberlite pipes probably are derived from upper mantle (∿70 km deep); spinel peridotites from alk. basalts and Alpine - type ultrabasites are more shallow rocks. Eclogites are divided into mantle variety (with pyrope) and crustal variety (with almandine). From samples of these rocks G from incs. were extr. by grinding and anal. by gas chrom. CO is absent in all (17) samples. Amount of C_2H_6 varies from 0.00005 to 0.0009 cm^3/kg and C_3H_8 - 0.000-0.0001 cm^3/kg; C_4H_{10} - C_5H_{12} and C_2H_4 - C_4H_8 are absent. Peridotites (five samples) bear (all given in cm^3/kg) He 0.0001-0.0007, H_2 0.41-0.62, O_2 (here and later probably contaminated with air) 0.004-0.019, N_2 0.12-0.17, CH_4 0.0063-0.016, CO_2 0.0076-0.068, H_2/CH_4 40-70; mantle eclogites (six samples) - He 0.00007-0.00015, H_2 0.45-1.13, O_2 0.009-0.013, N_2 0.10-0.51, CH_4 0.011-0.031, CO_2 nil - 0.10, H_2/CH_4 22-77; kimberlites (three samples) - He 0.00012-0.00035, H_2 1.89-3.64, O_2 0.0077-0.16, N_2 0.30-3.20, CH_4 0.068-0.14, CO_2 0.031-0.91, H_2/CH_4 15-53; also four samples of alt. rocks were anal. In general, fresh kimberlites contain highest amounts of gases. Deeper mantle rocks bear higher conc. of H_2, more shallow ones - higher conc. of CH_4. H_2O is released mainly at T 600-800°C, i.e., it is present essentially in secondary hydrous minerals of rocks. (Abst. by A.K.).

LYAKHOV, Yu.V., 1976, Regularities of formation of gold ores of various depths in Transbaikalia (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept., 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 23 (in Russian; translation by A. Kozlowski).

Au ore deps in Transbaikalia (and other regions of USSR) formed at shallow levels, xlized under conds. of abrupt decreases of P and boiling of sols. (T_H = 310-40°C, P = 40-30 atm). Au deps. of moderate deps. formed under relatively stable P-T conds. at T 450-40°C, P = 1200-200 atm. Depths of form. are 120-160 m and 2.5-3.5 km (based on fluid incs.), respectively, and they agree with geol. data. Decrease of T of min.-form. process was interrupted by abrupt increases of T (50-130°C at the beginning and 30-70°C at the end of process). Stability of P-T regime has also smaller fluctuations (5-10°C and several tens of atm), causing pption of mins. in deps. Increase in T, P and conc. of easily - soluble salts, and density of sols decreases towards major tectonic-magm. zones (e.g., Mongolian-Okhotsk zone) and locally near intrusive parent for ore min. (Darasun, Chernozipunikhinskoe ore fields, etc.).

MCCARTHY, T.S. and JACOBSEN, J.B.E., 1976, The mineralizing fluids at the Artonvilla copper deposit: An example of a silica-deficient, alkaline hydrothermal system: Econ. Geol., v. 71, p. 131-133.

The Emery Lode is one of four hydrothermal, replacement copper orebodies known as the Artonvilla mine, Messina, South Africa. Gangue and ore minerals exhibit a distinct zonal pattern, grading from sericite-quartz-pyrite-magnetite assemblages at the outer edge, through albite-chalcopyrite-bornite-chlorite, albite-epidote-chlorite-specularite-bornite-chalcocite to goethite-prehnite-albite-chlorite-chalcocite-native copper assemblages in the central parts. The body, which is ovoid in plan, is not exposed on surface, and is surrounded on all sides by fresh country rock. A narrow feeder conduit containing rocks of nepheline normative composition extends downward from the orebody. The nature of the mineral zonation and the absence of hydrothermal alteration in the rocks above the Emerry Lode are indicative of closed system conditions during mineralization. The ore fluid composition calculated on a basis of observed compositional changes in the host rocks resembles fluids which have been observed in experimental studies on alkaline rocks under hydrous conditions, and contains essentially water, soda, alumina, and silica, with lesser amounts of magnesium, calcium, copper, and sulfur. It is inferred that most of the metals were transported as anionic oxycomplexes in this alkaline fluid. These fluids reacted with country rocks, evolving continuously in consequence, leading ultimately to the formation of a sericitic halo at the outer extremity of the orebody. Subsequent retrograde reaction resulted in zonation of ore and gangue mineral assemblages.

The inferred composition of the ore fluid suggests an alkaline, undersaturated source magma. (Authors' abstract).

MCCORMICK, G.R., 1976, Mineral chemistry of the Crystal grey granite, Rockville, Minnesota: The Compass of Sigma Gamma Epsilon, v. 53, no. 4, p. 125-134.

Includes SEM photos of inclusion cavities with daughter minerals. (ER).

MACLEAN, W.H., 1976, Partitioning of Ti, V, Cr and Mn in sulfide/silicate liquids, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 992. Author at Dept. of Geol. Sciences, McGill Univ., Montreal, Quebec, Canada H3C 3G1.

MACLEAN, W. H. and SHIMAZAKI, H., 1976, The partition of Co, Ni, Cu, and Zn between sulfide and silicate liquids: Econ. Geol., v. 71, p. 1049-1057.

MACQUEEN, R.W., 1976, Sediments, zinc and lead, Rocky Mountain Belt, Canadian Cordillera: Geoscience Canada, v. 3, no. 2, p. 71-81. Author at Geol. Survey of Canada, 3303 - 33rd Street, N.W., Calgary, Alberta T2L 2A7, Canada.

Large numbers of zinc-lead mineral showings have been discovered recently in the northern part of the Rocky Mountain Belt, Canadian Cordillera. Many of the showings are of Mississippi Valley-type: stratabound, hosted by unmetamorphosed sedimentary carbonates, and remote from any obvious intrusive rock source. Mineralogy is simple, bitumen is a common associate, porosity and permeability are important controls, and stratigraphic control of many showings is evident. Carbonate-hosted deposits have been known for some time in the southern Rockies. The stratigraphic distribution of many of these deposits suggests that the petroleum geologist's concepts of source, migration, and trapping provide a useful framework within which Rocky Mountain Belt mineralization may be examined, and that basinal shales may have been important in supplying metals. More specifically, several lines of evidence suggest genetic links between mineralization and petroleum or organic matter in the Rocky Mountain Belt. Much evidence now supports the theory that oil and gas are the product of deep subsurface chemical processes. If mineralization is genetically related to oil maturation-migration processes, it too is likely to be a relatively late-stage event taking place under deep subsurface conditions. (Author's abstract).

MAE, S., 1976, The freezing of small Tyndall figures in ice: Jour. of Glaciology, v. 17, no. 75, p. 111. Author at Water Research Inst., Nagoya Univ., Nagoya, Japan.

Tyndall figures, small thin discs of liquid water containing a vapour cavity, were formed in the centers of grains of pure, polycrystalline ice and observed while freezing and growing. The results are pertinent to problems of freezing fluid inclusions (ER).

MAGARA, K., 1976, Thickness of removed sedimentary rocks, paleopore pressure, and paleotemperature, southwestern part of Western Canada Basin: Amer. Assoc. Petrol. Geol., Bulletin, v. 60, p. 554-565.

MAGARITZ, M. and TAYLOR, H.P., Jr., 1976a, Oxygen, hydrogen and carbon isotope studies of the Franciscan formation, Coast Ranges, California. Geoch. Cosmo. Acta, v. 40, p. 215-234. Authors at Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125.

The $\delta^{18}O$ values of orogenic andesites are too low for such magmas to have formed by direct partial melting of Franciscan-type materials in a subduction zone. Andesites either form in some other fashion, or the melts must undergo thorough isotopic exchange with the upper mantle. The great Cordilleran granodiorite-tonalite batholiths, however, are much richer in ^{18}O and may well have formed by large-scale melting or assimilation of Franciscan-type rocks. The range of δD values of Franciscan-type rocks is identical to the -50 to -80 range shown by most igneous rocks. This suggests that 'primary magmatic H_2O' throughout the world may be derived mainly by partial melting of Franciscan-type materials, or by dehydration of such rocks in the deeper parts of a Benioff zone. (From the authors' abstract).

MAGARITZ, M. and TAYLOR, H.P., Jr., 1976b, Isotopic evidence for meteoric-hydrothermal alteration of plutonic igneous rocks in the Yakutat Bay and Skagway areas, Alaska: Earth & Plan. Sci. Lett., v. 30, p. 179-190.

Oxygen and hydrogen isotope ratios were measured on coexisting minerals from quartz diorites and quartz monzonites from a section across the Coast Range batholith in the Skagway agea, Alaska.

The data imply that deep (~5km?) circulation of meteoric groundwaters is probably a characteristic of the later stages of emplacement of the Cordilleran batholiths of western North America, suggesting that the eastern sections of these batholiths in particular were emplaced at relatively shallow depths. (From the author's abstract).

MAGARITZ, Mordeckai and TAYLOR, H. P., Jr., 1976c, Reconnaissance $^{18}O/^{16}O$ and D/H studies of plutonic granitic rocks across southern British Columbia from Vancouver Island to the Okanagan and Nelson Batholiths, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 994. Authors at Div. of Geol. and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125.

More than 200 $\delta^{18}O$ and δD anal. of min. from tonalites, granodiorites and granites in southern B.C. indicate widespread hyd. alt. of many of these rocks. At least two types of H_2O are involved, a high-δD water (sea water or connate water?) in the west and a low-δD water (meteoric water) that becomes progressively more important to the east. (From the authors' abstract)

MAGARITZ, M. and TAYLOR, H.P., Jr., 1976d, $^{18}O/^{16}O$ and D/H studies along a 500 km traverse across the Coast Range batholith and its country rocks, central British Columbia: Canadian Jour. of Earth Sciences, v. 13, no. 11, p. 1514-1536.

See previous entry for abstract. (ER).

MAGARITZ, M. and TAYLOR, H.P., Jr., 1976d, Hydrogen and oxygen isotopic evidence for meteoric-hydrothermal alteration of plutonic igneous rocks in the Yakutat bay and Skagway areas, southeastern Alaska, (abst.): Amer. Geophys. Union Trans., v. 57, p. 350-351. Authors at Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, California 91125.

MAISKIY, Yu.G., 1976, Hydrothermal ore formation at Donbass, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst.

of Geol. p. 35 (in Russian; translation by A. Kozlowski).

A sandstone-shale complex of Carboniferous age bears quartz, carbonate, and quartz-carbonate veins with sulfide-polymetallic Au and Hg mineralization. Intervals of T (T_H?) of the main crystallization of minerals: 360-320, 280-220, 120-60°C, pressure 700-800 atm and less. Natural decrepitation of inclusions and their necking-down is noted. (From the author's abst.)

MAITRALLET, Philippe, 1976 - Tourmaline nodules in some French and Italian granitic rocks: Thesis, Université P. et M. Curie, 160 p. Author at Université P. et M. Curie, Paris, France (in French).

Includes a description of fluid inclusions in tourmaline and quartz (p. 148-152). The inclusions in tourmaline are preferentially developed along two directions perpendicular to the axis of elongation of the crystal. (Abstract M. Pagel).

MAKARON, V.M., 1974, Influence of the physicochemical conditions of formation of rare metal-bearing pegmatite on geochemical properties: Akad. Nauk SSSR, Dokl., v. 217, no. 3, p. 693-696, (in Russian).

MAKHNACH, A.S. and PANOV, V.V., 1976, New data on paleotemperatures of sedimentary cover, Akad. Nauk SSSR, Doklady, v. 226, no. 3, p. 677-680 (in Russian). First author at Inst. Geochem. Geophysics of Acad. Sci. of Belorussian SSR, Minsk.

Epigenetic mins. in Devonian salt deps. at Pripyat' rift zone bear incs. with T_H = 285-380°C. These Ts are compared with T data obtained by other methods and reflectance (R^a) of vitrinites. Similar T_H were meas. for other salt deps. (A.K.).

MALININ, S.D., 1976, Solubility of fluorspar (CaF_2) in NaCl and HCl solutions under hydrothermal conditions: Geokhimiya, 1976, no. 2, p. 223-228 (in Russian).

MALINKO, S.V., BERMAN, I.B., RUDNEV, V.V. and STOLIAROVA, A.N., 1976, Inclusions of boron-bearing hydrothermal solutions in quartz crystals, from data of (n,α) - radiography: Akad. Nauk SSSR, Doklady, v. 228, no. 4, p. 948-951 (in Russian). First author at All-Union Sci. - Research Inst. of Mineral Raw Materials, Moscow.

Quartz from silicified skarn from B-silicate (danburite, datolite) deposit at Soviet Far East, contains increased boron concs. in zones of numerous fluid incs. (T_H 154-286°C). Boron was detected by reaction ^{10}B (n,α). In inc.-free zones of quartz xls B was not detected, i.e., B is the component of sols. in inc. filling. (Abstract by A.K.).

MAL'KOV, B.A., 1976, Remnant stress in solid inclusions in diamond: Akad. Sci. SSSR, Doklady, v. 227, no. 6, p. 1432-1434 (in Russian). Author at Ukhta Industrial Inst., Ukhta, USSR.

Remnant stress P in solid incs., (pyrope, chromite and forsterite) in diamonds equals 0.9-22.7 kbar. (A.K.).

MALYSHEV, A.G. and SKOBEL', L.S., 1976, Peculiarities of growth of quartz crystals and of formation of inclusions in quartz from the rock-crystal deposits, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 46-47 (in Russian; translation by A. Kozlowski).

1. In the central parts of the natural quartz crystals fluid inclusions have T_H 435-410, 370-355 and 340-320°C, and P below 1000 atm; the minerals formed under sharply changing P-T-X conditions.

2. Under the above conditions, in the vicinity of acicular amphiboles, P fluid inclusions formed, up to 4 cm long. During the subsequent T increase of about 190-200°C, these fluid inclusions decrepitated, forming anomalous fluid inclusions bearing various L:G ratios, surrounded with aureoles of the daughter inclusions.

During growth of a quartz layer 4-6 mm thick the T decreased from 330 to 170°C and numerous minerals crystallized. (Authors' abst.)

MAMAEV, I.N., RADCHENKO, I.V., KAMALETDINOV, M.A. and KHAYRETDINOV, I.A., 1976, Hydrothermal mineralization of Priural'ye, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept., 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 13-14 (in Russian; translation by A. Kozlowski).

At Priural'ye the following hyd. deps. are known: Verkhne-Arshinskoe and Nikolaevskoe (polymet.), Kuzhinskoe (barite-polymet.), Avzyanovskiy region (Au), Kazanskoe Povolzh'ye (celestite), Orenburg region (barite, Hg, and fluorite). T_H dets: fluorite (100-200°C), barite (100-320°C), and celestite (100-230°C). (From authors' abstract).

MARAKUSHEV, A.A., 1976, Acid-alkaline features of water-free silicates and alumosilicates: Zapiski Vses. Mineral. Obshch., v. 105, no. 5, p. 562-579 (in Russian).

Interaction between water and silicates with water-free structure is presented, as well as mineralogical and petrological conclusions. (A.K.).

MARKOVSKIY, B.A., 1976, Indications of liquation in trachimelanobasalts from Kamchatka and possible petrogenetic consequences: Akad. Nauk SSSR, Doklady, v. 230, no, 1, p. 194-197 (in Russian). Author at All-Union Sci.-Research Geol. Inst., Leningrad.

Spherical~0.5 cm dia. structures, described as formed by melt immiscibility, have higher conc. of SiO_2 and alk., and lower Fe_2O_3, FeO and MgO, in comparison with background volcanic rock; pertinent to immiscibility in melt incs. (A.K.)

MARTIN, R.F. and BONIN, B., 1976, Water and magma genesis: The association hypersolvus granite-subsolvus granite: Canadian Mineral., v. 14, p. 228-237. First author at Dept. Geol. Sci., McGill Univ., P.O. Box 6070, Station A, Montreal, Que. H3C 3G1.

The authors propose that a late influx of water, possibly of meteoric origin, "soaked" the cooling hypersolvus granite once crystallized, inducing local near-complete fusion and remobilization of the early granite. At lower temperatures, the influx of water would be reflected in deuteric changes. (From the authors' abstract).

MARTINI, J.E.J., 1976, The fluorite deposits in the Dolomite Series of the Marico District, Transvaal, South Africa: Econ. Geol., v. 71, p. 625-635.

The upper part of the Precambrian Dolomite Series is mineralized with fluorite and minor lead-zinc. The deposits show similarities to the Mississippi Valley type but were subsequently metamorphosed in the contact aureole of the Bushveld Igneous Complex. The ore locations are mostly controlled by paleoporosity of the dolomite such as vuggy horizons and paleokarst. On a larger scale the fluorite district is localized on a paleorelief which acted as an ore trap. Several genetic hypotheses are proposed; the most attractive one is precipitation from solutions which derived fluorine from the Dolomite Series and/or Pretoria Series during diagenesis. Economically the fluorite district appears to be one of the largest in the world. (Author's abstract).

MATHEZ, E.A., 1976a, Sulfur and magmatic sulfides in deep sea basalt glass, (abst.): Amer. Geophys. Union Trans., v. 57, p. 408. Author at Dept. of Geological Sciences, Univ. of Washington, Seattle, WA 98195.

About half of the fresh basalt glasses probably were sulfide sat. prior to eruption; the others became sat. during quenching. S conc. are in the range 1000-1800 ppm and exhibit a positive, linear correlation with Fe conc.

Glass inc. in phen. either have comp. similar to matrix glass or are relatively depleted in elements entering host pheno. In either case, their S conc. are generally similar to or greater than S conc. of matrix glasses. This and the usually pristine character of fresh basalts with respect to other vol. and trace elements suggest that S in glasses is predominantly juvenile. (From the author's abstract).

MATHEZ, E.A., 1976b, Sulfur solubility and magmatic sulfides in submarine basalt glass: Jour. of Geophy. Research, v. 81, p. 4269-4276. Author at Dept. Geol. Sci., Univ. of Wash., Seattle, WA 98195.

A suite of 35 fresh basalt glasses collected in >1000-m water depth from 16 localities on or near the Juan de Fuca Ridge and 17 localities elsewhere in the Atlantic and Pacific basins were examined petrographically and with the microprobe. The data indicate that crystallization need not involve separation of large quantities of sulfide. Many of the most juvenile unfractionated submarine basaltic magmas are probably sulfide saturated and contain ∿900 ppm S. (From the author's abstract).

MATSUHISA, Yukihiro, GOLDSMITH, J.R., and CLAYTON, R.N., 1976, Oxygen isotopic fractionation in the system quartz-albite-anorthite-water, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 999. Authors at University of Chicago, Chicago, IL 60637.

Equil. O isotopic frac. factors in this system have been revised using high P app. (up to 15 kb) and direct isotopic anal. of water in the products. True isotopic exchange reactions were performed between each min. and pure water. (From the authors' abstract)

MAYSKIY, Yu. G., 1973, The thermodynamic conditions of hydrothermal mineralization in the central Donets Basin: Mineral. Sb. (L'vov. Gos. Univ.), no. 27, vypusk 2, p. 138-146 (in Russian with English sum.).

MEL'NIKOV, F.P., DEMIN, Yu.I., and POLYANSKIY, Ye.V., 1976, Distribution of hydrothermal deposits on external side of contact with intrusives (modeling on electronic calculator) (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept., 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 18 (in Russian; translation by A. Kozlowski).

Processes of xliz. and dynamics of thermal fields of intrusives in contact zones were modeled, where Mo-W (W. Transbaikal'ye) and pyrite-polymet. (Rudnyi Altai) deps. occur. (...) Data of thermometry of incs. were used. Logic schemes and programs of solution of above questions were made. Two-dimensional models of evolution of thermal fields were obtained. Dynamics of xliz. of intrusives and evol. of their thermal fields in great degree depend on wall-rocks. Thermal fields of intrusives of any morphology occurring in wall rocks with widely varying physical props. have eccentric devel. This is connected with existence of eccentric ore zones. Fronts of thermal fields overstep the migration of hyd. sols. only at early stages of devel. If process lasts sufficiently long, zones with high Ts agree with respective intervals of ore-form. in final parts of hyd. columns. (Authors' abst. shortened by A.K.)

MEL'NIKOV, Ye.P., 1976, Conditions of formation of metamorphosed vein quartz of the Urals, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 48 (in Russian; translation by A. Kozlowski).

In the Urals two formations of vein quartz may be distinguished: A - crystalline and B - recrystallized ("grained). Both formations are syngenetic and isofacial. All fluid inclusions consists of 95-98% CO_2 plus H_2O (over 10,000 analyses). By the water leachate method Cl, SO_4, HCO_3, K, Na, Ca and NH_4 were found. H_2O/CO_2 ratio depends on the degree of regional metamorphism; mean values are as follows: greenschist facies - 5, epidote-amphibolite facies - 4.5, amphibolite facies - 2.5, granulite facies - 1.4; Na/K ratio in inclusions of A-type quartz ranges from 4 to 7, in inclusions of the B-type quartz it is < 3. A-type quartz formed from Na-rich hydrotherms, B-type quartz from hydrotherms with abundant K and CO_2. (From the author's abst.)

MEL'NIKOVA, Ye.M. and KOKAREV, G.N., 1976, Accessory rare-metal mineralization in rock-crystal-bearing quartz veins at Pripolyarnyi Urals: Zapiski Vses Mineral. Obshch., v. 105, no. 1, p. 98-100 (in Russian). Authors at All-Union Sci.-Research Inst. for Synthesis of Mineral Raw Materials, Alexandrov.

Quartz veins, bearing as accessory mins. monazite and xenotime, xlized (T_H) at T 400-480°C (early veins) and 200-250°C (late veins). (A.K.)

MELTON, C.E. and GIARDINI, A.A., 1976, Experimental evidence that oxygen is the principal impurity in natural diamonds: Nature, v. 263, p. 309-310.

MERKEL, G.A., HAGGERTY, S.E. and BOYD, F.R., 1976, A unique olivine megacryst from Monastery, (abst.): Amer. Geophys. Union Trans., v. 57, p. 355. First author at Dept. of Geology, Univ. of Mass., Amherst, MA 01002.

An olivine megacryst contained within kimberlite from the Monastery Mine in S. Africa contains three types of inc.: 1) small olivine xls; 2) spherical globules of Fe-Ni sulfides (250-500 μm); and 3) pockets of kimberlite (0.2-1.0 cm) connected to the outside kimberlite host by radiating, planar veinlets of kimberlitic material.

Two possible origins are 1) entrapment of mag. liquid during growth of the olivine magacryst, or 2) infilling by magmatic kimberlite into vacated H_2O-CO-CO_2-H_2S fluid inc. pockets. In each model it is proposed that the veinlets formed when volatile pressures within the inc. caused fracturing of the megacryst during emplacement when external confining Ps were dropping. (From the authors' abstract).

METZ, P., 1976a, Experimental investigation of the metamorphism of siliceous dolomites III. Equilibrium data for the reaction: 1 tremolite + 11 dolomite $\rightleftharpoons$ 8 forsterite + 13 calcite + $9CO_2$ + $1H_2O$ for the total pressures of 3,000 and 5,000 bars: Contrib. Mineral. Petrol., v. 58, p. 137-148. Author at Min.-Pet. Inst. Univ., Goldschmidtstr. 1, D-3400 Göttingen, W. Germany.

METZ, P., 1976b, Temperature, pressure, and H_2O-CO_2 gas composition during metamorphism of siliceous dolomites from experimentally determined equilibrium conditions of forsterite-bearing assemblages (abst.): International Geol. Congress, 25th, Abstracts, p. 673. Author at Mineralogisches-Petrologisches Inst., Universitat Gottingen, W. Germany.

MINTSER, E.F., NECHELYUSTOV, G.N., MANUCHARYANTS, B.O., OVCHINNIKOV, V.V. and TURSUNGAZIYEV, B.T., 1976, Bismuth ore mineralization from Mironovskoe deposit: Geol. Rudn. Mest., v. 18, no. 4, p. 30-41 (in Russian). First author at Inst. Mineral., Geochem. and Crystallogr. of Rare Elements, Moscow.

Quartz from pyrite-magnetite assoc. bears one-phase L-CO_2, L-CO_2 + L-H_2O + G, and two-phase L-H_2O + G incs. (all P); the latter have T_H = 400-325°C (S incs. T_H =320-210°C); scheelite from same assoc. bears 3-phase and 2-phase incs. filled as above, T_H = 355-330°C, P = 1800-1400 atm. Quartz from tourmaline-chalcopyrite-bismuthinite assoc. contains 3-phase incs., T_H = 310-255°C; calcite, same assoc. - 2-phase incs. (white calcite T_H = 325-270°C, pink calcite - T_H = 245-200°C). Mins. from siderite-sulfobismuthite-polymetallic bear 2-phase L-H_2O + G incs. with T_H as follows: siderite, P incs. 280-230°C (S incs. 180-160°C), quartz, P incs. 260-180°C (S incs. 160°C), calcite 180-170°C and fluorite 210-150°C, both P incs. (Abst. by A.K.).

MODRESKI, P.J. and GRAEBER, E.J., 1976, Fumarolic gases from Kilauea volcano, Hawaii, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 1014-1015. Authors at Sandia Laboratories, Albuquerque, NM 87115.

MOGAROVSKIY, V.V., 1976, Genesis of the celestite deposit Chaltash (Tadzhikistan), (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir

Section, Acad. Sci. USSR, Inst. of Geol., p. 62 (in Russian; translation by A. Kozlowski).

Ore bodies in Paleogene limestones are connected with faults and brecciation zones. T_H and T_D of calcite 260-240°C, celestite - 240-140 and 80-50°C; the deposit formed in two stages. Water leachates of the first stage have Na>Ca>K and $Cl>SO_4>HCO_3$; those of the second stage have Ca(Sr)>Na>K and $SO_4>Cl>HCO_3$ or $Cl>SO_4>HCO_3$. Such compositions are the result of mixing of ascending Sr-bearing $Cl-HCO_3$ waters with SO_4-bearing waters of the Paleogene deposits. (Author's abstract).

MOGAROVSKY, V.V., FAISIEV, A.R., ALIDODOV, B.A., and MOROSOV, S.A., 1976, Bituminous inclusions in the minerals of some hydrothermal deposits in South Tien-Shan (abst.): International Geol. Congress, 25th, Abstracts, p. 811-812. Abstract published in Fluid Inclusion Research, v. 8, p. 122-123 (1975).

MONES-ROBERDEAU, L., ARBUNIES-ANDREU, M. and BOSCH-FIGUEROA, J.M., 1976, Microscopic study of surfaces and inclusions in diamonds [abstr]: Int. Geol. Congr. Abstr. - Congr. Geol. Int., Resumes, no. 25, v. 2, (Sect. 14; Mineralogy), p. 585.

MORGAN, B.A., 1976, Metamorphic forsterite and diopside in serpentinite (abst): U.S. Geol. Surv. Prof. Paper 1000, p. 176-177.

Nearly pure forsterite and diopside have been formed within intensely sheared zones in serpentinite from the large ultramafic complex near Sonora, Calif. probably took place by the reactions:

antigorite+ magnesite=2forsterite+fluid
3antigorite+calcite=4forsterite+diopside+fluid

Iron derived from the primary olivine and chromite has been oxidized and is almost entirely present in magnetite. On the basis of stratigraphic reconstructions, total load pressures are unlikely to have exceeded 3 kbar. At these pressures, the reactions should have taken place at about 400°±25°C and with a fluid composition ranging from nearly pure H_2O to less than 10 mole percent CO_2. The restriction of forsterite and forsterite+diopside to shear zones may be attributed to the presence of carbonate in the rock prior to metamorphism and to the dilution of the fluid phase by water external to the area of the reaction. (From the author's abstract).

MOROZOV, S.A., 1976, Main factors of mineral formation (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept., 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 24-25 (in Russian; translation by A. Kozlowski).

Endogene Au min. in Central Tadzhikistan is connected with magm. complexes of Upper Carboniferous-Lower Permian age. At T 550°C and P 1100 bar pyroxene and garnet-pyroxene skarns form, with later Au ores. Hyd. metasom., early and late sulfide, and quartz-carbonate stages have T_H (°C) from 450 to 190-75 and P (bars) from 1000 to 200-150. Sols. bear Cl, HCO_3, SO_4, Na, Ca, K, Mg, S, As, B, and CO_2 in G phase. (From authors' abst.)

MULLIS, J., 1976, The quartz crystals of the Val d'Illiez; indicators of late-Alpine movement: Eclogae Geol. Helv., v. 69, no. 2, p. 343-357 (in German with French, English sum.).

MURAMATSU, Y. and NAMBU, M., 1976, Studies on the mineralization of the pyrometasomatic copper and iron ore deposits of the Akagane mine, Iwate Prefecture, Japan (I) Filling temperature and salinity of fluid inclusions in quartz and calcite from the Hozumi and Sakae ore deposits: Jour. of the Japanese Assoc. of Min., Pet., and Econ. Geol., v. 71, no. 9, p. 264-272 (in Japanese with English abstract).

The filling temperature and the salinity of fluid inclusions in quartz and calcite from the Hozumi and Sakae pyrometasomatic copper and iron deposits of the Akagane Mine were investigated by means of the heating stage and freezing stage microscope. Quartz was collected from two different stages of mineralization. The earlier stage one (Quartz-I) is intimately associated with pyrrhotite and chalcopyrite, and the later stage one (Quartz-II) is mainly accompanied by pyrite. Calcite coexisting with epidote, quartz-II and chlorite is considered to belong to the latest mineralization stage.

The main filling temperature ranges are measured as follows: quartz-I 260-320°C, quartz-II 230-290°C, calcite 210-240°C. These results are concordant with the mineral succession obtained from the field evidence and microscope observation. Generally speaking, the filling temperature in minerals of the Sakae deposit are similar to those of the Hozumi deposit, and is inclined to rise from upper to lower levels at the two deposits, and from peripheral (the 5th ore body) to central ore bodies (the main and 3rd ore bodies) at the Sakae deposit. This fact will suggest the flow direction of ore-forming fluid originated in some deeper places of the granite porphyry masses.

On the other hand, the salinity of fluid inclusions in quartz-I range from 12.5 to 13.3 weight percent for the Hozumi deposit and from 18.6 to 21.4 weight percent NaCl equivalent for the Sakae deposit. (Author's abstract).

MUTANEN, T., 1976, Komatiites and komatiite provinces in Finland: Geologi, v. 28, no. 4-5, p. 49-63 (in English).

Silicate liquid immiscibility (involving metastable equilibria) is proposed for the origin of some komatiites of Finland (ER).

MYSEN, B.O., 1976a, Role of volatiles in mantle magma genesis, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 1025. Author at Geophysical Lab., 2801 Upton St., NW., Washington, DC 20008.

The presence of H_2O lowers the solidus of peridotite by 600-800°C whereas CO_2 reduces the T by <150°C. Water acts as a depolymerizer of silicate melts, and its presence stabilizes liquidus phases that are less polymerized than those of vol.-free magma. A partial melt of hydrous peridotite is therefore quartz-normative. Carbon dioxide stabilized more polymerized phases than vol.-free magma, and a partial melt of peridotite from CO_2-rich enviro. is nepheline and/or larnite normative. The liquid may become carbonatitic under extremely CO_2-rich cond. and high P (>25 kbar). Intermediate mixing ratios of H_2O and CO_2 have the effect of producing a magma comp. that resembles that of vol.-free partial melting of peridotite although the T of its form. will be lower. Regional variation of LIL trace elements of a peridotitic source region for abyssal tholeiite may be understood by combining vol.-free and vol.-present partial melting in a two-stage event of an initially homog. source. Mantle plumes of variable trace element content may therefore not be necessary. The assoc. of strongly silica-under-sat. alk. magmas assoc. with carbonatite and/or kimberlite in stable shield areas may be the result of partial melting of underlying peridotite upper mantle under CO_2-rich cond. The evol. of tholeiitic to nephelinitic rocks suites in oceanic regions (e.g., Hawaii) and andesite, tholeiite and nephelinitic suites in certain island arcs (e.g., Indonesia and Lesser Antilles) may be related to partial melting of a peridotite source that becomes progressively more CO_2-rich as melting proceeds. (Author's abstract)

MYSEN, B.O., 1976b, The role of volatiles in silicate melts: solubility of carbon dioxide and water in feldspar, pyroxene, and feldspathoid melts to 30 Kb and 1625°C: Amer. Jour. Sci., v. 276, p. 969-996. Author at Geophy. Lab., Carn. Inst. Wash., Washington, D.C. 20008 USA.

MYSEN, B.O., 1976c, Experimental determination of partitioning of Ni between ga, cpx, opx, ol, amph, and hydrous silicate liquid at high pressures and temperatures, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 1025. Author at Geophysical Lab., 2801 Upton St., NW., Washington, DC 20008.

MYSEN, B.O., EGGLER, D.H., SEITZ, M., and HOLLOWAY, J.R., 1976, Carbon dioxide in silicate melts and crystals, Part I. solubility measurements: Amer. Jour. Sci., v. 276, p. 455-479. First author at Geophy. Lab., Carn. Inst. Wash., Washington, D.C. 20008.

Precise data on the solubility of carbon dioxide in silicate melts quenched from pressures ≤ 40 kb and temperatures $\leq 1700°$ have been obtained by determination of carbon content of quenched glasses. These data were obtained by chromatographic analysis of gas released by decrepitation of quenched, CO_2-saturated glass and by counting beta-tracks in nuclear emulsions using carbon-14 as tracer (beta-track mapping). The CO_2 contents of quenched glasses obtained by these techniques agree with those obtained from phase equilibrium relations, strongly supporting the conclusion that beta-track mapping and gas chromatographic analysis give equilibrium CO_2 solubility data for the silicate melts.

Data have been obtained for nine melt compositions, including albite ($NaAlSi_3O_8$), orthoclase ($KAlSi_3O_8$), diopside ($CaMgSi_2O_6$), and an olivine melilite nephelinite melt. In all compositions, the solubility of CO_2 increases with increasing temperature in the range 1400° to 1700°C and with increasing CO_2 pressure in the range 5 to 40 kb. The solubility is considerably greater in basic than in acidic melts: at 1625°C and 30 kb, 7 wt. percent CO_2 dissolves in olivine melilite nephelinite melt versus 2.2 wt. percent in albite melt. Hydrous albite melt dissolves about 30 percent (relative) more CO_2 than melt containing CO_2 alone.

Infrared (IR) spectrometric analyses of quenched, CO_2-saturated albite, diopside, and olivine melilite nephelinite glasses indicate that both discrete CO_2 molecules and carbonate anions are present. In albite melt near its CO_2-saturated liquidus, the dominant species from IR spectra appears to be CO_2, although a CO_3^{2-} absorption band appears at higher temperatures. The solubility data confirm that carbonate formation is generally unimportant in feldspar melts, because CO_2 solubility in $MAlSi_3O_8$ melts (where M = K, Na, Ca, or Mg) does not vary. On the basis of the IR spectra, carbonate complexing is an important mechanism of solubility in diopside and olivine melilite nephelinite melt.

The solubility of carbon in olivine and diopside crystals at 30 and 20 kb, respectively, was determined to be 6.8 and 9.6 ppm. Judged from the frequency of CO_2-rich fluid inclusions in mantle-derived olivine and pyroxene, these low carbon solubility values preclude storage of significant amounts of carbon dioxide in the upper mantle within crystalline silicate materials. Rather, it is believed that upper mantle CO_2 is stored in a vapor phase, in carbonate, or in silicate melt. (Authors' abstract).

NAKAMURA, K., HIRANO, S.-I. and SŌMIYA, S., 1976, Fluid inclusions in hydrothermally synthesized brucite crystals: J. Japan. Assoc. Min. Petr. Econ. Geol., v. 71, p. 193-200 (in English). Authors at The Research Lab. of Eng. Mat., The Tokyo Inst. of Tech., Tokyo, Japan.

Brucite crystals were grown hydrothermally from $Mg(OH)_2$ powder in 7.5 and 15 mol% NaOH solutions. It is established from the observation of the surface micrographs that the crystals grew by the spiral mechanism. The filling degree of numerous fluid inclusions in the crystals grown under various conditions of pressure, temperature and concentration of solution are measured. The P-T-F.D. relations of NaOH solution are discussed on the basis of these measurements. (Author's abstract).

NASH, J.T., 1975, Fluid inclusion studies of vein, pipe, and replacement deposits, northwestern San Juan Mountains, Colorado: Econ. Geol., v. 70, p. 1448-1462.

Base and precious metal ores valued in excess of $300 million have been mined from vein, pipe, and replacement deposits located on the northwest side of, and structurally related to, the middle Tertiary Silverton caldera. A belt of normal faults radial to the caldera contains veins which have been mined for as much as 15,000 feet (4,600 m) along strike and 3,700 feet (1,100 m) downdip. Structural relations, metal distributions, and fluid inclusion data suggest that many of the veins were open at the same general time and received the same mineralization.

Fluid inclusions in quartz and sphalerite of the main ore stage of the Argentine and adjoining veins have filling temperatures ranging from 315° to 249°C and salinities from 7.9 to 0.1 wt percent NaCl equivalent. However, the majority of inclusions from base metal and gold stages are in a relatively narrow range near 280° to 290°C and salinities are unusually low (less than 2 wt %). Filling temperatures in postsulfide quartz and fluorite are as low 153°C and salinities are generally less than 0.5 wt percent. A pressure correction of about +25°C should be added to the filling temperatures. Ore fluids were physically homogeneous liquids over the 3,700-foot (1,100 m) vertical and 11,200-foot (3,400 m) lateral range studied and no systematic variations in filling temperatures or salinity in this space are noted, but significant fluctuations are evident locally.

Recently developed base metal replacement deposits occur in the Eocene Telluride Conglomerate adjacent to many metal-bearing veins.

Calc-silicate alteration of the conglomerate host was probably by moderately saline fluids that ranged in temperature from 320° to about 400°C. Quartz-bearing clasts in altered zones contain secondary halite-bearing inclusions with filling temperatures of about 250°C and salinities about 34 wt percent; such inclusions are not known from the base metal stage and are interpreted to have been preore. Hydrothermal quartz, sphalerite, and calcite from replacement pods contain inclusions with filling temperatures ranging from 204° to 309°C and salinities from 11.2 to 0.2 wt percent. That the replacement zones and throughgoing veins are genetically related is suggested by the similarity of filling temperatures and compositions of base metal-stage fluid inclusions and by structural evidence.

Small high-grade pipe deposits of base and precious metals occur along the ring-fault zone of the Silverton caldera. Filling temperatures for inclusions in quartz, sphalerite, and barite of the main ore stage of these deposits range from 2.6° to 308°C and salinities range from 1.6 to 0.2 wt percent NaCl. Quartz in altered wall rocks and silicified capping contains moderately saline secondary inclusions with relatively uniform liquid: vapor ratios that suggest filling temperatures of about 225° to 300°C. From the available samples there is no fluid inclusion evidence for boiling. Throttling, which had been hypothesized to explain the telescoped nature of the pipe ores, is neither substantiated nor discredited by the inclusion data. (Author's abstract).

NASH, J.T., 1976, Fluid-inclusion petrology -- data from porphyry copper deposits and applications to exploration: U.S. Geol. Surv. Prof. Paper 907D, 16 pp.

Fluid-inclusion studies of 37 porphyry copper deposits, mainly in the United States, demonstrated that all but 3 evolved through a hydrothermal stage characterized by very high salinities, generally in excess of about 35 weight percent NaCl equivalent. Temperatures of these fluids ranged from about 250° to 700°C for various stages and deposits. Most systems boiled. High salinities, shown by halite-bearing inclusions, and boiling, suggested by coexisting gas and liquid-rich inclusions, are considered to be diagnostic of epizonal intrusions which are the most favorable parents for porphyry copper mineralization. Depth of emplacement of many copper-bearing stocks is deduced from fluid inclusions to have been about 6,000 to 10,000 feet (1,800 to 3,000 meters); fluid pressures during mineralization are interpreted generally to be less than 500 bars.

Moderate-salinity (less than about 12 percent) and moderate-temperature (<350°C) fluids are noted in all porphyry copper deposits and were responsible for the deposition of most copper and molybdenum in deposits, such as Bagdad, Esperanza, Mineral Par, Morenci, Ray, Sierrita, in the Southwestern United States and several in southern British Columbia. However, with only three exceptions, high saline fluids apparently were present at an early stage and also deposited metals. The relative amounts and economic importance of copper and molybdenum deposited from high- and moderate-salinity fluids varies within the porphyry deposit class.

There is compelling geologic and geochemical evidence that chloride is important for transport of metals, but the porphyry coppers stand out as a class associated with fluids of especially high salinity during at least one stage of their formation. Halite cubes in fluid inclusions are an effective, although rough, indicator of those salinities and can be conveniently monitored during petrographic study of thin sections. Thus, fluid inclusions can be used to characterize favorable intrusions, metal anomalies, and caprocks as an additional method of detecting possible disseminated porphyry copper metallization. The presence of halite-bearing inclusions, especially coexisting with gas-rich inclusions, is considered to be a favorable fluid anomaly in the search for porphyry ore. (Author's abstract).

NAUMOV, G.B., MIRONOVA, O.F., NAUMOV, V.B., 1976, Carbon compounds in fluid inclusions of hydrothermal quartz: Geokhimiya, 1976, no. 8, p. 1243-1251 (in Russian with English abstract). Authors at V.I. Vernadsky Inst. of Geochem. and Anal. Che., USSR Acad. of Sci., Moscow.

On the basis of microscopic observations and of the results of chemical analyses of fluid inclusions in quartz of various genesis the authors have shown not only the broad participation of carbon dioxide in them, but of the more reduced varieties of carbon too. The possible errors of the method resulting from heating during opening of the inclusions during the experiments were analyzed. The role of different forms of carbon as regulators of acidity and redox potentials of hydrothermal solutions is discussed. (Authors' abstract).

NAUMOV, G.B. and NAUMOV, V.B., 1976, Thermodynamic analysis of evolution of ore-forming solutions on results of studies of gaseous-liquid inclusions (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept., 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 15 (in Russian; translation by A. Kozlowski).

(...) In G/L incs. chlorides and carbonates of Na and K strongly prevail, and in G phase - CO_2. Evol. of pH of sols. is det. by wall-rocks, and T and P. Decrease of T of Cl and CO_3-bearing sols. causes a wave-like change of acid features, according to Korzhinskiy's empirical sequence: early alk., acid, late alk. Decrease of P results in increase of alk. features, but in zones of local enrichment in CO_2 the reverse tendency is possible. Changes of redox potential of endogene sols. depend on relation between oxidized and reduced forms of C and their equil with Fe mins. Decrease of T leads to increase of oxidizing features of CO_2-bearing sols. Decrease of P in tectonic zones may cause the release of CO_2 and local increase of reducing features, with influence on behaviour of other elements forming polyvalent ions, including S. (Authors' abst. shortened by A.K.)

NAUMOV, V.B., 1976a, Results of thermometric measurements of inclusions in standard quartz samples carried out in laboratories of the USSR: Geokhimiya, 1976a, no. 7, p. 1109-1112 (in Russian).

A full translation of this important article appeared in Fluid Inclusions Research, v. 8, p. 208-211, 1975. (ER).

NAUMOV, V.B., (ed.), 1976b, Inclusions in minerals. Bibliography of foreign literature 1954-1974. Moscow, Acad. Sci. USSR, Vernadsky Inst. Geochem. and Anal. Chem., Scientific Council on Ore-Formation of Acad. Sci., Section on Ore-Forming Fluids in Inclusions, 72 pp (in Russian).

This little booklet, printed in only 300 copies, lists 612 references, arranged alphabetically, each in its original language (except Japanese). The individual items are complete, with titles and full reference. (ER).

NAUMOV, V.B., NIKITIN, A.A., and SALAZKIN, A.N., 1976, Conditions of formation of the polymetallic and fluorite mineralization, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol. p. 36-37 (in Russian; translation by A. Kozlowski).

Polymetallic (Savinskoe No. 5) and fluorite (Garsonuyskoe and Darinskoe) Mesozoic deposits occur a few hundred meters apart. Hydrothermal processes at the first one were interrupted by injection of porphyrite dikes. During the earlier stage polymetallic ores formed, and during the late one - fluorite. T_H of P fluid inclusions for the early stage is 370°C, sphalerite crystallized at T 300°C; T_H for fluorite stage is 235-125°C, and for zeolite-carbonate one - 100-40°C. Several generations of fluorite were distinguished: in early generations P polyphase inclusions, bearing 1 - 2 daughter minerals, have T_H 375-340°C. T_H of inclusions in the main mass of fluorite is 250 to 150°C.

Pressure in inclusions, on PVT data of CO_2 in quartz, calcite, and fluorite, varies from 1200 to 180 bars. (Authors' abst.)

NELSON, R., 1974, Fluid inclusion study of the Fernvale Limestone, northern Arkansas: Master's thesis, Univ. Missouri, Columbia.

NEPOCHATYKH, V.P., 1976, Conditions of formation of the siliceous shales of the Mukasovskiy level (Magnitogorsk megasynclinorium)(abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 60 (in Russian; translation by A. Kozlowski).

Decrepigraphs of jaspers from Il'inskoe gold ore deposits yielded two ranges of T_D; the main range is 350-500°C (the second range is not given); 20 samples were run, by the vacuum method. T_D testifies to metasomatic origin of the siliceous shales. (From the author's abst.)

NEPOCHATYKH, V.P. and KALMURZINA, G.Z., 1976, Temperature conditions of formation of veinlet and dispersed Au-bearing ores of the Mindiakskoe depsoit (S Urals), (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 34-35 (in Russian; translation by A. Kozlowski).

Ores in post-diabase listvenites are a stockwork of quartz-carbonate, pyrite-bearing veinlets. T_H for quartz = 300-210°C, for carbonates - 130-180°C; T_D of pyrite is 140, 180, 240 and 310°C. Au-bearing pyrite crystallized together with quartz and earlier than carbonates. (...) (Authors' abst.)

NESBITT, B.E., 1976, Fluid and magmatic inclusions in the carbonatite at Magnet Cove, Arkansas. MS thesis, Univ. Michigan, Ann Arbor, Mich.

NESTEROV, I.I., NEMCHENKO, N.N., ROVENSKAIA, A.S., SHPILMAN, K.A., 1976, Isotopic composition of argon in natural gases of north-western Siberia in connection with the problem of their genesis: Akad. Nauk SSSR, Doklady, v. 230, no. 4, p. 942-944 (in Russian).

NEWTON, R.C. and GOLDSMITH, J.R., 1976, Stability of the end-member scapolites: $3NaAlSi_3O_8 \cdot NaCl$, $3CaAl_2Si_2O_8 \cdot CaCO_3$, $3CaAl_2Si_2O_8 \cdot CaSO_4$: Zeit. f. Krist., v. 143, p. 333-353 (in English). Authors at Dept. of Geophy. Sci., The Univ. of Chicago.

Important in discussions of the geochemistry of Cl, CO_3, and SO_4. (ER).

NEYKUR, T.L., 1976, Conditions of formation of rock-crystal-bearing quartz veins: Zapiski Vses. Mineral. Obshch., v. 105, no. 1., p. 18-29 (in Russian). Author at Inst. Geol. Geochem. of Urals Sci. Center of Acad. Sci. USSR, Sverdlovsk.

Studied veins occur in metavolcanites in coaly argillaceous and carbonate rocks of Silurian-Upper Devonian age, in contact with one of the granite massifs of E. Urals. Quartz veins are connected with metasomatites in metavolcanites. Metasomatites formed in several stages, under action of Na-Ca-Cl-HCO_3 sols. (six quant. anal. of leachates) at T_H 690 to 160°C. Ground quartz released 4.2 - 83.2 cm^3/kg (seven anal.), consisting of (vol. %) CO_2 (15.4-95.0), H_2 (6.4-69.0) and N_2 (0-42). Anal. of G phase of individual incs. (44 quant. anal. in 10 samples) proved the following ranges of mean values (vol. %): CO_2 - 28-87, H_2 - 5-49, N_2 - 4-50, H_2/CO_2 - 0.1-2.3. Higher values of H_2/CO_2 are char. for early stages of min.-form., and lower values for late ones. Incs. contain L-CO_2 and dms (halite? - A.K.). (Abst. by A.K.)

NIKANOROV, A.M., SIANISIAN, E.S. and TARASOV, M.G., 1976, Genesis of the deep brines of the Forecaucasian, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 56-57 (in Russian; translation by A. Kozlowski).

G/L inclusions were studied in Jurassic and Cretaceous deposits (calcite, quartz, limestone, anhydrite). Dimensions of inclusions vary from tenths to several tens of micrometers. Concentrations of Na, K, Ca, Cl, SO_4 and HCO_3 were determined; T_H ranges from 250-110°C. Presumably inclusions formed during dia- and katagenesis and they bear parent brines of the former marine basins, i.e., the brines are syngenetic with Jurassic and Cretaceous deposits. This is supported by the chemical composition of inclusion contents. (From the authors' abstract).

NOONER, D. W., GIBERT, J. M., GELPI, E., and ORO, J., 1976, Closed system Fischer-Tropsch synthesis over meteoritic iron, iron ore and nickel-iron alloy: Geochim. Cosmo. Acta, v. 40, p. 915-924. First author at Dept. Biophy. Sci., Univ. of Houston, Houston, Texas 77004.

Meteoritic Fe, Fe ore and Ni-Fe alloy (either alone or in some cases mixed with alumina, carbonaceous chondrite, potassium carbonate or sodium carbonate) were used to catalyze the reaction of deuterium and carbon monoxide in a closed reaction vessel. The mole ratio of deuterium to carbon monoxide ranged from 1/2:1 to 10:1, the reaction T from 195 to 370°C, and the reaction time from 6 to 480 hr. Anal. of the reaction products showed that normal alkanes and alkenes (C_{11}-C_{25}), their monomethyl substituted isomers and aromatic HCs (e.g., naphthalene, acenaphthene, fluorene, phenanthrene and the methyl derivatives of these HCs) were syn. In addition to the aforementioned HCs, one reaction product was shown to contain perdeutero normal fatty acids (10:0-16:0). (Authors' abstract)

NORMAN, D.I., ALEXANDER, E.C., Jr., and SAWKINS, F.J., 1976, Helium in cordierites: a possible indicator of low temperature metamorphic events, (abst.): Amer. Geophys. Union Trans., v. 57, p. 352. Authors at Dept. of Geology, Univ. of Minnesota, Minneapolis, MN 55455.

Gases released during the heating of cordierites from diff. localities have been meas. The He contents of the cordierites with simple, well-dated histories show a remarkable logarithmic dependence with age. Those cordierites from rocks whose ages have not been det. have a He content "age" that is geol. reasonable. Several dated cordierites give younger He content "ages" which correspond to known tectonic events. For example a Telemark cordierite, dated at 1.1 b.y., gives a Caledonian "age". A possible explanation is that locally high radiogenic He Ps result in diff. of that gas into cordierite. Low T events, perhaps assoc. with tectonic movements, result in He loss. At this prelim. stage in the invest. it appears that He content of cordierite records the age of the last thermal event. He loss from cordierites may provide a sensitive tech. for det. low T thermal events. (Authors' abstract).

NORMAN, D.I., LANDIS, G.P., and SAWKINS, F.J., 1976, H_2S and SO_2 detected in fluid inclusions, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 1031. First author at Dept. of Geol. and Geophysics, Univ. of Minnesota, Minneapolis, MN 55455.

Gases released by thermal decrep. of fluid inc. were meas. with a quadropole mass spec. Samples were anal. from Tribag, Ontario and Messina, South Africa, both breccia pipes containing principally Cu sulfides; and Pasto Bueno, Peru, a W-base metal vein dep. In most inc. assemb. in paragenetic assoc. with sulfide minerals H_2S was detected. Typical conc. were 0.01-0.001 mol/(Kg. inc. H_2O). SO_2 was det. in fewer instances, usually from samples not related to sulfide min., and was often accompanied by nitrogen oxide gasses.

The type of sulfur gases meas. in the Pasto Bueno samples parallels the results of stable isotope studies which indicate dep. of sulfides primarily from mag. waters, with an influx of meteoric water coincident with wolframite dep. Gas anal. indicates the mag. waters contained H_2S and H_2. The second fluid was lacking in H_2 and contained SO_2 and/or nitrogen oxide gases.

These prelim. results suggest: 1) Since sulfur gases were found in inc. in the first three hyd. sulfide dep. invest., they may be present in most fluids from which sulfide ores are dep. 2) The amount of H_2S present agrees with several author's calc. of H_2S conc. in hyd. ore fluids. 3) Oxidation of hyd. waters may play a key role in the dep. of ore min. (Authors' abstract)

NORRIS, R.J. and HENLEY, R.W., 1976, Dewatering of a metamorphic pile: Geology, v. 4, p. 333-336.

NORTON, Denis, 1976, The nature of hydrothermal fluids in porphyry copper systems: sourcelines, sources, and masses of circulating fluid, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 1033. Author at Dept. of Geosciences, Univ. of Arizona, Tucson, AZ 85721.

OEDER, R., SCHARMANN, A., and SCHWABE, D., 1976, Distribution coefficients, cavity formation and cellular structures in Czochralski $CaWO_4$ crystals: Journal of Crystal Growth, v. 36, p. 1-3. Authors at I. Physikalisches Inst. der Justus Liebig-Univ. Giessen, 63 Giessen, Germany.

OHLE, E.L., 1976, Precipitation mechanisms for Mississippi Valley-type ore deposit, a discussion: Econ. Geol., v. 71, p. 1060-1061.
A discussion of Beales, 1975 (this volume) (ER).

OHMOTO, Hiroshi, 1975, Review of Fluid Inclusion Research, v. 4, 1971: Econ. Geol., v. 70, p. 1300-1301.

OHMOTO, Hiroshi, 1976, Applications of experimental data on the fractionation of stable isotopes to problems of ore genesis (abst.): International Geol. Congress, 25th, Abstracts, p. 822-823. Author at Dept. of Geosciences, The Pennsylvania State Univ., University Park, PA 16802 U.S.A.

O'KEEFE, J.A., 1976, Tektites and their origin: Amsterdam, Elsevier Sci. Pub. Co., 254 pp. Author at Theoretical Studies Group, NASA Goddard Space Flight Center, Greenbelt, MD, USA.
Includes discussion of gas inclusions (p. 176-177)(ER).

OKRUGIN, V.M., 1976, Thermobarogeochemistry of ore veins in SE Kamchatka, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 40-41 (in Russian; translation by A. Kozlowski).
Vein mineralization is polymetallic, with minerals of Ag, Te, sulfosalts of Cu, Sb, As, and Au-quartz. Fluid inclusions were studied in quartz, calcite, rhodochrosite, sphalerite, galena, pyrite and tetrahedrite. P, PS and S inclusions have dimensions 0.005-0.03 mm. Their composition: G (35-5 vol.%), water solution, and halite. Maximum T_H = 380-350°C, most intensive precipitation of ores was at 270-150°C. T_H and T_D of inclusions in quartz coexisting with pyrite, are 300-280°C. Hydrotherms were of $Cl-HCO_3-Na$ composition at T = 380-150°C, depth of vein formation was 400-600 m. (Author's abst.)

OLLIVER, J.G., SPENCER, W.G. and COOPER, R., 1976, Unusual mottled barite from Matthews deposit, Flinders Ranges: Geol. Survey S. Australia, Quart. Geol. Notes no. 59, p. 13-16.
A strong odor similar to acetylene is emitted when the gray barite is scratched (ER).

OLSON, E.R., 1976, Oxygen isotope study of diabase, Heber geothermal field, Imperial Valley, California, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 1036. Author at Inst. of Geophysics and

Planetary Physics, Univ. of California at Riverside, Riverside, CA 92502.

The diabase in the Holtz Number One Well has been affected by O isotope exchange with hyd. fluids. The isotopic equil. WAS at a T consistent with those det. by fluid inc. homog.meas. No relationship between O isotope comp. and depth could be det. for either the ign. or hyd. min. (From the author's abstract)

OLSZYŃSKI, W., KOZŁOWSKI, A., and KARWOWSKI, L., 1976, Bismuth minerals from the Karkonosze massif: Acta Geologica Polonica, v. 26, no. 3, p. 443-449 (in English).

Geothermometry based on emplectite and native bismuth is in agreement with published decrepitation and homogenization studies (Kozlowski et al., 1975, Fluid Inclusion Research, v. 8, p. 98, 1975). (ER)

O'NEIL, J.R. and KHARAKA, Y. K., 1976a, Hydrogen and oxygen isotope exchange reactions between clay minerals and water: Geochim. Cosmo. Acta, v. 40, p. 241. First author at U.S. Geological Survey, Menlo Park, CA 94025.

The extent of H and O isotope exchange between clay min. and water has been meas. in the T range 100-350° for bomb runs of up to almost 2 years. H isotope exchange between water and the clays was demonstrable at 100°. Exchange rates were 3-5 times greater for montmorillonite than for kaolinite or illite and this is attributed to the presence of interlayer water in the montmorillonite structure.

Negligible O isotope exchange occurred at these low Ts. The great disparity in D and O^{18} exchange rates observed in every exper. demonstrates that H isotope exchange occurred by a mechanism of proton exchange independent of the slower process of O^{18} exchange.

At 350° kaolinite reacted to form pyrophyllite and diaspore. This was accompanied by essentially complete D exchange but minor O^{18} exchange, and implies that intact structural units in the pyrophyllite were inherited from the kaolinite precursor. (Authors' abstract)

O'NEIL, J.R., and KHARAKA, Y.K., 1976, Hydrogen and oxygen isotope exchange reactions between clay minerals and water: Proc. Internat. Symp. on Water-Rock Interaction, Czechoslovakia, 1974, J. Cadek and T. Paces, eds.: Prague, Geological Survey (ČSSR), p. 356-362.

ORLOVA, L.M. and BAZAROV, L.Sh., 1976, The character of the change of composition of the liquid phases of inclusions in beryls from rare-metal pegmatites: Soveshch. Molodykh Uchenykh Mineral., Geokhim., i Metodam Issled. Mineral (Tezis. Dokladov), Primor. Otdel., Vses. Mineralog. Obshch. Dal'nevostoch. Geol. Inst., Vladivostok, p. 92-93 (in Russian; translation courtesty of Michael Fleisher). Authors at Inst. Geol. Geophys. Sib. Branch, Akad. Nauk SSSR, Novosibirsk.

1. The char. of the change of comp. of the liquid phase of inc. in beryls was studied by means of a new method of successive aq. extr. dev. by the authors. The method consists essentially of successive openings of incl. having T_H by heating in a specific selected T interval, and later anal. of the extracts by various chem. and phys. chem. methods.

2. The conc. of elements in the liquid phase of inc. for each T interval (in weight %) were calc., taking account of the contents of

H_2O and CO_2 in these inc., by the method of fractional freezing out, developed by L. Sh. Bazarov and M. Yu. Mikhailov.

3. Beryls were studied from two struct. - min. zones of peg. of albite type: (1) from quartz-cleavelandite (blue beryl); (2) from albite-lepidolite (rose beryl). The albite-lepidolite zone was formed later than the quartz-cleavelandite zone, as indicated by the interrelations between these parageneses. This is also confirmed by data of min. therm.; T_H of the highest T inc. of sol.-melt of the blue beryl is 660°, the T_H of rose beryl is 620°. We have a case of overgrowth of the blue beryl by the rose.

4. Successive aq. ext. were performed after 5 T intervals: 200-300, 300-400, 400-500, 500-600, and 600-700°. Anal. were made for Li, Na, K, Ca, Mg, Al, F, Cl, HCO_3, SO_4, and SiO_2. The conc. range of the main elements in the liquid phase of the inc. of sol.-melt in the blue and rose beryls is given in the table below.

5. The conc. are higher in the rose than in the blue beryl for corresponding T intervals.

6. All these elements clearly show a decreased conc. as the T of xliz. of beryl (T_H) decreases.

Range of conc. of elements in the liquid phase of inc., in wt.%

Element	Blue beryl	Rose beryl
Li	0.049 - 0.508	0.159 - 0.473
Na	0.517 - 3.094	0.672 - 5.486
K	0.077 - 1.074	0.253 - 2.012
HCO_3	1.804 - 12,494	3.859 - 20,457
SiO_2	1.445 - 21,650	2.211 - 13.096
CO_2	11.08 - 27.66	13.88 - 27.91
H_2O	36.78 - 84.79	31.30 - 78.94

OSTROUMOVA, A.S., TSENTER, I.Ya., and SYSOEV, A.G., 1976, Composition and features of rock-forming minerals as index of depth of crystallization of basalt-andesite melts: Zapiski Vses. Mineral. Obshch., v. 105, no. 2, p. 164-172 (in Russian).

Of pertinence to the det. of depth of formation and estimates of P from incs. (A.K.)

OVCHINNIKOV, L.N., 1976, Role of SO_2 in hydrothermal ore formation: Akad. Nauk SSSR, Doklady, v. 227, no. 3, p. 680-683 (in Russian). Author at Inst. Min., Geochem.,+Crystallochem. of Rare Elements, Moscow.

Discussion of role of SO_2 in various geol. conds., evolution of SO_2/H_2S ratio, and form. of hyd. sulfates, especially anhydrite. (A.K.)

PAGEL, Maurice, 1975a, The determination of the physico-chemical conditions of the diagenetic silicification of the Athabasca sandstones (Canada) by fluid inclusions: Compt. Rend. Acad. Sci., Paris, v. 280, série D, p. 2301-2304. Author at Centre de Recherches Pétr. et Géochim., C.O. n° 1, 54500 - Vandoeuvre-les-Nancy, France.

A microthermometry study of fluid inclusions located between the detritic grain boundaries and the zone of authigenic growth permits a determination of the chemical nature of fluids contemporaneous with the beginning of silicification as well as the P-T conditions of trapping. From this information the thickness of the sedimentary cover at the moment of silicification in the region of the Carswell circular structure and an average geothermal gradient of 35°C/km for the Athabasca Basin can be deduced. (Author's abstract).

PAGEL, Maurice, 1975b, Geological setting of the uranium deposits in the Carswell structure (Canada). A study of the fluid phases: Thèse de spécialité, C.R.P.G., E.N.S.G., Université Nancy I, June 1975, 141 pp. plus 8 plates. Author at Centre de Recherches Pétr. et Géochim., C.O. n° 1, 54500 - Vandoeuvre-les-Nancy, France.

Several microscopic criteria have been defined by which it has been possible to establish a relative chronology of the generations of fluids in the different petrographic facies of the Carswell structure. Mineral assemblages and fluid inclusions show that acid and basic gneissic rocks were metamorphosed to granulite facies grade. The earliest fluid phase contains essentially CO_2 with a maximum density of 0.98 g/cm^3. P-T conditions are estimated to be 650-800°C and 5.5 to 7 kb. In the granitic volatiles in addition to CO_2, there is a weakly saline aqueous fluid (5 wt.% equiv. NaCl). The density of this fluid is compatible with low-P metamorphic conditions. The late diagenetic silicification of the Athabaska sandstones is marked by an increase, as a function of depth of burial, in salinity and temperature of the solutions trapped at detrital grain boundaries. The impact hypothesis for the Carswell structure is supported by the physicochemical characteristics of the trapped fluids. The evidence consists of the absence of CO_2, which is an essential constituent of volcanic gases, and the absence of a fluid generation indicating elevated pressure of formation. On the contrary, observations indicate that fractures were healed under high temperature and extremely low pressure conditions, such as are thought to prevail after an impact. (Author's abstract, abbreviated).

PAGEL, Maurice, 1976, Depositional conditions of automorphic quartz and dolomite from the Rabbit Lake uranium deposit (Canada)(abst.). 4éme réunion annuelle des Sciences de la Terre, Paris, p. 314 (in French). Author at Centre de Recherches Pét. et Géochim., C.o. no. 1, 54500 Vandoeuvre-les-Nancy, France.

Fluid inclusions in quartz and dolomite formed after pitchblende were studied by microthermometry, by chemical analysis of aqueous leachates, and by gas phase chromatography. Quartz crystallized at 160 ± 10°C and 700 ± 150 bars from a saline aqueous solution (approx. 30 wt. % equiv. NaCl) containing dissolved CO_2 and hydrocarbons. Dolomite formed at a temperature greater than 130°C and pressures greater than 300 bars from a saline aqueous solution (approx. 28 wt. % equiv. NaCl) containing CO_2 as a separate phase. Cl/Br ratios of 55 and 65 were measured in the inclusion brines from quartz and dolomite, respectively. These brines very likely formed during the diagensis of the overlying Athabasca sandstones and then infiltrated into the underlying basement, since similar P-T conditions and fluid compositions have been found for the diagenesis of the Athabasca sandstones. (Abstract abridged by M. Pagel and translated by A. Barabas).

PARILOV, Yu.S., MITRYAEVA, N.M., KORMUSHIN, V.A. and MIKHALEVA, V.A., 1976, Temperature conditions of formation of ores at deposit Zhayrem: Geol. Rudn. Mest., v. 18, no. 2, p. 106-110 (in Russian). Authors at Satpaev's Inst. Geol. Sci. of Acad. Sci. Kazakh SSR, Alma-Ata.

Ore mins. from stratiform dep. Zhayrem were invest. by use of vacuum decrepitometer, applied on grain size 0.1-0.01 mm (inc. size $\sim$0.001 mm); the highest intensity of gas release from incs. was accepted as T_D. Ores of the first stage, rhythmites of globular pyrite and sphalerite, have T_D = 40-60°C (pyrite) and 60-70°C (pyrite + sphalerite), i.e., the ores are of hyd.-sed. origin. Rexliz. ores and ores partially redepos. during dislocation meta. consist of pyrite having T_D = 100-120°C. Galena-sphalerite-barite ores of the second stage decrep. at 140-150°C. Ores of the third stage (barite, pyrite, chalcopyrite, hematite and quartz) xlized from hyd. sols. connected with small intrusions of trachyte porphyries, and have T_D and T_H, respectively, as follows: quartz-barite aggregates - 330 and 300°C, barite with nests of chalcopyrite - 280 and 280°C, barite-hematite veinlets - 170 and 175°C. (Abst. by A.K.)

PARRY, W.T. and JACOBS, D.C., 1975, Fluorine and chlorine in biotite from Basin and Range plutons: Econ. Geol., v. 70, p. 554-558.

The concentrations of fluorine and chlorine in biotite, apatite, hornblende, sphene, and chlorite from plutons of intermediate composition in the Basin and Range province have been determined by microprobe methods. Maximum and minimum concentrations in weight percent are 0.4 to 3.8 F and 0.0 to 0.26 Cl in biotite and 0.7 to 3.6 F and 0.0 to 0.8 Cl in apatite. Apatite is generally richer in Cl and F than associated biotite.

Chlorine and fluorine concentrations differ significantly between individual plutons, but no differences which might prove useful for exploration could be recognized between mineralized and nonmineralized plutons. Hydrothermal biotite and apatite have equilibrated with saline, hydrothermal fluid and may contain either more or less chlorine and fluorine than magmatic minerals, which reflect the relative abundance of HCl, HF, and H_2O in the magma. The highest Cl content in biotites occurs in plutons containing pyroxene, whether mineralized or not. (Author's abstract).

PATTERSON, G.C., and RUCKLIDGE, J.C., 1976, Chlorine in altered ultramafic rocks (abst.): Geol. Assoc. Canada - Mineral. Assoc. Canada Program with Abstract, v. 1, p. 63. Authors at Department of Geology, University of Toronto, Toronto, Ontario M5S 1A1.

PERTSEV, N.N., 1976, Conditions of formation of high-temperature borates: Geol. Rudn. Mest., v. 18, no. 1, p. 46-56 (in Russian). Author at Inst. Geol. Rudn. Mest., Petrogr., Mineral and Geochemistry of Acad. Sci. USSR, Moscow.

Thdy. calc. and exper. data together with obs. of natural parageneses of borates from skarns, permit evalution of the depth of xliz. of borates and $a_{B_2O_3}$ necessary for their form. (A.K.)

PETERSON, R.C. and FRANCIS, Donald, 1976, The origin of spherical sulfide inclusions in a clinopyroxene megacryst, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 1049. Authors at Dept. of Geological Sciences, McGill Univ., Montreal, Quebec, Canada, H3C 3G1.

This phenomena may have been caused by diff. controlled growth resulting in local immiscibility of a sulfide melt in the boundary layer between the xl and the melt. (From the authors' abstract)

PETRICHENKO, O.I. and SHAIDETSKAIA, V.S., 1976, Inclusions in halite from veins in diabase, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 59 (in Russian, translation by A. Kozlowski).

In numerous salt structures (Kaplintsevskaia, Romenskaia, Adamovskaia, etc.) of the Dnepr-Donets depression, diabases and gabbro-diabases occur.

P inclusions in halite are divided into groups: one-phase (L or solid), two-phase (G+L) and polyphase (G+L+solids). By analysis of individual inclusions the inclusion brines have a Cl-Na-Ca composition with high Ca (26-80 g per l) and low K (1-10 g per l); Cu, Mo, V, Ti, Ba, Sr were found in inclusions. Eh ranges from -10 to -20 mV; T_H 70-90°C, P at 20°C - 80-120 atm. Diabases in halite rocks are strongly altered. In veins and amygdules in diabases, in addition to prehnite, anhydrite, calcite, epidote, apatite, and hornblende, halite is also common. In vein halite following inclusions were found: sylvite crystals, G+L, G+L+sylvite. Solution has composition: Cl-Na-Ca (Ca 100-150 g per l, K 40-50 g per l, Mg 10-15 g per l); Eh from + 50 to +300 mV; T_H in liquid from 64 to 58°C. P inclusions were not found in halite from amygdules in diabase. (Author's abst.)

PHILPOTTS, A.R., 1976, Silicate liquid immiscibility: its probable extent and petrogenetic significance: Amer. Jour. Sci., v. 276, p. 1147-1177. Author at Dept. Geol., Univ. Conn., Storrs, CT 06268.

A review of the evidence for immiscibility in the Monteregian alkalic province in Quebec, and some of the implications of immiscibility in petrology (ER).

PINEAU, F., and JAVOY, M., 1976a, Study of the composition of fluid inclusions in the "popping rocks" of the Mid-Atlantic Ridge: Réunion annuelle des Sciences de la Terre, 4ème Paris, p. 332 (in French). Authors at Université Paris VII, 2 Place Jussieu 75221 Paris Cedex 05, France.

Two groups of fluid inclusions have been distinguished in the "popping rocks". One group of millimeter-sized inclusions contains CO_2 with constant isotopic composition ($\delta^{13}C = -7.6^{\circ}/_{\circ\circ} \pm 0.5^{\circ}/_{\circ\circ}$), which the authors believe to represent CO_2 escaping from the mantle. The second group of inclusions, with micron size cavities, is characterized by CO_2 with $\delta^{13}C$ varying between -15 and $-24^{\circ}/_{\circ\circ}$. This is believed to represent residual CO_2 exsolved from the basalt during cooling. (Author's abstract abridged by M. Pagel and translated by A. Barabas).

PINEAU, F. and JAVOY, M., 1976, Isotopic study of the granulite facies across a quartzite series from the Bamble province (Norway)(abst.):

4ème réunion annuelle des Sciences de la Terre, Paris, p. 334 (in French). Authors at Univ. Paris VII, 2 Place Jussieu, 75221 Paris Cedex 05 France.

Some of the generations of fluid inclusions contained in the Bamble quartzites are essentially pure CO_2. A carbonate mineral occurring in probable syngenetic intergranular aggregates has a constant isotopic composition $\delta^{13}C = -7.5\ ^{o}/_{oo}$ and $\delta^{18}O = +12\ ^{o}/_{oo}$) which corresponds with equilibrium with quartz under the conditions of the granulite facies. The $\delta^{13}C$ of the carbonic inclusion fluids with the highest density (-7 to $-9^{o}/_{oo}$) was calculated by eliminating the contributions from late-stage CO_2-rich inclusions and from the solid carbonate phase (less than 30% of the total rock carbon) to the total rock isotopic composition (-15 to $-7^{o}/_{oo}$). The $\delta^{13}C$ values suggest a contribution of fluid from the mantle to the deep crust and an opening of the system during retrometamorphic phenomena. (Authors' abstract abridged by M. Pagel; translated by A. Barabas).

PINEAU, F., JAVOY, M., and BOTTINGA, Y., 1976, $^{13}C/^{12}C$ ratios of rocks and inclusions in popping rocks of the Mid-Atlantic Ridge and their bearing on the problem of isotopic composition of deep-seated carbon: Earth Planet. Sci. Lett., v. 29, no. 2, p. 413-421.

PLIMER, I.R., 1973, The pipe deposits of molybdenite, bismuth and wolframite of Eastern Australia: Unpublished Ph.D. thesis, Macquarie University, N.S.W., Australia.

Joint-controlled quartz-rich molybdenite-bismuth and wolframite pipes (e.g., Kingsgate and Wolfram Camp) occur in the altered margins and roof zones of high level leucocractic granitic plutons. The host granitic plutons have been sericitised at their margins and roof zones with more local intense alteration (sericitization, greisenization, spessartitization) zonally arranged around the pipe loci. Ore distribution is patchy and the ore grade decreases with depth. The pipes are internally assymetrically zoned and comprise quartz, molybdenite, ferberitic wolframite and bismuth minerals with minor amounts of other ore and silicate minerals. Jointing of the pluton occurred during or after the last stages of crystallization as a result of contraction or fluid pressure. A magmatic aqueous phase was released and ascended joints close and subparallel to the contact plane and collected in the roof zones beneath high grade metamorphic rocks. This high temperature (T_H max. 356°C) aqueous phase was released at $P_{H_2O} > 0.3$ kb; had a low pH, Eh, f_{O_2} and f_{CO_2}; salinity $\leq$ 11%NaCl equiv. and high f_{S_2}; and contained complexes of W, Mo and Bi which were partitioned from the melt into the aqueous phase. During ascent of this aqueous phase there was minor lateral movement away from the joint loci producing zonal alteration assemblages as a result of H^+ digestion, f_{O_2} and Eh increase. Ore mineral precipitation was possibly a result of fluid mixing or temperature decrease. A number of episodes of hydrothermal fracturing were recognized and the temperature and salinity of the aqueous phase decreased with each successive fracturing event. These pipe deposits in eastern Australia have many similarities with the Mo pipe deposits of Japan and the circum Pacific porphyry copper deposits. (From the author's abstract).

POLYAKOV, A.I., ILYIN, N.P. and MURAVYEVA, N.S., 1976, Conditions of the crystallization of rocks of the Iceland rhyolite-basalt association on the basis of studying the composition of phenocrysts and the distribution coefficients: Geokhimya, 1976, no. 7, p. 963-982 (in Russian with English abstract). Authors at V.I. Vernadsky Inst. Geochem. and Anal. Chem., USSR Acad. of Sci., Moscow.

The composition of silicate phenocrysts has been determined in rocks of the Iceland rhyolite-basalt association by the method of electron microprobe. The distribution coefficients of iron, magnesium, manganese and calcium have been estimated for olivines and clinopyroxenes (between phenocrysts and the rock as a whole). The crystallization temperatures of plagioclase phenocrysts have been calculated by the Kudo-Weill method. The comparison of the calculated results with temperatures of homogenization has shown that crystallization of plagioclases occurred from melts undersaturated with water.

Olivines are not zoned in the alkaline olivine-basalt series and display variations in composition of up to 10% in one rock. Olivines were in equilibrium with the melt whose composition corresponded either to the rock as a whole or to the groundmass. In rocks of the Iceland rhyolite-basalt association a regular change of the composition of phenocrysts from basic to acid rocks is observed that may point to a genetic relation of these rocks. (Author's abstract).

POLYKOVSKIY, V.S., MOSKALYUK, A.A. and BOGATYREV, V.V., 1976, Salt composition of hydrotherms in inclusions of fluorite veins at Mogov deposit, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 53 (in Russian; translation by A. Kozlowski).

1. Ores are connected with the submeridional tectonic zones in granites of Middle and Upper Carboniferous age at S slopes of the Central Gissar.

2. Deposits are of calcite-barite-fluorite formation.

3. T_D of fluorite I (gray and white) 300-180°C, fluorite II (pink) 280-160°C, fluorite III (deep green) 280-160°C, fluorite III (apple-green) 260-160°C, fluorite III (pale green) 240-120°C, fluorite IV (blue and bluish-green) and fluorite V (light violet) 240-80°C, fluorite VI (colourless) 240-140°C.

4. Triple water leachates have following concentrations (mg per 100 g of sample): total 18.13 - 19.14, NH_4Cl - 0.10, KCl 0.59-0.98, NaCl 8.59-14.49, NaF 0.0-3.15, CaF_2 0.0-0.23, Na_2SO_4 0.0-0.35, $CaSO_4$ 0.68, Mg (sic.) 0.73, Na_2SO_4 0.35, $NaHCO_3$ 0.0-1.26, $NaHCO_3$ 1.21-5.99 (sic).

Late colourless crystals of fluorite contain the following salts: total to 5.49, KCl 0.59, NaCl 0.70, Na_2SO_4 1.85, $CaSO_4$ 0.41, $Ca/HCO_3/_2$ 1.94.

High quality optical fluorite forms from low-temperature from dilute hydrotherms. (Authors' abstract).

PONOMAREVA, N.I., 1976, Peculiarites of the composition of water leachates from quartz of the pegmatites of N. Karelia, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 46 (in Russian; translation by A. Kozlowski).

1. Water leachates from quartz of various pegmatites have a SO_4-Cl-HCO_3 composition; cation contents vary widely. In the microcline-

free pegmatites Ca is the main cation; Ca/Σ cations is 0.7. The role of K and Na is small: K/Σ cations is 0.03, Na/Σ cations is 0.27. In the essentially microclinic pegmatites Ca/Σ cations decreases to 0.18; an increase was found for Na/Σ cations to 0.33. On a triangular plot Na-K-Ca the fields of the microcline-free pegmatites and the microclinic pegmatites of the ceramic and mica-ceramic type, are separate. Completely separate on the diagram is the quartz-muscovite aggregate with Ca/Σ cations = 0.02.

2. Leachates from quartz of the mica pegmatites are enriched in Cl and SO_4.

3. In leachates from quartz of the mica pegmatites the contents of Na and K decrease and Ca increases in late quartz compared with early quartz. (Author's abst.)

POPOV, V.A. and BARKHUDARYAN, N.B., 1976, Conditions of formation of gold ore mineralization in a certain region of E. Chukotka (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept., 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 29-30 (in Russian; translation by A. Kozlowski).

Au-quartz and Au-quartz-sulfide veins with T_H 230-340 and 450-540°C occur at N. part of ore zone, and those with T_H 230-380 and 60-160°C - at S. part. IR absorption of H_2O in quartz (3400 cm^{-1} band DI) increases from N. to S. part of ore zone, from 1.9 to 4.9 (arbitrary units). Also absorption of CO_2 in quartz (2350 cm^{-1}, DII) decreases from S to N from 1.0 to 0.26, and then increases to 0.38 (arbitrary units). DII:DI value (carbon dioxide ratio) is almost constant for all localities. Veins with highest Au content formed at 240-60°C from sols. with increased CO_2 conc. (From authors' abst.)

PORYVKIN, D.S., NIKOLAEV, V.A., NIKITIN, A.A., SHKURKO, E.I., and VASIL'KOVA, I.V., 1976, Thermobaric conditions of formation of mica-fluorite deposits of Primor'ie, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 42-43 (in Russian; translation by A. Kozlowski).

1. The deposits occur in schists, argillites, sandstones and limestones of Riphean - Lower Cambrian age, in contact with Caledonian granitoids. Ore bodies are stockworks and sheet deposits of similar mineral composition.

2. T_H of fluid inclusions in fluorites range from 370 to 60°C. Fluorite of greisen zones in granites formed at 370-360°C. The main mass of fluorite has T_H 270-160°C. Late fluorite veinlets in limestones have T_H 140-60°C. Zoning was recognized in the sheet deposits.

3. On the basis of studies of CO_2-bearing inclusions in fluorite and quartz, the minimum P varied from 1330 to 480 bars, but most commonly P equalled 650-740 bars. (Authors' abst.)

POTAP'YEV, V.V., POLYAKOV, V.O. and SHCHERBAKOVA, Ye. P., 1975, On specific composition of ore-forming solutions separated from domes of various elevations in the Chalbinskiy pluton (Yakutian ASSR): Acad. Sci. USSR, Doklady v. 224 no. 4, p. 933-936 (in Russian). First author at Div. Exper. Research of Central Sci.-Research Geol. Prospect. Inst., Tula.

In cassiterite ore zones of various domes of granitoid massif different parageneses are found, regardless of T. Cassiterite from main, upper dome occurs with tourmaline and fluorite is absent (sols. rich in B). Fluorite is common in min. zones of lower domes of II range (sols. rich in F, poor in B), where tourmaline was not found. Authors explain this by differences in P (depth of xliz. and degree of opening of min.-forming systems of main and subordinate domes). T_H of incs. in cassiterite from various parageneses ranges from 370-380°C for greisens (dep. Osennee) and 360-380°C for quartz veins (dep. Chalba I) to 340-355°C for quartz-low-sulfide (dep. Krasivoe) and 330-345°C for sulfide-quartz (dep. Bezymyannoe). (Abst. by A. K.).

POTTER, A.P., 1975, Silicate liquid inclusions in olivine crystals from Kilauea, Hawaii: M. Sc. thesis, Queen's Univ., Kingston, Ont. Canada.

A detailed study was made of silicate glass inclusions (formerly silicate melts) in Hawaiian olivines from the 1840 Puna flow of Kilauea. Olivines and silicate inclusions were heated to temperatures above 1200°C and the resulting included liquids quenched to glasses. A range in quenched glass composition was found to be present at any one temperature; this was attributed to the presence of initial inhomogeneities in included liquid composition, to the presence of chromite and to the formation of quench crystals. For the olivine-included liquid system, after these effects were taken into account, glass inclusions gave compositions which showed a strong correlation with temperature.

The temperature of inclusion was calculated using compositional gradients in the olivine adjacent to the glass. These indicated an entrapment temperature of 1245°C to 1265°C.

From the previous data, the composition of the original included liquid was calculated and gave an MgO content of 9.5 to 10.25%. This is considered to be the composition of the parent magma in the Kilauean magma column in equilibrium with crystallizing olivine.

The presence, in glass inclusions, of sulphur-bearing, spherical, opaque blebs with high iron and nickel contents was noted. These are thought to have been primary, sulphide-rich, immiscible globules.

Diffusion of oxygen out of olivine grains during experimental runs was suspected and is thought to have caused local reduction of olivine, included liquids and sulphide globules. (Author's abstract).

POTY, Bernard, LEROY, Jacques and JACHIMOWICZ, Léon, 1976, A new device for measuring temperatures under the microscope: the Chaixmeca microthermometry apparatus: Bull. Soc. Fr. Minéral. Cristallogr., v. 99, p. 182-186 (in French; see translations).

Description of an apparatus for measuring the temperature of micro-samples under the microscope in the range -180°C to + 600°C. Precision and accuracy are discussed. Use of this apparatus is foreseen in physics, chemistry, mineralogy and biology. (Author's abstract).

POTY, Bernard and WEISBROD, Alain, 1976, Fluid inclusions as a guide in metal deposit exploration: Annales des Mines, Feb. 1976, p. 29-40 (in French). Authors at Centre de Recherches Pét. et Géoch., C.O. no. 1, 54500 Vandoeuvre-lès-Nancy, France.

The contribution of fluid inclusions as a supplementary tool available to geologists for mineral deposit exploration is considered generally, and then for two specific cases as examples: porphyry coppers and uranium deposits.

Information of immediate practical use for exploration geologists includes (1) The distinction of superficial alteration from hydrothermal alteration (2) The gas content (CO_2 for example) associated with solution and deposition mechanisms (3) Indications of boiling or of "non-boiling", and (4) Calculations of the mass transfer balance.

For porphyry coppers, simply to search for the favorable association (boiling and Cu concentration of solutions) allows the elimination of misleading indications and provides a very efficient way of choosing and centering exploration targets. On the other hand, no immediate application has been determined for uranium deposits although a large number of studies have now shown that uranium mobility is associated with the presence of CO_2 in the solutions.

Thus, in the first case, inclusions are already a working took while in the second, they permit a better understanding of the geological history of the area of a deposit. (Abstract by M. Pagel, translated by Chris Eastoe).

POZDEEV, K.M., 1976, Peculiarities of formation of Arkhonskoe ore field, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bahskir Section, Acad. Sci. USSR, Inst. of Geol., p. 40 (in Russian; translation by A. Kozlowski).

1. Arkhonskoe polymetallic deposit is a part of the Sadonskoe Pb-Zn ore field (...).

2. Ore-bearing quartz of the N part of deposit bears only two-phase inclusions, T_H = 290-170°C, in liquid. Quartz from veins in the S part contains two- and three-phase (CO_2-bearing) inclusions. T_H of two-phase inclusions are 340-160°C; CO_2 in three-phase inclusions dissolves (sic.; homogenizes?) at 17-15°C, testifying to the heterogeneity of the hydrotherms and P = 1350-1300 atm. At lower levels of N part, in quartz of veins: Molodiozhnaya, Komsomol'skaya and Novaya, two- and three-phase inclusions were found. The first ones have T_H = 340-180°C, the second ones - T_H = 290-280°C, CO_2 dissolves at 9.5-11.5°C; P = 1450-1750 atm.

3. (...). (Author's abst.)

PRASOLOV, E.M., 1976, Excess argon in gas-fluid inclusions of rocks and minerals, in Razvitiye i primeneniye metodov yadernoy geokhronologii (Shukolyukov, Yu. A., editor; et al.), p. 153-176, Izd. Nauka, Leningrad, USSR (in Russian).

PRICE, L.C., 1976, Aqueous solubility of petroleum as applied to its origin and primary migration: Amer. Assoc. Petrol. Geol., Bull., v. 60, p. 213-244.

Essentially the full publication of 1973 Ph.D. work abstracted in Fluid Inclusion Research, v. 7, 1974, p. 175. (ER)

PRICE, W. F., 1976, Extraction and analysis of gases from lavas (abst.): Mineralog. Soc. Bull, (London), no. 30, April, 1976, p. 4. Author at Dept. of Geol., Reading University.

Collection and analysis of volcanic gases allows data on magmatic volatiles to be obtained from currently active magmas. However, this only represents the volatile phase at one point in time, and at one particular stage in the volcano's eruptive cycle. Therefore, to explore the nature of the volatile phase co-existing with ancient igneous rocks (representing a wider spectrum of eruptive conditions) different methods must be developed.

This paper presents data from pilot experiments in which an obsidian from Lipari (Eolian Islands) is heated under reduced pressure and the resulting gases analysed using a mass spectrometer. The preliminary results lead to two important findings: (i) the size of sample fragments is critical, and (ii) the gas composition is strongly dependent on the duration of the experiment. These factors will be discussed in terms of the sites in which the volatiles are trapped and the mechanisms of gas release. (Author's abstract)

PROKOPTSEV, N.G., 1976, Early-magmatic liquation-dynamic differentiation in alkaline-basaltic abyssal submarine lavas: Akad. Nauk SSSR, Doklady, v. 228, no. 6, p. 1426-1429 (in Russian). Author at S. Division of Inst. Oceanology of Acad. Sci. USSR, Gelendahik.

Pertinent to melt immiscibility in incs. (A.K.)

PUZANOV, L.S. and KANDIDOV, M.I., 1976, Conditions of formation of the "ratovkite" mineralization from some regions of the Soviet Union, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 47 (in Russian; translation by A. Kozlowski).

In the East-European and Siberian platform, in the foothills of the Urals and E. Sayan, in the graben zones of the Krasnoiarskiy country and Kazakhstan, stratiform deposits of fluorite are abundant. In the deposits of Kungurian age near Sylva River (Perm Priural'ie) and in the rocks of the Lower Carboniferous age in the Minusinskiy region, common genetic peculiarities were revealed, especially connected with the stages of formation. Fluorite and calcite bear fluid inclusions with T_H = 200-70°C (Sylva River) and 170-80°C (Minusinskiy region). The mineralization is similar to the barite-polymetallic-fluorite ores of Mississippi Valley type. (From the authors' abst.)

PUZANOV, L.S. and KANDIDOV, M.N., 1976, Temperatures of formation of stratiform fluorite mineralization at Minusinsky trough: Acad. Nauk SSSR, Doklady, v. 227, no. 1, p. 176-179 (in Russian). Authors at All-Union Sci. - Research Inst. of Min. Raw Mat., Moscow.

Stratiform fluorite deps. occur in carbonate rocks of Lower Carboniferous age. T_H of G/L incs. in calcite (deps.: Zhurskoe, Dodonovskoe, Vypasnoe, Vilenskoe, and Mokrushinskoe) ranges from 95 to 180°C; in fluorite (deps.: Zhurskoe and Dzhelandakskoe) - 150 to 180°C. Horizontal T zones may be obs.: the lowest T were found in E. part of dep., the highest ones - in W. part. (Abst. by A.K.)

RAJAMANI, V., 1976, Distribution of iron, cobalt, and nickel between synthetic sulfide and orthopyroxene at 900°C: Econ. Geol., v. 71, p. 795-802.

RAJAMANI, V., and NALDRETT, A.J., 1976a, Partitioning of Fe, Ni, Cu and Co between sulfide and silicate liquids (abst.): Geol. Assoc. Canada - Mineral. Assoc. Canada Program with Abstract, v. 1, p. 56. Authors at Department of Geology, University of Toronto, Toronto, Ontario, M5S 1A1.

RAJAMANI, V., and NALDRETT, A.J., 1976b, Experimental modelling for the composition of Ni-Cu sulfide deposits, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 1058-1059. Authors at Dept. of Geol., Univ. of Toronto, Toronto, Ontario M5S 1A1.

(Sulfide immiscibility invoked).

RAJAMANI, V. and NALDRETT, A.J., 1976c, Experimental studies relevant to the formation of magmatic Ni-Cu sulfide ores (abst.): International Geol. Congress, 25th, Abstracts, p. 823. First author at University of Tornoto, 170 College Street, Toronto, M5S 1A1, Canada.

This study suggests that the distribution of Fe, Ni and Cu between immiscible sulfide liquid and silicate magma is a function of the composition of the silicate magma, temperature and fugacities of oxygen and sulfur at the time of segregation of sulfide liquid from the silicate magma. (From the authors' abstract)

RANKIN, A.H., 1976a, Fluid-inclusion studies in apatite from some East African carbonatites, (abst.): Mineralog. Soc. Great Britain Bull. 30, April, 1976, p. 5. Author at Mining Geology Div., Royal School of Mines, Imperial College, London).

Detailed studies of primary fluid-filled cavities in the apatites from carbonatites of the Tororo, Wasaki and Homa complexes of E. Africa reveal that the media from which the apatites crystallized consisted of highly mobile, subcritical and super-critical, alkali carbonate brines. Sodium and potassium were the principal cationic species present in these 'carbonatitic fluids', with sodium slightly in excess of potassium ($Na^+:K^+$ wt. ratios for 9 samples range from 2.4 to 6.0). These observations show that water and alkalis played an important role in the formation of the carbonatites from these complexes.

Recent experimental studies by Malinin and Dernov-Pegarev (Geokhimiya, 1974, p. 454) have shown that at low-temperature (up to 250°C), concentrated alkali carbonate brines can be effective agents in the transport of substantial amounts of calcium carbonate, a fact borne out by the presence of crystalline inclusions of calcite, coexisting with aqueous inclusions in the same apatite crystals from all three complexes studied.

Homogenization temperature (T_H) determinations on the primary aqueous inclusions represent minimum formation temperatures of the host apatites. Over 500 determinations on individual inclusions from 9 separate carbonatite samples gave the following minimum formation temperatures: Limekiln Hill (Tororo), 328°, 321°, 359°; Tororo Rock (Tororo), 353°, 365°; Wasaki & Sokolo complex, 263°, 299°, 411°; and Homa mountain, 299°. (Author's abstract).

RANKIN, A.H., 1976b, Macro fluid inclusions in fluorite from the northern Pennine orefield (abst.): Geological Society-Mineralogical Society (Britain) Symposium on fluid inclusions, Univ. of Durham, Abstracts of meeting (unpaginated), to be published in Trans. I.M.M. Sect. B.

Systematic study of more than 1500 fluorite samples from worldwide localities, housed in the Natural History Museum, London, has revealed the presence of a considerable number of large (>2 mm) fluid-filled cavities. These 'macro fluid inclusions' are most commonly observed in purple or green fluorites from the Weardale area of the northern Pennine orefield, particularly those from two specific localities - Boltsburn mine and Heights mine.

Approximately 4% of the northern Pennine fluorites studied contained macro fluid inclusions. The largest cavity observed contained about 0.25 ml of liquid and had a maximum dimension of 13 mm. The greatest number of macro inclusions in any one sample, a 20-mm cube, was 7 (range of maximum dimension, 3-7 mm).

Attention is drawn to possible factors that control the formation of macro fluid inclusions, and the significance of these trapped portions of ancient mineral-forming fluids is discussed. Data are not yet available on the composition of these fluids but research in this direction is currently being undertaken. (Author's abstract)

RANKIN, A.H., and JACKSON, N.J., 1976, Fluid inclusion studies at St. Michael's Mount: Ussher Soc., Proc., v. 3, pt. 3, p. 430-433. First Author at Dept. Geol., Kings College, London.

Fluid inclusions in quartz and cassiterite from a W-Sn-Cu vein associated with a granite porphyry stock (Cornwall area) were studied. Most inclusions in quartz are L-V; only rarely do they have halite, a small opaque phase (sulfide?), hexagonal platelets (mica?), a birefringent prism (anhydrite?), or a fibrous, pale green phase (dawsonite?). Those in cassiterite are simple L-V. T_H (uncorrected for pressure, which might add pressure correction of 50-100°C): quartz-cassiterite and quartz-wolframite 340-400°C; quartz-stannite 280-300°C; individual cassiterite crystals 400° (core) to 340°C (rim). Inclusions in cassiterite generally are ∿40°C above those in (apparently) cogenetic quartz. On cooling, much metastability was encountered. Inclusions in quartz intergrown with cassiterite had T_{Frz} -3.6 to -16.5°C (mostly -5.5 to -9.5°C) (8-14 wt. % NaCl). P inclusions in cassiterite were between -5.5 and -9.5°C. Bulk crushing and leaching shows Na/K ratios of ∿2, for early portions and ∿14 for later portions of the vein (ER).

RAPP, J.B., 1976, Amino acids and gases in some springs and an oil field in California: Jour. Research U.S. Geol. Survey, v. 4, no. 2, p. 227-232. Author at U.S. Geol. Survey, Menlo Park, CA.

Samples of water and gas were collected from six springs and two wells in the Upper Cretaceous Great Valley sequence and Franciscan Formation underlying the Coast Range of northern California and from four oil wells penetrating Tertiary sedimentary rocks in the Kettleman North Dome oil field. Comparison of the dissolved free amino acid compositions of the waters from the two locations show overlapping ranges with many more similarities than differences. The detection of nonprotein amino acids (sarcosine, β-amino n-butyric acid, and others) indicates the protein degradation is partly chemical rather than strictly biological. Other low molecular weight degradation products (methane, ethane, nonvolatile organic acids, and other organic chelating agents) were found. This may be one mechanism for the transportation of organic matter from the source rocks to the reservoir rocks of an oil deposit. (Author's abstract).

RASUMNY, J., 1974, Prospects for using the Nachet microscope crushing stage for the study of inclusions: Congr. Natl. Soc. Savantes, Sect. Sci., C.R., no. 96, Tome 2 (Geologie, mineralogie), p. 369-373, (in French).

RASUMNY, H.J. et al., 1976, Some aspects of the study of intracrystalline cavities by electronic microscope (abst.): Geological Society-Mineralogical Society (Britain) Symposium on fluid inclusions, Univ. of Durham, Abstracts of meeting (unpaginated), to be published in Trans. I.M.M. Sect. B.

Examination by scanning electron microscopy of lacunae that occur during the growth of crystals of salt deposited by evaporation of natural brine furnishes a means for investigation of those factors that potentially influence the dimensions, morphology, abundance and distribution of these cavities. Comparisons are attempted with minerals of very different genesis. (Author's abstract)

RASUMNY, Janin, BASSETT, A.M., DEICHA, G., 1976, Contribution to the electron microscopic studies of cavities in artificial and natural minerals (abst.): International Geol. Congress, 25th, Abstracts, p. 593. First author at Laboratorie de Geologie Structurale et Appliquee, Universite de Paris-Sud. 91405 Orsay, France.

A new series of electron fractographs have been obtained on halite crystals to investigate the factors ruling the formation of cavities in other kinds of crystalline materials. They vary widely in size, morphology, habit, and abundance. (ER)

REZNITSKIY, L.Z., 1976a, Dynamics of mineral crystallization in phlogopite veins from Sliudianka, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 48-49 (in Russian; translation by A. Kozlowski).

In growth zones of calcite, apatite, phlogopite, scapolite etc., T_H of fluid inclusions varies from 410 to 330°C. Certain zones bear inclusions trapped from boiling solutions; pairs of inclusions are common with homogenization in liquid and in gas, both at T 385-360°C. The solutions have low concentrations of CO_2 and salts. Minerals crystallized at 550-360°C and 1.5-2 kbar to 0.3-0.4 kbar. (From the author's abst.)

REZNITSKIY, L.Z., 1976b, Syngenetic microinclusions of anhydrite in calcites and apatites from phlogopite veins at Slyudyanka (S. Baikaly'ye): Akad. Nauk. SSSR, Doklady, v. 226, no. 2, p. 433-436 (in Russian). Author at Inst. of Earth's Crust of Sib. Div. of Acad. Sci. USSR, Irkutsk.

Anhydrite (ident. by immersion and X-ray methods) in calcite forms euhedral xl incs. 0.1-1 mm long. Calcite contains 0.1-0.5 wt % of anhydrite. Dim. and orientation of anhydrite incs. in calcite are very close to P G/L incs. in the same host min. Morphology of anhydrite is not typical for this min. and points to strong influence of calcite symmetry on anhydrite growth. Apatite contains 0.1 wt % of anhydrite (dim. one to tens µm) as inc., elongated along L_6 of host min. Moreover calcite and quartz incs. in apatite were found all distrib. in distinct zones. Anhydrite also occurs inside G/L incs. Other mins. do not bear anhydrite incs. P G/L incs. in host mins. homog. at 330-410°C (T_D = 360-600°C). At T - 360-385°C some incs. homog. either in L or in G, incs. with T_H = 380-390°C homog. also with crit. phenomena. Soly of $CaSO_4$ in NaCl sols. is also discussed. (Abst. by A.K.).

RICH, R.A. and BARABAS, A.H., 1976, Mineralogy, paragenesis, fluid inclusions, and origin of the Schwartzwalder uranium mine, Jefferson County, Colorado, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 1068. Authors at Hoffman Laboratory, Dept. of Geol. Sciences, Harvard Univ., Cambridge, MA 02138.

Laramide hyd. U min. at the Schwartzwalder mine occurs in veins and breccia zones within Precambrian metasediments. The vein paragenesis consists of three stages: I. adularia-pitchblende-jordisite (amorphous MoS_2)-org. matter; II. ankerite-pyrite/marcasite-minor base metal sulfides; and III. calcite. Within stage I adularia was dep. both prior to and synchronous with pitchblende; jordisite was dep. with and after pitchblende. The org. matter has low reflectivity and low radioactivity; it was apparently dep. before pitchblende and jordisite. One- and two-phase aqueous fluid inc. (L or L+V) were obs. in min. of all three paragenetic stages. The abundance of wallrock hematite and the close assoc. of jordisite and pitchblende with carbonaceous matter suggest that U and Mo were transported in the +6 valence state and that the pption of pitchblende and jordisite followed the reduction of U and Mo to the +4 valence state. This model for the transport and pption of u is geochemically similar to models proposed for the form. of sandstone-type U dep. (Authors' abstract)

RICHET, Pascal and BOTTINGA, Yan, 1976, Theoretical distribution of hydrogen isotopes in the system H_2 - HCl - OH - HCN - H_2O - H_2S - NH_3 - CH_4: Acad. Sc. Paris, Comptes Rend., v. 283, Série D, p. 299-302 (in French). Authors at Lab. Géol. et Cosmo. 4, Place Jussieu 75230 Paris Cedex 05, France.

Equilibrium deuterium fractionation among gaseous molecules of geochemical interest has been calculated for the temperature interval 200 to 1300°C. The calculated results agree well with the few available experimentally determined equilibrium constants. Some geochemical application are discussed. (Authors' abstract)

RIPLEY, E.M., 1976, Oxygen and hydrogen isotopic composition of ore-forming fluids and metamorphic fluids at the Raul mine, Peru, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 1071. Author at Dept. of Geosciences, The Pennsylvania State Univ., State College, PA 16802.

Stratabound cupriferous dep. at the Raul Mine occur in a Late Cretaceous volcano-sed. sequence along the coast of central Peru. Previous studies suggested that the majority of the ores were formed on or near the seafloor at 100-400°C, and underwent subsequent metam. as high as 300-500°C.

Heating and freezing studies of fluid inc. in quartz and calcite from ore units suggest sal. > 30 wt. %. The isotopic and chem. data are interpreted as indicating that both ore-forming and meta. fluids originated from seawater which underwent evaporation in a restricted basin, and subsequent isotopic exchange with country rocks during circulation through the volcano-sed. pile.

Post-met. fluids, represented by water in S fluid inc. in ore material, are much lower in δD (-56 to $-118‰$) and $\delta^{18}O$ ($+5$ to $-2‰$), suggesting an origin by mixing of meteoric water and evolved seawater. (From the authors abstract.)

ROBERTSON, J.M., 1968, Crystal growth from boiling solutions: an experimental study: unpublished MS thesis, Univ. Mich., 53 p.

Crystals of $NaCO_3$ were grown from supersaturated water solution at 65°C (non-boiling) and at 100°C (actively boiling conditions) and their inclusions compared. About 11% of the inclusions grown from boiling solutions contained too-large vapor bubbles (ranging up to 100% vapor). Considerable metastable stretched liquid was encountered at both temperatures (ER).

ROBINSON, B.W. and INESON, P.R., 1976, Oxygen, sulphur and carbon isotopes in the origin of the galena-barite-fluorite deposits, Derbyshire, UK (abst.): International Geol. Congress, 25th, Abstracts, p. 183-184. First author at Inst. Nuclear Sciences, DSIR, Lower Hutt, NZ.

Mississippi valley-type mineralisation occurs in massive L. Carboniferous limestones as genetically related stratiform and cross-cutting bodies. The limestones contain intercalated basic lavas and tuffs (toadstones) and are unconformably overlain by U. Carboniferous Edale shales. Both shales and toadstones have been important in determining the form of the ore bodies. Most deposits are confined to the top 50 m of limestone below the shales. Structurally, the area forms the S. Pennine dome, which is actually a complex of fairly gentle folds with a general east-west trend rising to a north-south line of culmination.

The dominant primary ore minerals are galena, fluorite, barite and calcite, with minor quartz, pyrite, sphalerite and chalcopyrite. Mineral zonation occurs, as in the N. Pennines, with fluorite (hottest zone) in the east and barite, then calcite, to the west. Galena is evenly distributed and sphalerite diminishes westwards. East of the ore field, two limestone inliers are mineralised and minor barite-galena veins occur at Whitwell in Permian Magnesian Limestone. Radiometric dating of the Derbyshire ores suggests Lower and Upper Permian episodes of mineralisation and the Permian and Carboniferous Deposits are thought to be closely related.

Primary galena, barite and calcite samples were collected from fifty localities in the ore field, inliers and Whitwell.

The isotopic compositions of: oxygen and sulphur in barite, oxygen and carbon in calcite and limestones, and sulphur in sulphides were measured as permil deviations from SMOW for oxygen, PDB for carbon, and CDT for sulphur. The galena $\delta^{34}S$ values range from -23.2 to +6.6‰, with a trend to increasing values eastwards. Within crystal variations do not exceed 3‰. In banded galena-barite samples, and vein samples where paragenetically early and late galena can be distinguished, the $\delta^{34}S$ values increase markedly with time. The isotopic compositions of the barites ($\delta^{34}S$ +4 to +23‰, $\delta^{18}O$ +9 to +26‰) do not change with time, but the barite $\delta^{34}S$ values tend to increase eastwards. In contrast, barites from the N. Pennines and Ireland group at around +19‰ and +13‰ for $\delta^{34}S$ and $\delta^{18}O$, respectively. Derbyshire samples, when plotted as $\delta^{34}S$ versus $\delta^{18}O$, group in linear arrays with best fit straight line slopes of about 0.7 (0.5 for Whitwell). Experimental isotope calibration curves can be used to show that the barites precipitated in isotopic equilibrium with the ore fluid and reduced sulphur in solution (H_2S or HS^-) with temperature variations (about 50 to 150°C) causing the linear isotopic variations. In addition, changes in the isotopic compositions of the ore fluid and reduced sulphur with location explain the multiple lines and could be caused by the mixing of two ore fluids and/or two reduced sulphur sources. The isotope data also suggest that connate Mississippian sea water was the sulphate source; its isotopic composition changing in response to temperature variations and mixing.

Barite-galena mineral pairs give isotopic temperatures 200-400°C higher than published fluid inclusion filling temperatures (80-140°C for fluorite). The galena possibly formed from different reduced sulphur to that which equilibrated with the barite. Two reduced sulphur sources, one biogenic light sulphur and one deeper seated heavier sulphur, probably interacted. Oxygen isotope data on a banded calcite-barite sample suggest that two ore fluids were present, at least one of which was of ultimate meteoric origin. Carbon isotope values of vein calcite and limestones lie between +1 and +4‰; the normal range for marine limestones. Thus carbon is derived from the limestones without isotopic fractionation. No systematic oxygen isotope changes were observed in the limestones adjacent to the veins.

Many differences in the mineral isotopic compositions of the Derbyshire ores and those of comparable deposits in the N. Pennines, Ireland, the U.S.A., and Canada, are apparent. Some of the isotope trends are unique to the Derbyshire area and reflect a high degree of interaction between fluids and components from different sources. (Authors' abstract)

ROCK, N.M.S., 1976, The role of CO_2 in alkali rock genesis: Geological Magazine, v. 113, p. 97-113.

ROEDDER, Edwin, 1976a, Fluid-inclusion data on the environments of sedimentary diagenesis--a review, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 2, p. 258. Author at U.S.G.S., Reston, VA 22092.

Most sed. diagenesis involves rexliz. or overgrowths on original min., or the growth of new phases. This new growth may trap fluid as inc. that provide data not only on the nature, comp., P, and d. of the fluids present during diagenesis, but particularly on the T at which the host xls grew. As most optical methods of study require inc. >1-2μm in diam., fine-grained products of diagenesis, in the 10-20μm range, seldom provide useful material. The possibilities of finding inc. of useful size increase with the size of the host xl. In spite of these limitations, reasonably valid quan. or qual. phy. and chem. data, both new and from the lit., have been obtained on inc. from the following specific diagenetic envir.:

1) xl-lined vugs in carbonate rocks (e.g., from Clay Center, Ohio, and Herkimer County, New York);
2) calcite cement in detrital carbonate rocks;
3) bedded halite and other saline dep.;
4) petroleum reservoir rocks;
5) Mississippi Valley-type ore dep. in carbonate or sandstone;
6) geodes and min. fossils;
7) sed. U and barite dep.; and
8) sphalerite in bituminous coal beds from the Illinois basin.

Most inc. T in these various envir. range from 150° to 25°C, and the fluids are generally saline brines which commonly contain petroleum and up to tens of atm. of methane-rich gas. T_H of inc. in some Mississippi Valley-type ore dep. are higher than 150°C but seldom exceed 200°C.

ROEDDER, E., 1976b, Fluid inclusions in New Lead belt ores from Missouri (abst.): U.S. Geol. Survey Prof. Paper 1000, p. 3.

Fluid inclusions in a suite of ore samples from the New Lead belt in Missouri ("the Viburnum trend"), supplied in part by the St. Joseph Lead Company, St. Joseph, MO. were studied. This material contained few fluid inclusions suitable for study, but over 100 small inclusions were located in sphalerite from several mines. Much metastability was encountered in freezing studies. With few exceptions, all inclusions had freezing temperatures in the range -20° to -28°C, which correspond to those of very saline brines. Homogenization temperature ranged from 82° to 145°C. These results are very similar to those obtained on inclusions from many other Mississippi Valley-type deposits and indicate that the New Lead belt, although different from other Mississippi Valley-type deposits in several important features, was deposited by the same type of hot saline brines. (Author's abstract).

ROEDDER, E., 1976c, Petrologic data from experimental studies on crystallized silicate melt and other inclusions in lunar and Hawaiian olivine: Amer. Min., v. 61, p. 684-690. Author at 959 U.S. Geol. Survey, Reston, VA 22092.

Full paper corresponding to abstract given in Fluid Inclusion Research, v. 8, p. 153 (Roedder, 1975a). (ER).

ROEDDER, Edwin, 1976d, Fluid-inclusion evidence on the genesis of ores in sedimentary and volcanic rocks, chapter 4, p. 67-110 in Handbook of Strata-bound and Stratiform Ore Deposits, K.H. Wolf, ed.: Amsterdam, Elsevier Pub. Co.

A review (122 references) of the subject, dealing mainly with the Mississippi Valley-type ores, and to a lesser degree, with the Kuroko-type, and covering also the basic assumptions and significance of the various types of data available from inclusions. Actual T_H and T_{Frz} data from the literature and unpublished sources are summarized in a table. Includes a detailed table of criteria for evaluating a primary vs pseudosecondary vs secondary origin for inclusions and a 10-page section on laboratory technique -- sample selection, cutting and polishing, choice of inclusions and problems in microscopy, and heating and cooling stages and their operation. (ER)

ROGERS, P.J., 1976, Preliminary fluid inclusion studies on fluorite from the Derbyshire orefield (abst.): Geological Society-Mineralogical Society (Britain) Symposium on fluid inclusions, Univ. of Durham, Abstracts of meeting (unpaginated), to be published in Trans. I.M.M. Sect. B.

Preliminary data were gathered for comparative purposes with other mineralized areas of the Pennines. It is presented to assist in the interpretation of possible genetic models for the Derbyshire mineralization.

Fluorite samples from 29 localities yielded mean homogenization temperatures in the range 103-165°C (corrected for pressure). Freezing studies indicated the ore-forming fluid to have a mean salinity range of 18-24 eq. wt % NaCl. Semi-quantitative analysis of leachates from crushed fluorite showed the presence of a potassium-enriched fluid, compared with modern formation waters, but potassium-deficient fluids compared with data from Askrigg and Alston Blocks. (Author's abstract)

ROSASCO, G.J. and ROEDDER, Edwin, 1976a, Application of a new laser-excited Raman spectrometer to nondestructive analysis of sulfate in individual phases in fluid inclusions in minerals, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 1075. First author at U.S. Natl. Bureau of Standards, Washington, DC 20234.

A shorter version of abstract of talk presented at IGC, Sydney, 1976 (See Fluid Inclusion Research - Proceedings of COFFI, v. 8, p. 156-157). (ER)

ROSASCO, Gregory and ROEDDER, Edwin, 1976b, Application of a new laser-excited Raman spectrometer to nondestructive analysis of sulfate in individual phases in fluid inclusions in minerals (abst.): International Geol. Congress, 25th, Abstracts, p. 812-813. Abstract published in Fluid Inclusion Research, v. 8, p. 156-157 (1975).

ROSE, A. W., 1976, The effect of cuprous chloride complexes in the origin of red-bed copper and related deposits: Econ. Geol., v. 71, p. 1036-1048.

Geol., min., and isotopic data indicate that red-bed copper dep. are introduced into their host rocks after sed. by flowing subsurface waters approximately in equil. with hematite, quartz, feldspar, and mica at Ts less than about 75°C. (From the author's abstract)

ROSSOVSKIY, L.N., CHMYREV, V.M., EREMENKO, G.K. and AKBAR, MIR, 1976, Geology and conditions of formation of spodumene deposits from Hindukush (Afghanistan): Geol. Rudn. Mest. v. 18, no. 6, p. 19-33 (in Russian). First author at Krasnoyarsk Div. of Sci. - Research Inst. of Geol. Geoch. Min. Raw Mat., Krasynoyarsk.

Lit. data on incs. in mins. from rare-metal pegs., p. 30-31. (A.K.).

RUTHERFORD, M.J., HESS, P.C., RYERSON, F.J., CAMPBELL, H.W., and DICK, P.A., 1976, The chemistry, origin and petrogenetic implications of lunar granite and monzonite: Proc. Lunar Sci. Conf., 7th, p. 1723-1740. Authors at Geol. Dept., Brown Univ., Providence, R.I.

Considerable discussion of the petrology of silicate liquid immiscibility. (ER).

RUTHERFORD, N.F., 1976, Petrochemistry of ignimbrites from the central North Island and Coromandel, New Zealand: PhD Dissert., Univ. Auckland, 208 pp. plus approx. 200 pp. Appendices.

Ignimbritic eruptives (21; SiO_2-63 to 76%), both welded and non-welded, were studied by a variety of procedures. Various geothermometers were applied, indicating quench temperatures of <765 to >820°C. Phenocryst assemblages suggest eruption from 10-15 km. Fugacity of gas species in system H-O-S estimated (as range of -log f_{gas}) O_2 10/16; H_2 -1.8/-0.6; S_2 1.8/4.3; SO_2 0.5/3.7; SO_3 6.9/11.1; H_2S -1.8/0.5. P_{H_2O} ranged from 1/2 P_{total} to P_{total} at time of eruption (2-5 kb P_{H_2O}). Melts formed from greywacke at >1000°C at P>3 to 5 kb, presumably at 20-25 km, as relatively dry melts, and acquired water (4-6% by wt) on rising in crust. Heat came from primary basic (basalt-andesite) magmas at 1300-1400°C which could produce 1.5-3x their volume of greywacke melt. Hundreds of analyses, by XRF and wet chemistry, and by electron microprobe for phenocrysts. Got pyrrhotite inclusions in titanomagnetite and pyroxene phenocrysts from immiscibility (p. 50). Embayed quartz from apparent resolution. Some daughter crystals illustrated. Silicate melt inclusions compared with 5 other thermometers (p. 80 on). On heating bubble decreased but opacity developed at ∿576°C precluding T_H determinations. (ER).

RYE, R. O., SCHUILING, R. D., RYE, D. M. and JANSEN, J. H., 1976, Carbon, hydrogen, and oxygen isotope studies of the regional metamorphic complex at Naxos, Greece: Geochim. Cosmo. Acta, v. 40, p. 1031-1049. First author at Branch of Isotope Geology, U.S. Geological Survey, Federal Center, Denver, CO 80225.

At Naxos, Greece, a migmatite dome is surrounded by schists and marbles of decreasing meta. grade. Sillimanite, kyanite, biotite, chlorite, and glaucophane zones are recognized at successively greater distances from the migmatite dome. Quartz-muscovite and quartz-biotite O isotope and min. Ts range from 350 to 700°C.

The meta. complex can be divided into multiple schist-rich (including migmatites) and marble-rich zones. The $\delta^{18}O$ values of silicate min. in migmatite and schist units and quartz segregations in the schist-rich zones decrease with increase in meta. grades. The cal. $\delta^{18}O_{H_2O}$ values of the meta. fluids in the schist-rich zones decrease from about 15‰ in the lower grades to an average of about 8.5‰ in the migmatite.

The δD values of OH-minerals (muscovite, biotite, chlorite, and glaucophane) in the schist-rich zones also decrease with increase in grade. The cal. δD_{H_2O} values for the meta. fluid decrease from -5‰ in the glaucophane zone to an average of about -70‰ in the migmatite. The δD values of water in fluid inc. in quartz segregations in the higher grade rocks are consistent with this trend.

The $\delta^{18}O$ values of silicate min. and quartz segregations in marble-rich zones are usually very large and were controlled by exchange with the adjacent marbles. The δD values of the OH min. in some marble-rich zones may reflect the value of water contained in the rocks prior to meta.

Detailed data on 20 marble units show systematic variations of $\delta^{18}O$ values which depend upon meta. grade. Below the 540°C isograd very steep $\delta^{18}O$ gradients at the margins and large $\delta^{18}O$ values in the interior of the marbles indicate that O isotope exchange with the adjacent schist units was usually limited to the margins of the marbles with more exchange occurring in the stratigraphic bottom than in the top margins. Above the 540°C isograd lower $\delta^{18}O$ values occur in the interior of the marble units reflecting a greater degree of rexliz and the occurrence of Ca-Mg-silicates.

Almost all the $\delta^{13}C$ values of the marbles are in the range of unalt. marine limestones. Nevertheless, the $\delta^{13}C$ values of most marble units show a general correlation with $\delta^{18}O$ values.

The CO_2/H_2O mole ratio of fluid inc. in quartz segregations range from 0.01 to 2. The $\delta^{13}C$ values of the CO_2 range from -8.0 to 3.6‰ and indicate that at some localities CO_2 in the meta. fluid was not in C isotopic equil. with the marbles. (Authors' abstract)

SABOURAUD, Christiane, 1976a, The conditions of formation of certain types of intracrystalline cavities, as elucidated by experiment: Bull. Soc. Fr. Minéral. Cristallogr., v. 99, p. 74-77 (in French). Author at Labo. Géol. E.N.S.G., 46 rue d'Ulm, 75005 Paris, France.

On the basis of observations on crystals of natural gypsum and synthetic gypsum, correlations are made between the formation medium and the internal aspect of the intracrystalline cavities. First, the form of the inclusions may depend on the included solution. Very great differences are found in the frequency and the dimensions of cavities in synthetic gypsums formed from $CaSO_4$-H_2O solutions and those formed from $CaSO_4$-NaCl-H_2O. When the mother solution is diluted (to vary the concentration of NaCl), primary v-shaped alignments of inclusions are reproduced experimentally. This type of experiment can be invoked (to explain) sedimentary minerals which have not undergone advanced diagenesis and in which the cavities could not have been subjected to the type of transformation cited by Roedder (COFFI, 1968, p. 4). This method can indicate the growing medium of minerals with crystallization cavities too small to be studied by microthermometry, in particular in sedimentary rocks. (Abstract by M. Pagel, translated by Chris Eastoe).

SABOURAUD-ROSSET, Christiane, 1976b Solid and liquid inclusions in gypsum: Thèse d'Etat, Univ. Paris Sud, Centre d'Orsay, 173 pp., 23 plates. Author at Lab. de Géol., Ecole Normale Supérieure, 16, rue d'Ulm, 75005, Paris, France (in French).(Brief abstract in v. 8, p. 160).

Occurrences ot gypsum have permitted the study of inclusions trapped at low temperature:

Authigenic solid inclusions: (1) the identification of original, primary gypsum seeds in recrystallized "lark's foot" (pieds d'alouette) crystals confirm the authigenic formation of gypsum as well as the importance of gypsum in crusts formed in present-day salt marshes. (2) Authigenic quartz contemporaneous with gypsum grew from biologic nuclei (pollen) and developed perfect bipyramidal crystal forms. (3) Fluorite of evaporitic origin was trapped on the growing faces of gypsum crystals. (4) Other authigenic minerals forming at the same time as gypsum include calcite, anhydrite, and pyrite.

Intercrystalline cavities: The morphology and the distribution of cavities in synthetic and natural gypsum were compared. Varying fluid concentrations lead to the formation of cavities in a synthetic gypsum which are similar to those frequently observed in ancient gypsum.

Study of included fluids: Homogenization temperatures for Quaternary gypsum are climatic indicators: 26°C, Chile; 42°C, Sahara; 32°C, Morocco. For gypsum synthesized at 50° and 60°C the percentage of inclusions at equilibrium at 20°C varied between 0 and 88%, depending on the formation temperature and the cavity dimensions. Thermal shock (avoiding fracturing due to cooling) and ultrasonic treatment were used to try to make the vapor bubble appear in metastable one-phase inclusions. These methods were sometimes effective, but the overall success rate was low. The deposition of salts on the cavity walls was observed to change homogenization temperatures in successive determinations on the same inclusion. The evolution of salinities of fluids (measured with the cooling stage) trapped in marine gypsum toward fresh water compositions indicates important contributions from meteoric waters. Neutron activation analyses of Cl/Br ratios were made in 1971-1972. Samples were crushed after irradiation in order to reduce the risk of contamination.

Interpretation of the sedimentary origin of recent gypsum: Fluids trapped during the growth of gypsum by evaporation of $CaSO_4$ solutions with and without NaCl, and of sea water, have equivalent salinities, as determined by microthermometry, consistent with the actual salinities. A histogram of inclusion salinities for gypsum from the Aigues-Mortes salt marsh is similar to that for gypsum synthesized from sea water (0-23 wt% equiv. NaCl). Secondary effects have modified the salinity distribution of inclusions in gypsum from the Bourg-de-Batz salt marsh. In both cases the Cl/Br ratio remained close to that of sea water (300). Thus the circulation of late-stage fresh waters affects the salinity distribution but not the Cl/Br ratio. Gypsum from a mangrove marine salt marsh contained fluids with a salinity distribution similar to that of unaltered Aigues-Mortes marine gypsum. The Cl/Br ratios of 157 and 206, however, are due to bromine enrichment from abundant organic material. Fluids in gypsum from a coastal sabkha (Tunisia) are saturated or supersaturated with NaCl of marine origin, as confirmed by the Cl/Br ratio of 194 (Cl ions are trapped by halite). Inclusions in samples from a continental sabkha (Sahara) contain at least 23 wt.% equiv. NaCl, since hydrohalite always formed during cooling. Recrystallized gypsum from an Oligocene bed contains fresh water. In Alpine gypsum of Triassic age salinities of 3 wt % equiv. NaCl and Cl/Br ratios of 1160 (normal for this type occurrence) are found.

Interpretation of the origin of ancient gypsum: In the Eocene of the Paris Basin some cavities still containing concentrated brines have been found (15-18 wt % equiv. NaCl at Cormeilles-en-Parisis and 16 wt % at Vaujours). The Cl/Br ratio is 233 in the former deposit. The fluid from which the "lark's foot" gypsum from Portel (Oligocene, southeastern France) formed was less concentrated and lower in bromine content (Cl/Br = 630) than the Paris Basin gypsum. Fluids from Mazan have maximum salinities of 9 wt % equiv. NaCl and Cl/Br = 380. Salinities of fluids from the Miocene of Sicily are similar but the average Cl/Br is 175. These results show that ancient gypsum can often be genetically linked to a marine environment. (Author's abstract modified and translated by A. Barabas).

SADAGHYANI-AVAL, Firouz, 1976, Geological study of the Khal-Eh-Zari mine region, Iran: Mineralization and fluid inclusions: Thèse, Université Nancy I, 165 p. (in French).

One chapter (p. 100-146) is devoted to fluid inclusions in quartz veins, studied by microthermometry and mass spectrometry. A late stage (post copper mineralization), has uniquely aqueous fluid (1.5-3 wt. % equiv. NaCl) with homogenization temperatures between 120 and 400°C. Average values for individual samples ranged from 190 to 312°C with the highest averages for surface samples. (Abstract by M. Pagel, translated by A. Barabas).

SAINTIVES, J. P., 1976, Some morphological aspects of solids trapped in inclusions in pegmatitic quartz revealed by the scanning electron microscope: Bull. Soc. Fr. Minéral. Cristallogr., v. 99, p. 178-181 (in French). Author at Départment de Géologie Appliquée, Université Pierre et Marie Curie, 4 Place Jussieu, 75230 Paris Cedex 05, France.

SAL'NIKOVA, R.N., 1976, Main features of antimony-mercury formation of Central Tadzhikistan: Geol. Rudn. Mest., v. 18, no. 2, p. 23-33 (in Russian). Author at Methodic Expedition for Geol.-Econ. Research of Geol. Office of Ministry Board of Tadzhik SSR, Dushanbe.

Beginning of ore-forming process is connected with metasom. alt. of wall rocks by sols. at T = 420-380°C. Individual types of deps. formed at Ts as follows: Magianskaya group - quartz-zinkenite-sphalerite-antimonite and quartz-heteromorphite-sphalerite-antimonite - 320-290°C; quartz-dickite-antimonite, quartz-antimonite, quartz-fluorite-antimonite, quartz-calcite-antimonite and quartz-calcite-cinnabar - 270-150°C; Yagnobskaya group - quartz-tetrahedrite-sphalerite-galena-antimonite - 260-160°C, quartz-antimonite and quartz-calcite-antimonite-cinnabar - 250-110°C, fluorite - 195-50°C. (Abst. by A.K.)

SANBORN, W.B., 1976, Oddities of the mineral world: New York, Van Nostrand Reinhold Co.

Includes discussions of inclusions and geodes (p. 41, 44, 51-54). The oil-filled geodes of Niota, Illinois were found by S.R. Silverman of Standard Oil of Calif. Research to be typical of Illinois crude oils in isotopic composition. (ER)

SAWKINS, F.J. and RYE, R.O., 1976, The Messina copper deposits, Republic of South Africa: ore genesis associated with an intra-continental rift zone, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 1086-1087. First author at Dept. of Geol. and Geophysics, Univ. of Minnesota, Minneapolis, MN 55455.

Studies of fluid inc. in quartz assoc. with late Cu min. indicate that the ore was dep. from low-T (130-210°C), variable-sal. (1-26 equiv. wt. % NaCl), low CO_2 fluids at a probable depth of less than 1 km. δD values of water in fluid inc. have a narrow range (-44 ± 5 permil). $\delta^{18}D$ values of quartz, however, are variable (10.9 to 15.8 permil). Calc. $\delta^{18}O$ values of water in the fluids range from -2.1 to -6.7 permil and, within the limits of sampling tech., do not correlate with T or sal. data. $\delta^{34}S$ values of all sulfides range from 0.0 to -3.4 permil.

Geol. and geochem. data are consistent with a genetic model of ore generation entirely by meteoric hyd. systems activated by underlying alkali intrusives. We consider rift basalts as likely sources of the Cu and S, and saline lake dep., typical of such environments, as possible sources of the salts in the ore fluids. (From the authors' abstract)

SCHOLLE, P.A., 1976, Chalk diagenesis as a burial depth indicator, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 2, p. 261-262. Author at U.S.G.S., 955 Natl. Center, Reston, VA 22092.

SCHWARCZ, H.P., HARMON, R.S., THOMPSON, Peter, and FORD, D.C., 1976, Stable isotope studies of fluid inclusions in speleothems and their paleoclimatic significance: Geochimica et Cosmochimica Acta, vol. 40, pp. 657-665. First author at Department of Geology, McMaster University, Hamilton, Ontario, Canada.

Fluid inc. found trapped in speleothems (cave dep. travertine) are interpreted as samples of seepage water from which enclosing calcium carbonate was dep. The inc. are assumed to have preserved their D/H ratios since the time of dep. Initial $^{18}O/^{16}O$ ratios can be inferred from δD because rain- and snow-derived seepage waters fall on the meteoric water line ($\delta D = 8\delta^{18}O + 10$). Est. of T of dep. of the carbonate can be calc. from incl. D/H ratios and $\delta^{18}O$ of enclosing calcite in Pleistocene speleothems. For most speleothems invest. (0-200,00 yr old) $\delta^{18}O$ of calcite appears to have decreased with increasing T of dep. indicating that the dominant cause of climate-dependent change in $\delta^{18}O$ of calcite was the change in K_{cw}, the isotope fract. equil. constant, with T: $\delta^{18}O$ of meteoric pption generally increased with increasing T, but not sufficiently to compensate for the decrease in K_{cw}.

SEWARD, T. M., 1976, The stability of chloride complexes of silver in hydrothermal solutions up to 350°C: Geochim. Cosmo. Acta, v. 40, p. 1329-1341. Author at Institut für Physikalische Chemie und Elektrochemie, Universität Karlsruhe, Kaiserstrasse 12, 75 Karlsruhe, W. Germany.

It is concluded that chlorosilver (I) complexes ($AgCl_2^-$) play an important role in the transport and dep. of silver from hyd. ore sol. (From the author's abstract)

SHANKS, W.C. and BISCHOFF, J.L., 1976, Ore transport and deposition in the Red Sea geothermal system, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 1101. First author at Geol. Dept., Univ. of California, Davis, CA 95616.

SHAPENKO, V.V., 1976, Themobaric-geochemical reconstruction of the mineralization conditions in the Kholtoson tungsten field (Western Transbaikal region): Vestnik Moskovskogo Universiteta, Geologiya, v. 31, no. 2, p. 123-125 (in Russian); translated in Moscow Univ. Geol. Bull., v. 31, no. 2, p. 100-101, Allenton Press, Inc.)

The Kholtoson tungsten deposits occupy the western flank of the Dzhida ore field and are represented by a series of extended (hundreds of meters) steeply dipping quartz-hubnerite-sulfide-rhodochrosite veins in Paleozoic diorites. T_H of various vein minerals was as follows: quartz of quartz-hubnerite veins 150-340°C; microcline 280-310°C; hubnerite 200-280°C; fluorite 110-275°C; rhodochrosite 280°C; triplite 240-250°C; sphalerite 240-245°C; and calcite 230-240°C. Liquid CO_2 is present in quartz, hubnerite, rhodochrosite and fluorite. Up to 3 daughter crystals were seen, which did not dissolve on reheating for 4 hours at 30 above T_H. These crystals were calcite, based on optics. Quartz-molybdenite veinlets contain H_2O, CO_2 and salt, with T_H 300-400°C. Pre-ore granite porphyry dikes have glass inclusions and highly concentrated brine inclusions with halite, sylvite, a hexagonal ore mineral, and numerous unidentified phases. All inclusions homogenized in the liquid phase "so pneumatolysis is not involved". (ER)

SHARBATYAN, P.A., MILOVSKIY, A.V., and LOBANOVA, G.M., 1975, Bitumens and organic compounds of mercury in cinnabar ores: Geol. Rud. Mestorozhd., v. 17, no. 3, p. 110-113 (in Russian).

SHATOV, V.V., 1976, Problem of source of ore substance of rare-metal - polymetal deposits: Zapiski Vses. Mineral. Obshch., v. 105, no. 6, p. 687-697 (in Russian). Author at All-Union Sci.-Research Geol. Inst. (VSEGEI), Leningrad.

Pertinent to the geochemistry of ore-forming fluids. (A.K.)

SHCHEPOT'EV, Yu. M. and ANDRUSENKO, N.I., 1976, Genetic features of near-surface gold and mercury deposits of Kamchatka: Int. Geol. Rev., Sept. 1976, p. 1059-1066.

Abstracted from original Russian in Fluid Inclusion Research, v. 8, p. 163-164 (ER).

SHCHERBAN', I.P. and GIBSHER, N.A. , 1976, Role of paleotemperature gradients in formation of pyrite-polymetallic deposits, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 37-38 (in Russian; translation by A. Kozlowski).

1. Pyrite-polymetallic deposits of Rudnyi Altai and other provinces have similar ore composition and zoning, but clear differences appear in wall-rock metasomatism - anthophyllite and carbonate-free sericite-chlorite, listvenite-berezite and argillite.

2. Hydrotherms, forming these metasomatites, had similar composition but they differed in P, T and pH, as well as in paleotemperature gradients. Maximum T of formation of deposits with anthophyllite metasomatites was 550°C at P ~ 800-1000 atm and paleotemperature gradients of 15-20°C/100 m; with carbonate-free metasomatites T~420°C, P~1500 atm; with listvenite-berezites T~380°C, P~600-800 atm, gradient 10-12°C/100 m; with argillites T~300°C, P~50-60 atm, gradient 40°/100 m.

3. Zoning is determined by a limited number of hydration reactions of Mg-Fe-alumosilicates and carbonatization on boiling of hydrotherms. At 550-420°C only carbonate-free anthophyllite and chlorite-sericite metasomatites form; when gradient is 15-20°/100 m, they alter into listvenite-berezites in upper levels, but when gradient is 30-40°C/100 m - they alter into argillites.

4. Commercial ores form below 350°C. Most prospective deposits formed with a gradient ∿ 10-12°C/100 m; deposits with gradient ∿ 40°C/100 m ought to develop over a smaller vertical interval and they have less uniform distribution of ore components. (Authors' abst.)

SHCHERBAN, I.P., DOLGOV, Yu.A., BOROVIKOVA, G.A. and GIBSHER, N.A., 1976, Physico-chemical conditions responsible for formation of Tishinsk cinnabar-polymetal deposit in Rudni Altai: Akad. Nauk SSSR, Sib. Otdel., Geol. i Geofiz., 1976, no. 12, p. 46-56 (in Russian with English abstract).

Physico-chemical conditions of formation of Tishinsk cinnabar-polymetal deposit have been examined. The changes in the altering carbonate-free quartz-sericite-chlorite metasomatites are discussed as well as their causes, the latter have been developed in the roots of deposits, also by metasomatites of listvenite-beresite rock series from the upper parts of the deposit. (Authors' abstract). Nine quantitative inclusion gas analyses for acid gases, CO_2, CO, H_2 and N_2 are listed, plus 3 qualitative analyses of salts in solution. T_H ranges from 200 to 380°C maximum for various stages (ER)

SHEPHERD, T.J., 1976, Fluid inclusion characteristics of the Witwatersrand Au-U ores and their mineral exploration potential (abst.): Geological Society-Mineralogical Society (Britain) Symposium on fluid inclusions, Univ. of Durham, Abstracts of meeting (unpaginated), to be published in Trans. I.M.M. Sect. B.

Fluid inclusions, preserved in quartz pebbles of the uraniferous and auriferous Precambrian oligomictic conglomerates of the

Witwatersrand basin, provide a unique insight into the genesis of the ores. By use of differences in inclusion characteristics in conjunction with intra- and inter-deformational textures for adjacent pebbles, a distinction is made between pre- and post-depositional inclusions. With the exclusion of those related to subsequent brittle fracture, the former comprise five principal types, two of which are distinguished by the development of liquid carbon dioxide. Collectively, they indicate a moderate to high pressure--temperature environment of vein quartz formation. Systematic variation in the relative abundance of these inclusion assemblages for different sections of the orefield demonstrate the importance of well defined provenance areas or multiple entry points into the basins. A marked sympathetic relationship between uraniferous banket ores and the presence of vein quartz, rich in liquid carbon dioxide inclusions, together with a corresponding antipathetic relationship for gold, strongly suggests separate sources for the metals. The temporal and spatial aspects of the U-CO_2 association also imply a uranium influx into the basin from discrete areas of the hinterland comtemporaneous with the sediments. Post-depositional inclusions are subordinate and offer no support for the alternative epigenetic model and show only later interaction of relatively cool circulating groundwaters. The probable nature and origin of uranium in the source rocks and its mode of transportation is discussed. A concluding proposal is made for the use of applied fluid inclusion research in the evaluation of and exploration for similar deposits. (Author's abstract)

SHEPARD, T.J., BECHINSALE, R.D., RUNDEL, C.C. and DURHAM, J., 1976, Genesis of Carrock Fell tungsten deposits, Cumbria: fluid inclusion and isotopic study: Inst. Min. and Metallur., Trans., Sect. B, Applied Earth Sci., v. 85, p. B63-B73.

Based on a combined fluid inclusion, oxygen isotope and K-Ar age study of the Carrock Fell tungsten deposits, their genesis and relationship to the Skiddaw granite are discussed. The results indicate extensive alteration of the granite soon after emplacement (390 m.y.) and contemporaneous mineralization by chemically similar fluids (moderately saline NaCl brines, enriched in tungsten and peridocally charged with CO_2). The data also suggest a significant interaction between the granite and isotopically light water of probable non-magmatic origin under the same pressure-temperature conditions as for the mineralization (800 bars; 250-300°C). K-Ar ages for coexisting chlorites and muscovites indicate that chlorite ages are systematically too young, and do not record the time of mineralization as closely as the muscovite ages.

A model of ore genesis is presented which is analogous to the water-rock interaction model proposed for the porphyry coppers. The implications and recommendations for future exploration in the area are considered, with particular reference to the tungsten enrichment in the granite enclosing the zone of known mineral veins. (Authors' abstract). Neutron activation analysis was used for Cl, Br and I and X-ray fluorescence analysis for SO_4 (ER)

SHEPPARD, S.M.F. and GUSTAFSON, L.B., 1976, Oxygen and hydrogen isotopes in the porphyry copper deposit at El Salvador, Chile: Econ. Geol., v. 71, p. 1549-1559.

$\delta^{18}O$ and/or δD values were measured for quartz (11 samples), plagioclase (3), K-feldspar (3), biotite (4), hornblende (1), sericite (3), chlorite (1), kaolinite (2), and pyrophyllite (1) from the porphyry copper deposit at El Salvador, Chile. The samples analyzed were chosen to represent the hypogene evolution from early K-silicate alteration and quartz veining to late pyritic veining and sericitic alteration to very late advanced argillic alteration, as well as supergene kaolinization.

The isotopic compositions of the biotites are identical to those from most other porphyry copper deposits, and the sericite compositions are similar to those from Santa Rita. The requirements for equilibrium isotopic geothermometry are met only for unmineralized "L" Porphyry and K-silicate alteration assemblages, yielding minimum temperatures of about 650°C and 525°C, respectively. Temperatures estimated from various other geologic evidence are used to calculate the equilibrium isotopic compositions of hydrothermal solutions. These solutions show a distinct trend of ^{18}O depletion and deuterium enrichment from early to late stages and from high to low temperatures. The $\delta^{18}O$ and δD values of fluids responisble for Early K-silicate alteration assemblages are similar in isotopic composition to magmatic waters but are enriched in deuterium relative to the later unmineralized "L" Porphyry even though it is petrologically similar to the earlier mineralized porphyries. Later fluids are dominantly meteoric waters enriched in ^{18}O by reaction with the host rock. Late and presumably shallow advanced argillic assemblages developed from acid geothermal waters of meteoric origin that were enriched in deuterium and ^{18}O by near-surface evaporation processes. There was possibly some mixing between these fluids and the deeper meteoric-hydrothermal fluids. The similar isotopic compositions of both meteoric and magmatic waters and the variety of possible processes modifying their isotopic compositions prevent a quantitative analysis of the relative proportions of each at the different stages in the evolution of the hydrothermal fluids (Authors' abstract).

SHETTLE, D.L., Jr. and OHMOTO, H., 1976, Oxygen isotopic fractionation between H_2O and hydrous silicate melts, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 1105. Authors at Dept. of Geosciences, The Pennsylvania State Univ., University Park, PA 16802.

O isotopic exchange exper. between H_2O and H_2O-sat. silicate melts were conducted at 800° and 900°C and 2 and 5kb. These data suggest significant isotopic effects on ign. min. and mag. fluids during fract. xliz of hydrous magmas. (From the authors' abstract)

SHIKAZONO, Naotatsu, 1976, Thermodynamic interpretation of Na-K-Ca geothermometer in the natural water system: Geochemical Journal, v. 10, p. 47-50. Author at Geol. Inst., Fac. of Sci., Univ. of Tokyo, Hongo, Tokyo 113, Japan.

A cation-chloride concentration diagram showing the stability of minerals in natural water system at elevated temperatures is constructed. The curves on this diagram showing the equilibrium between aqueous solution and minerals commonly occurring in nature generally satisfy the empirical Na-K-Ca relationship obtained by Fournier and Truesdell (1973). This indicates that the chemical composition of natural waters is largely controlled by minerals commonly occurring in nature. (Author's abstract).

SHIKHIN, Yu.S. and ISHCHENKO, Ye.N., 1976, Method of mineral-thermometric studies of age interrelations of dikes and mineral veins: Zapiski Vses. Mineral. Obshch., v. 105, no. 6, p. 676-686 (in Russian).

Studies were performed at the Au dep. Shkol'noe (SW Karamazar, Tadzhikistan), where quartz-carbonate veins are cut by diabase dikes. Authors discerned in decrepigraphs of mins. from vein, six T generations of incs.: I - 700-687°C, II - 675-660°C, III - 640-570°C, IV - 540-470°C, V - 430-380°C, VI - 320-360°C. High-T generations give max. of low intensity, and low-T ones give high intensity. Each generation has increased activity at the contact of vein with dike, next the activity decreases, and later one may observe the second, main maximum of intensity, most distant from dike. (Abst. by A.K.)

SHIMA, H. and NALDRETT, A.J., 1975, Solubility of sulfur in an ultramafic melt and the relevance of the system Fe-S-O: Econ. Geol., v. 70, p. 960-967.

SHIMAZAKI, H. and MACLEAN, W.H., 1976, An experimental study on the partition of zinc and lead between the silicate and sulfide liquids: Mineral. Deposita (Berl.), v. 11, p. 125-132. First author at Geol. Inst., Fac. of Sci., Univ. of Tokyo, Hongo, Tokyo 113, Japan.

SHMAKIN, B.M., 1976, Muscovite and rare metal pegmatites: Novosibirsk, "Nauka" Pub. House, 367pp (in Russian).

This book, which presents a very thorough study of muscovite pegs (approx. 800 refs), contains a short section (p. 245) on the use of incs. for T, quoting literature data. (ER)

SHNAY, G.K. and LEVITSKIY, Yu.F., 1976, Gold ore mineralization and metasomatic processes in alkaline rocks (exemplified by Aldan complex) (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept., 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 28-29 (in Russian; translation by A. Kozlowski).

All mins. from invest. dep. have decrep. peak at 320-380°C and the second peak, 220-280°C, occurs only in barren vein quartz, in quartz from rocks rexlized under low-T conds. and in Au-poor late sulfides. T_D 320-380°C is char. for commercial Au-bearing paragenesses. (From authors' abst.)

SHOJI, Tetsuya, 1975, Role of temperature and CO_2 pressure in the formation of skarn and its bearing on mineralization: Econ. Geol., v. 70, p. 739-749.

SHUL'DINER, V.I., 1976, Biotite-garnet geothermometer at elevated temperatures: Akad. Nauk SSSR, Doklady, v. 229, no. 3, p. 714-716 (in Russian). Author at Far-East Geol. Inst. Far-East Sci. Center AN USSR, Vladivostok.

Reinvest. of Perchuk's biotite-garnet geotherm. especially for granulites. (A.K.)

SHULTZ, D.J., PANKOW, J.F., TAI, D.Y., STEPHENS, D.W., and RATHBUN, R.E., 1976, Determination, storage and preservation of low molecular weight hydrocarbon gases in aqueous solution: Jour. Research U.S. Geol. Survey, v. 4, no. 2, p. 247-251.

A gas chromatograph with a flame ionization detector was used in conjunction with a stripping chamber and cold trap apparatus to measure microgram-per-litre quantities of low molecular weight hydrocarbon gases in water samples. Glass bottles with ground-glass stoppers were used to store the samples. Formalin was added to stop bacterial activity and preserve samples with no measurable losses for as much as 7 days. (Authors' abstract).

SHUVALOV, V.B., POLYKOVSKIY, V.S., and ELINSON, M.M., 1974, Composition of gases in hydrothermal solutions that took part in the formation of the Ayutor fluorite deposit western Tien Shan: Uzb. Geol. Zh., no. 2, p. 67-70. (in Russian)

SIDORENKO, P.P., ALEKSEENKO, V.A., and KHOVANSKITY, A.D., 1976, Temperatures of formation of polymetallic deposits at Mirgalimsay and Shalkiya (Karatau), (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 42 (in Russian; translation by A. Kozlowski).

The deposits are stratiform, of uncertain origin. Vacuum-decrepitation analysis of dolostones and dolomitic limestones from the ore-bearing levels and underlying strata yielded T_D (T of gas emanation) intervals: 40-160, 240-360 and 420-600°C. At Mirgalimsay the individual parts of the deposit are characterized by T_D of dolostones: 80-140, 200-250 and 330-390°C. At Shalkiya carbonates ∿10 m from the top and bottom of the ore sheet are especially rich in gases. These data suggest a polystage formation of the deposits. (Authors' abst.)

SIDOROV, A.A., GONCHAROV, V.I., EREMIN, R.A., TRUSHIN, A.V., and ANDREEV, B.S., 1976, Temperatures of formation of gold-silver ore mineralizations at Chukotka (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept., 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 25-27 (in Russian; translation, adapted from the authors' abstract, by A. Kozlowski).

Incs. in quartz of Vostochnyi ore field (o. f.) have T_H 330-210°C (arsenopyrite assoc.), 200-175°C (Au-sulfide assoc.), and 280-200°C (antimonite assoc.); Zapadnyi o. f. - 310-130°C (Au-sulfide assoc.) and 220-200°C (antimonite assoc.): Zvyozdnyi o. f. - 285-245°C (Au-sulfide assoc.); Silnyi o. f. - 250-205°C (Au-sulfoantimonite assoc.) and 240-200°C (antimonite assoc.). Carbonate from Zapadnyi o. f. has T_H 240-180°C. Quartz from antimonite assoc. (depth 280 m) contains incs. with L_{CO_2}; incs. with L_{CO_2} are very numerous in (barren? - A.K.) meta. quartz. The deeper the min. the higher T_H.

SIDOROV, A.A., NAIBORDOIN, V.I., and SAVVA, N.E., 1976, Manganese mineral associations in gold-silver deposits (abst.): International Geol. Congress, 25th, Abstracts, p. 795-796. First author at North-Eastern Complex Research Institute, U.S.S.R.

Eastern Asiatic gold-silver deposits were formed within continental volcanic belts of Late Cretaceous (Okhotsk-Chukchee) age and Paleogene (Sikhote-Alin) age. Mineralization is associated with subvolcanic bodies having various compositions and is followed by intensive hydrothermal-metasomatic alteration of host rocks (propylitization, silicification, argillitization).

Ores are of composite mineralogic constitution, and they comprise several productive mineral associations which include native gold (electrum), silver and different sulphides or sulphosalts of silver (argentite, aguilarite, pyrargyrite, stephanite, polybasite, freibergite and other minerals). Quartz, adular and carbonates are the principal gangue minerals. Ore-formation processes took place in a broad temperature range -- from 450° to 50°C, but moderate temperature conditions were prevalent.

Wide development of manganese mineralization which was formed mainly during productive stages of the process of mineral formation, is characteristic for many gold-silver deposits. Two major associations are identified, i.e., carbonate association and rhodonite-rhodochrosite association.

The carbonate association is mostly characteristic for the deposits with high gold-silver ratios (Au:Ag=0.1-0.5); andesites are the usual host rocks of these deposits. Ore minerals are predominantly represented by pyrite, sphalerite, galena, chalcopyrite, low-grade ore, and such like. Different minerals of the rhodochrosite-oligonite-siderite series are prevalent among the carbonates. They are constantly associated with dolomite-ankerite with up to five per cent content of rhodochrosite molecules; within certain deposits kutnahorite was identified. Sphalerite of the association contains up to 0.5% of manganese. Alabandite is present as an admixture mineral. Carbonate associations were formed after the majority of gangue and ore minerals had been deposited.

The rhodochrosite-rhodonite association is predominantly present within the deposits with low Au/Ag ratio (0.03-0.001) which occur in acid volcanites. The association comprises also bustamite, quartz, and - to a lesser degree - adular. Its deposition commonly occurred before the principal productive stage. Among ore minerals comprised by the rhodochrosite-rhodonite association are pyrite, sphalerite, galena, alabandite; in other cases the minerals are represented by native gold and argentite; the data obtained through gaseous-liquid inclusions studies suggest that the formation of rhodonite-rhodochrosite associations took place at 410-260°C. Mineral aggregates generally have metacolloidal structures, and colloform (rhythmically banded, spherolite) structures.

Within many gold-silver deposits, the formation of minerals of the productive stage was crowned by deposition of pink manganocalcite and sometimes by deposition of black calcite, both these carrying scattered dissemination of manganese oxides. Also late garnet-prehnite-epidote streaks with piedmontite have been observed.

Within the hypergenesis zone the rhodochrosite-rhodonite association is very unstable and it is displaced by various oxides, i.e., manganite, pyrolusite, vernadite, and other minerals that not infrequently are grouped into appreciable concentrations with suggest their commercial exploitation. (Authors' abstract)

SIGURDSON, D.R. and LAWRENCE, E.F., 1976, Mineral paragenesis and fluid inclusion thermometry at four tungsten deposits in the Western

U.S.A. (abst.): International Geol. Congress, 25th, Abstracts, p. 813-814. Abstract published in Fluid Inclusion Research, v. 8, p. 169-170 (1975).

SIGVALDASON, G. E. and ÓSKARSSON, Níels, 1976, Chlorine in basalts from Iceland: Geochim. Cosmo. Acta, v. 40, p. 777-789. Authors at Nordic Volcanological Institute, University of Iceland, Reykjavik, Iceland.

Cl has a higher soly. in basaltic magmas than other vol. A theoretical degassing model predicts that less than 10% of the Cl originally present in the magma is lost to the atm. during surface degassing. This prediction is born out by strong correlation between Cl and nonvol. elements in samples from recent volcanic eruptions in Iceland. It is concluded that the Cl content of subaerial basaltic lavas is proportional to the Cl content of the magmas. Assuming a roughly constant ratio between Cl and water in the mag. gas phase and assuming further that this ratio approximates the Cl/H_2O ratio in sea water and seds. it is possible to assign each basaltic magma a fixed amount of water. The figures thus obtained (0.3-1.2% H_2O) are identical with previously assumed water contents of basaltic magmas.

The implied water contents of the melts are discussed in terms of derivation from hydrous mantle phases. It is concluded such phases can supply only a fraction of the assumed water content, the rest is derived from an additional vol. source in the mantle. The mantle source giving rise to alkali basalts in Iceland has a lower content of vol. than the tholeiite source. (Authors' abstract)

SIMMONS, G. and RICHTER, D., 1976, Microcracks in rocks, pp. 105-137 in The Physics and Chemistry of Minerals and Rocks, R.G.J. Strens, ed.: London, J. Wiley and Sons, 697 pp.

A review, with 30 illustrations, of the various types of "cracks" found in rocks. Many are now secondary fluid inclusion planes (i.e., "bubbles"), but the inclusion literature is almost unmentioned (ER).

SIMONOV, V.A., 1976, Physico-chemical features of formation of nepheline miaskite-pegmatites: Soveshch. Molodykh Uchenykh Mineral., Geokhim., i Metodam Issled. Mineral (Tezis. Dokladov), Primor. Otdel., Vses. Mineralog. Obshch., Dal'nevostoch. Geol. Inst., Vladivostok, p. 35-36 (in Russian; translation courtesy of Michael Fleischer). Author at Inst. Geol. Geophys., Sib. Branch, Acad. Sci. USSR.

Inc. in four different types of nepheline from miaskite-peg. of the Il'men mineralogical national reservation were studied: gray turbid, gray transparent, rose transparent, and yellowish-brown transparent.

Gray turbid nepheline contained P multiphase inc. of melt-brines, with gas (∿30-40%), xline phases (∿ 40%), and liquid. The xline phases are xlites of various salts, silicates, and ore min. Partial homog. occurs at 450-480°C. Complete homog. (melting of last xlites) is obs. at 700-730°C. By the method proposed by Lemmlein (1955), the P is det as ∿ 2.5 kbars. The gas phase of individual inc. contains: sum of H_2S, SO_2, SO_3, and HCl (5-7%), CO_2 (83-81%), and CO (12%). The gray transparent nepheline contains P inc. of two types. One group is very similar to those of the gray turbid nepheline, with partial homog. at 370°C and complete homog. at 670-700°C; P 3-3.5 kb; the gas phase has a rather variable comp.: H_2S, SO_2, SO_3, HCl (41.5 - 90%),

CO_2 (8-20.5%), CO ($\leq$ 17%), H_2 ($\leq$ 11.5%), and N($\leq$ 9.5%). Inc. of the second type are analogous to those in the rose transparent nephelines.

P tubular inc. in the rose transparent nepheline vary in phase comp. from essentially gaseous to typical inc. of melt-brines. Partial homog. is at 570°C; complete homog. is at 670-700°C; P $\sim$ 1-1.3 kb; gas phase: sum of H_2S, SO_2, SO_3, HCl + CO_2 ($\sim$ 100%).

In the yellowish-brown transparent nepheline there were found only S, comparatively low-T G-L inc.

From these studies, xliz. of gray turbid nepheline occurred from melt-brines at a 700-730°C and 2.5 kb; then the P rose to 3-3.5 kb. at relatively constant T, then decreased sharply to 1-1.3 kb., associated in all probability, with form. of fractures and opening of the system. In the min.-forming processes, the main role began to be played by melt-brines of diff. comp. As the result of the reaction of these melt-brines, introduced from outside, on the gray turbid nepheline, there was formed first the gray transparent nepheline, then the rose transparent nepheline, and then the yellowish-brown.

SINKEVICH, T.P., 1976, Inclusions in iron and gold ore formations, (abst), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept., 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 32 (in Russian; translation by A. Kozlowski).

Calcite and aragonite from Angara Fe ore form, have T (T_D?) 350-140°C; quartz from Lena Au ore region, T_D 140-170°C.

SKURIDIN, V.A., SOTNIKOV, V.I., NIKITINA, Ye. I. and PROSKURYAKOV, A.A., 1974, On finding of specific rocks formed in front part of zones of explosive brecciation (Zhireken deposit): Acad. Sci. USSR, Doklady, v. 217, no. 2, p. 443-445 (in Russian). Authors at Inst. Geol. Geoph. Sib. Branch Acad. Sci. USSR, Novosibirsk-90.

Rocks, consisting of plagioclase (two varieties: 1-3 mm grains of Ab_{90-92}, usually strongly alt. to sericite + clay min. pseudomorphs, and 0.2 - 0.4 mm grains of Ab_{83-88}) up to 37%, quartz to 25%, biotite to 40%, celestite to 7.5%, apatite, zircon, and magnetite, formed under action of pneum. and hyd. sols. from granites of Bushuleyskiy massif, Amananskiy complex. T_H of incs. in quartz 600-450°C (in G) and 470-380°C (in L), P $\sim$ 1000 atm, in apatite 350-300°C, in celestite <300°C. (Abst. by A.K.)

SLACK, J.F., 1976, Hypogene zoning and multistage vein mineralization in the Lake City area, western San Juan Mountains, Colorado: Ph.D. Thesis), Stanford Univ., 327 p.

Polymetallic (Ag,Pb,Zn,Au,Cu) fissure veins occur in an arcuate belt around the N, NE, and E margins of the 22.5 m.y. Lake City caldera in the western San Juan Mountains, Colorado. Veins are open-space fillings of steeply dipping fractures and minor fault zones typically 0.5 to 1.5 m wide and up to 2000 m long within intermediate to silicic volcanic rocks. Seven major stages of mineralization have been identified throughout the district. From oldest to youngest, they are (I) preore quartz-pyrite, (II) banded quartz-sulfide ores, (III) massive rhodochrosite, (IV) postore quartz-carbonate-fluorite, (V) barite-sulfosalt ores, (VI) Au-Ag telluride ores, and (VII) postore barite-chalcedony.

Detailed fluid inclusion studies were carried out on doubly polished plates of quartz, sphalerite, barite, calcite, and fluorite from Stages

II-V at the Ute-Ulay mine. Inclusions are principally of two types, liquid-rich (Type I) and vapor-rich (Type II). No daughter minerals or liquid CO_2 were observed. Uncorrected median filling temperatures for Stages II-IV systematically decrease outward along the vein system, from 265°-190°C. Salinities follow a similar pattern, from ca 4 (II) to 1.8 (III) to only 0.1 (IV) euqivalent weight percent NaCl. Stage V ores contain both primary Type I and Type II inclusions that yielded a wider range of filling temperatures (200-380°C) and salinities (1-12.4 equiv. wt.% NaCl). At the Ute-Ulay mine, Stage V ores were superimposed on older periods of mineralization and were emplaced during brecciation and reopening of the vein system. Fluid inclusion data support geologic relationships (including dense, fine-grained ore textures) that suggest local fluid boiling and throttling during Stage V mineralization.

Where Stage V ores crosscut earlier mineralization, Stage V fluids were trapped by secondary inclusions within Stage II, III, and IV minerals. Anomalously high filling temperatures and salinities recorded for one Stage II location are explained by superimposed Stage V ores. Stage V is in places juxtaposed near Stage IV, where postore carbonates and fluorite of Stage IV show preferential hydrothermal leaching by Stage V mineralization. At such locations, postore Stage IV fluorite contains numerous vapor-rich (Type II) inclusions which provide filling temperatures above 300°C. Where Stage V is absent, similar fluorite contains only Type I inclusions and consistently displays temperatures below 200°C. Type II inclusions locally within Stage IV fluorite are not primary and are not related to Stage IV boiling, but rather document trapping of secondary vapor-rich inclusions during brecciation and hydrothermal leaching by superimposed Stage V ores. (Author's abstract).

SLAVINSKIY, V.V., 1976, Clinopyroxene-garnet geothermometer: Akad Nauk SSSR, Doklady, v. 231, no. 1, p. 181-184 (in Russian). Author at Geol. Inst. of Acad. Sci. USSR, Moscow.

Detailed discussion.

SLEEP, N.H. and WOLERY, T.J., 1976, Mid-ocean ridge hydrothermal systems: some physical and chemical constraints, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 1110-1111. First author at Dept. of Geol. Sci., Northwestern Univ., Evanston, IL 60201.

SMIRNOV, V.I., 1976, Ore-forming elements of juvenile gases from Tolbachik volcano: Geol. Rudn. Mest. v. 18, no. 6 p. 82-85 (in Russian). Author at Moscow State Univ., Moscow. (Abstract by A.K.)

Gas samples were taken during eruption in Tolbachik volcanic group (Kamchatka), which began July 6, 1975. Eruption details: speed of gas flow 100-200 m/sec., and sometimes ultrasonic; erupted pyroclastic mat. 250 t/sec., for 10 months: 2 km^3, i.e., $3x10^9$t; height of volc. cloud, 13 km; lava flows have surface area of 70 km^2, comp. range from high-Mg basalts at beginning to high-Al subalk. ones at the end; T of lava flows in crater 1000-1200°C; T of gas streams to 1500°C, speed of migration of mantle mat. from depth 220-100 km to magm. chamber at depth 50-60 km and to surface - 100-150 m/hour. Comp. of volatile and condensed (L) phase (under room cond.) are given in Tables 1 and 2 (A - gases from lava flow 400 m from cone, B - gases from lava flow 1000 m from cone). Note that after condensation ore components don't form ppts but remain in sol.

Table 1. Comp. of juvenile volcanic gases from liquid lavas of 1975 Tolbachik eruption (vol. %, standard T & P)

Sample	Date	T, °C	H_2O	HF	HCl	SO_2	H_2S	CO_2	CO	H_2	NH_3	N_2	O_2	N_2/O_2
A	Dec. 16	980	88.39	0.003	0.10	0.11	0.001	0.14	-	-	0.004	8.97	2.24	4.0
B	Dec. 22	1020	94.02	0.060	0.36	0.36	0.004	0.15	-	0.55	-	3.91	0.89	4.4

Table 2. Comp. of condensed (L) phase of gases from lavas of Tolbachik eruption (ppm)

Sample	pH	F	Cl	SO_4	HSO_4	H^+	NH_4	Na	K	Ca	Mg	Fe^{3+}	Al	Cu	Zn	Pb	Sn	Ag	As
A	0.60	2800	14609	188	1013	312	3	429	182	3.0	6.1	33.5	290	2	16	1.6	0.09	0.002	0.50
B	0.43	2700	21347	231	1474	452	10	700	240	3.4	9.3	9.0	202	14	9	0.3	0.03	0.002	0.20

SMITH, F.W., 1976, Hydrothermal temperature gradients in vein deposits (abst.): Geological Society-Mineralogical Society (Britain) Symposium on fluid inclusions, Univ. of Durham, Abstracts of meeting (unpaginated), to be published in Trans. I.M.M. Sect. B.

Although it is commonly believed that cooling was the major cause of mineral deposition in many veins, surprisingly little is known about the actual temperature gradients that existed in hydrothermal systems. Fluid inclusion geothermometry can be used to reconstruct isotherms for individual phases of mineralization -- provided that one has reliable evidence for the contemporaneity of the specimens used. It is then possible to measure flow path cooling gradients (which are usually vertical rather than horizontal).

Flow path cooling gradients and simple vertical temperature gradients have been abstracted from the literature concerning fifteen regions, orefields or deposits. They range from 1/1.4 to 1/25° C/m, most being between 1/1.4 and 1/14°C/m. There is no obvious distinction according to type of deposit and individual differences can probably be explained in terms of local geology.

Cooling gradients from Weardale quarter-point fluorite orebodies lie mainly in the range 1/5.6 to 1/8.9°C/m. Minimum temperatures of mineralization measured at more than 40 horizons over a vertical range of 880 m suggest the contemporaneous background temperatures, or rock geothermal gradient, which can be compared with present-day observations. (Author's abstract)

SOBOLEV, N.V., YEFIMOVA, E.S., KOPTIL', V.I., LAVRENT'IEV, Yu. G., and SOBOLEV, V.S., 1976, Inclusions of coesite, garnet and omphacite in Yakutian diamonds - first finding of paragenesis of coesite: Akad. Nauk SSSR, Doklady, v. 230, no. 6, p. 1442-1444 (in Russian). First author at Inst. Geol. Geophysics, Sib. Div. Acad. Sci. USSR, Novosibirsk - 90.

Min. and chem. char. of solid incs. in diamonds, and P-T conds. of xliz. were estimated to be 60 kbar and 1200°C. (A.K.)

SOBOLEV, V.S., BAKUMENKO, I.T., and KOSTYUK, V.P., 1976, The possibility of using melt inclusions for petrologic conclusions: Akad. Nauk SSSR, Siberian Branch, Geol. i Geofiz. 1976, no. 5, p. 146-149. See translations.

SOBOLEV, V.S. and KOSTYUK, V.P., eds., 1975, Magmatic crystallization based on a study of melt inclusions: Novosibirsk, Nauka Press (in Russian; see translations).

SOTNIKOV, V.I., BERZINA, A.P., KOROLIUK, V.N., NIKITINA, Ye. I. and SKURIDIN, V.A., 1976, Possible source of chlorine in mineral-forming solutions: Akad. Nauk SSSR, Doklady, v. 230, no. 3, p. 705-708 (in Russian). Authors at Inst. Geol. Geophysics, Sib. Div. Acad. Sci. USSR, Novosibirsk -90.

Electron microprobe dets. of F (0.03 - 2.63 %) and Cl (0.02 - 0.40 %) in biotites suggest that these mins. may be source of F and Cl in hyd. sols. (A.K.)

SPOONER, E.T.C., BRAY, C.J., and CHAPMAN, H.J., 1976, Sea-water source for hydrothermal fluid which formed the ophiolitic cupriferous pyrite ore deposits of the Trodos Massif, Cyprus (abst.): Geological Society-Mineralogical Society (Britain) Symposium on fluid inclusions, Univ. of Durham, Abstracts of meeting (unpaginated), to be published in Trans. I.M.M. Sect. B.

It has recently been suggested that the hydrothermal fluid that formed the ophiolitic sulphide ore deposits of the Troodos Massif, Cyprus, was of sea-water origin. This hypothesis has been tested by determination of freezing points of samples of the hydrothermal fluid preserved in fluid inclusions and by examining the strontium isotopic composition of mineralized material.

Fluid inclusions in quartz from 9 samples from 3 mineralized stockwork deposits (Limni (2) and Alestos) give homogenization temperatures from 301 ± 14°C (1σ; 30 determinations) to 351 ± 4°C (1σ; 20 determinations). The mean and standard deviation of 205 measurements of fluid inclusion freezing points was found to be -1.9 ± 0.4°C. The value is identical to a freezing point of -1.9°C for average sea water with a salinity of 35%(sic).

The strontium isotopic composition of 13 samples from 5 mineralized localities (Limni (2), Mathiati and Mousoulos mines) demonstrates strong enrichment in ^{87}Sr relative to the initial magmatic ^{87}Sr:^{86}Sr ratios of the Troodos ophiolitic rocks (0.70338 ± 0.00010 to 0.70365 ± 0.00005). Determined values range from 0.7052 ± 0.0001 to values exactly as high as the ^{87}Sr:^{86}Sr ratio of Upper Cretaceous sea water (sample CY/75/55, 0.7075 ± 0.0002; cf. Upper Cretaceous sea water, 0.7076 ± 0.0003 (1σ)), but no higher.

These data confirm, therefore, that heated sea water did indeed constitute the hydrothermal fluid that produced the sulphide deposits of Cyprus. (Authors' abstract)

SREBRODOLSKIY, B.I., 1976, Mineral formation from solutions bearing sulfuric acid: Acad. Nauk SSSR, Doklady, v. 226, no. 3, p. 659-660 (in Russian). Author at L'vov Univ., L'vov.

Pertinent to fluid inc. studies in native sulfur and other mins.

from sulfur deps. (A.K.)

STALDER, H.A., 1976a, Fluid and gas inclusions in quartz crystals: Die Naturwissen-Schaften, v. 63, p. 449-456 (in German with English abstract). Author at Naturhistorisches Museum, Bern, Switzerland.

Fluid inclusions in quartz crystals from alpine fissures are described. The quartz crystals are in close genetic relation to alpine metamorphism. For this reason, the inclusion fillings show significant differences according to the degree of metamorphism; the inclusions can be used as geologic thermometers and barometers. (Author's abstract).

Daughter crystals stated here to be anhydrite (?) were later found to be calcite by Raman spectrometry (personal commun.) (ER)

STALDER, H. A., 1976b, Fluid inclusions in quartz crystals from the Swiss Alps: Bitsch (Valais), Camperio (Tessin) and Legenbach (Valais): Bull. Soc. Fr. Minéral. Cristallogr., v. 99, p. 80-84 (in French). Author at Muséum d'Histoire Naturelle, Bernastrasse 15, CH - 3005 Berne, Switz.

Description of the changes in fluid composition during the Alpine orogeny in three mineral occurrences of the Swiss Alps. Microthermometric data for many types of inclusions, including H_2O - CO_2 and halite-bearing inclusions, but without interpretation of the results. (Abstract M. Pagel)

The daughter crystals identified as anhydrite (?) here were later found to be calcite by Raman spectrometry (personal commun.) (ER).

STALDER, H.A., 1976c, Carbon isotopic composition of CO_2 from fluid inclusions in Alpine fissure quartz (abst.): Geological Society-Mineralogical Society (Britain) Symposium on fluid inclusions, Univ. of Durham, Abstracts of meeting (unpaginated), to be published in Trans. I.M.M. Sect. B.

The fluid inclusions in quartz crystals from Alpine mineral fissures formed during the Alpine metamorphism contain different quantities of CO_2. In those from the southern part of the Swiss Alps, i.e., in the central Pennine Alps, the amount of CO_2 often exceeds that of H_2O. This is the region of highest grade Alpine metamorphism. There are two main possibilities for the origin of this CO_2: juvenile (originating from deeper parts of the earth), or decarbonation of the Mesozoic sediments in the course of the Alpine metamorphism. To choose between these two possibilities $\delta^{13}C$ values of CO_2 in quartz crystals have been measured. The values obtained are variable, they range between -1.5 and -17.0, and indicate that decarbonation of the Mesozoic sediment cannot be considered as the only CO_2 supply.

The optical and microthermometrical investigations reveal that the composition of the fluid phases in mineral fissures changed systematically during the formation of the quartz. There was a decrease of CO_2 content, an increase of H_2O content and a decrease of salinity. Measurements on gases expelled from inclusions in four big quartz cystals from different locations have shown that the isotopic ratio $^{13}C:^{12}C$ decreased. The change can, at least partially, be explained by the fact that, at a later time of quartz crystallization, the graphite of the country rock reacted with the fluid phase of the mineral vein. (Author's abstract)

STEEN-MCINTYRE, V.C., 1976, Method for estimating ages of volcanic ash beds in late Cenozoic sedimentary deposits (abst.): U.S. Geol. Surv.

Prof. Paper 1000, p. 175.
See Fluid Inclusion Research, v. 8, p. 174-175 (ER).

STEVENS, E.L., 1971, The nature and significance of inclusions in pneumatolytic minerals: M. Sc. thesis, School of Applied Geology, Univ. NSW, Kensington, NSW, Australia

The inclusions of a number of associated pneumatolytic lode minerals from New South Wales and Queensland were investigated for their characteristics and possible genetic significance, using a combination of physical and chemical techniques. In addition, a comprehensive study of the host and coexistent minerals themselves, particularly for trace elements, was undertaken.

Homogenization studies of the inclusions were carried out on quartz, topaz, beryl, and fluorite, and the results obtained for the localities are detailed in the relevant parts of the thesis. Values obtained vary from 120° (fluorite, Emerald mine, Emmaville) to 450°C (topaz, Innot Hot Springs, Queensland).

Chemical studies of the inclusions showed them to be mainly alkali chlorides with some fluorides, the main cations being sodium and potassium with minor calcium, magnesium and iron. (From the author's abstract).

STEWART, M.K. and HULSTON, J.R., 1976, Stable isotope ratios of volcanic steam from White Island, New Zealand: Bull. volcanologique, v. 39, no. 1, Special issue (Geochemistry of volcanic gases), p. 28-46. Authors at Inst. of Nuclear Sciences, Dept. of Scientific and Industrial Research, Lower Hutt, New Zealand.

The D/H and $^{18}O/^{16}O$ ratios of fumarole condensates from White Island, an andesite volcano in the Bay of Plenty, have been measured during the period 1965 to 1969 to determine the origin of the water and the changes which occur as the volcanic activity changes. The D/H and $^{18}O/^{16}O$ ratios of all of the samples were correlated with a slope of -2. The $\delta^{18}O$ values were proportional to the logarithm of the chloride concentration but with distinctly different relationships between the period from 1965 to 1967, and the period of tephra eruptions in 1968. In the latter period the chloride contents were close to that of sea water while in the former quieter period the contents were lower. The δD values follow a similar pattern but with a poorer correlation, indicating that a more variable process is controlling the deuterium results.

Possible hydrothermal models are: mixing of near surface water and magmatic water; progressive leaching of chloride from underground rocks and exchange of isotopes (Craig, 1966); and lastly, equilibrium evaporation at about 255°C of either sea water or local surface water.

The first of these models is considered mostly unlikely because of the incompatible logarithmic relationship between the chloride content and the oxygen isotope results. The second model has some merit, but the available evidence favours the last of the three models in which the 1965-67 samples derive from surface water or vapour from a boiling chloride water aquifer of sea water origin and the 1968 samples derive from the boiling chloride water, because of disturbance of the system during the tephra eruptions. (Authors' abstract).

STOGNII, G.A., 1976, Inclusions in corundum from corundum-containing metasomatites of the Urals: Soveshch. Molodykh Uchenykh Mineral., Geokhim., i Metodam Issled. Mineral (Tezis. Dokladov), Primor. Otdel., Vses. Mineralog. Obshch., Dal'nevostoch. Geol. Inst., Vladivostok, p. 66-67 (in Russian; translation courtesy of Michael Fleischer). Author at Inst. of Geol. and Geophys., Sib. Branch, Acad. Sci. USSR, Novosibirsk.

Inc. in corundum permit reliable modelling of the process of form., both of corundum, and also of the corundum-containing rock. Inc. were anal. in min. from: (1) the Il'men Reservation (210, 299, and 300 pits); (2) the Sysertsk dep.; (3) the Borzovskii dep.; (4) the corundum showing of the Rai-Iz massif. The country rocks of the first of these are syenites and syenite-gneisses, for the others meta. ultrabasics.

The color of the corundum, except for that of Rai-Iz, is either ruby (Cr_2O_3 1.4% to 3.5%), blue, gray, or light brown, in part zoned or mottled. The xls are usually rimmed by oligoclase, in which inc. have not been found. The inc. in corundum can be divided into the following groups:

1. Solid - rutile in the Il'men samples from the 300 pits; drop-like dep. of chromspinel in ruby;

2. Gas single-phase inc. in ruby; N_2 is predominate in the gas phase.

3. Flat single-phase inc. of sol. P. xlites of salt appear at 0°C, the T_{Frz} is -53 to -56°C.

4. Incs. of CO_2, often of negative form, especially in the Borzovskii corundum, occur both isolated, and as zones and bands, (PS). T_H is 27-30°C, T_{Frz} is -54 to -57°C. The comp. of the gas phase in the Borzovskii corundum (vol. %): CO_2 74-76, N plus rare gases 24-26.

5. Incs. of CO_2 with a solid phase. Partial homog. 25-29°C, T_{Frz} - 54 to -58°.

The solid phase begins to darken above 500° and rexlizes. T_H is obs. at 560-650°C in corundum from the 210 pit; in the Sysertsk, and from the 299 pit, at 600-700°C. On cooling, the solid phase in the last case grew wholly on the wall of the vacuole, in the form of secondary corundum. In some inc. an aq. phase appears. This can be explained by the assumption that the solid phase is a hydroxide of aluminum, which dehydrates during the heating. It is planned to anal. all the solid inc. and phases on the microprobe.

The form. of corundum in plumasites - marundites occurred at 560-700°; the P, cal. from the Kennedy diagram, is est. to be 1.2-1.5 kb., and, what is especially important, CO_2 played a leading role in the fluid.

STUPAKOV, G.P. and DOROGOVIN, B.A., 1976, Comparison of gold-bearing veins from Aldan and Urals by phase state of mineral-forming solutions (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept., 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 27-28 (in Russian; translation by A. Kozlowski).

G/L incs. in quartz of commercial stages at Lebedinoe and Kochkarskoe deps. are mainly two-phase, rarely - three-phase incs. with L-CO_2 or dms (carbonates, halite). At Lebedinoe incs. contain 20-60 wt % salts; at Kochkarskoe - 10-20 wt %. Highly conc. sols. have HCO_3-Cl-Na comp., and low conc. - HCO_3-Ca comp. T_H ranges from 440-360 to 270-150°C, P from 0.8 to 0.25 kbar. Diff. in activities of alk., S^{2-}, HCO_3, O_2, and especially CO_2 suggest that at Lebedinskoe pption of quartz was quick, with intensive rexliz., under isothermal conds. and at

Kochkarskoe pption was slow and long. Ore form. at Lebedinoe was accompanied by metasom. replacement and removal of material, and at Kochkarskoe - with influx of min. substance.

SU, B.-C., 1976, Fluid inclusion geothermometry of fluorite, Star Range, Utah. M.S. thesis, Univ. Utah, Salt Lake City, Utah.

Inclusions in fluorite from the scattered small-scale Pb-Zn-Ag-Au-Cu deposits in sedimentary rocks associated with Middle Tertiary igneous rocks are two-phase liquid + vapor, with T_H of 135-205°C. P correction was estimated at +53°C. (ER)

SUNAGAWA, Ichiro and OHTA, Eijun, 1976, Mechanism of formation of chalcedony: Tohoku Univ. Science Repts., series 3, v. 12, no. 2, p. 131-146 (in English).

In the process of chalcedony formation in cavities in lavas or welded tuffs, three stages are distinguished; the first stage is the formation of chalcedony with a fibrous structure and a banding, which principally lines the wall of the cavity; the second stage is growth of coarsely crystalline quartz, which may be absent in some cases; and the last stage is the formation of horizontal stratiform chalcedony characterized by a granular structure. The sequence may repeat a few times until a cavity is entirely filled by chalcedony, but the order is always maintained. The microstructures of this chalcedony and coarsely crystallized quartz were studied by means of optical microscopy, and electron microscopy using replication technique and transmission technique. On the basis of these results, as well as the bloc nuclei model recently put forward by Glasner et al., the mechanism of formation of chalcedony is discussed. It is considered that chalcedony is not formed by crystallization of amorphous silica due to reaction with a hydrothermal solution, but by the adhesion on the wall of a cavity of bloc nuclei formed by heterogeneous nucleation on impurity ions in hydrothermal solution (fibrous type), and coagulation of bloc nuclei to form crystallites followed by their deposition (stratiform type). (Authors' abstract).

SUTTON, F.M., 1976, Pressure-temperature curves for a two-phase mixture of water and carbon dioxide: New Zealand Jour. of Sci., v. 19, p. 297-301. Author at Applied Math. Div., Dept. of Sci. and Ind. Research, Box 1335, Wellington, New Zealand.

Pressure-temperature curves are calculated for a two-phase system of CO_2 and water under conditions typical of Broadlands geothermal field. (Author's abstract).

SUZUOKI, Tetsuro and EPSTEIN, Samuel, 1976, Hydrogen isotope fractionation between OH-bearing minerals and water: Geochim. Cosmo. Acta, v. 40, p. 1229-1240. First author at Department of Chemistry, Meteorological College, Asahi-Cho, Kashiwa, Chiba-Pref., 277, Japan.

H isotope frac. factors between hydroxyl-bearing min. and water were det. at Ts ranging between 400 and 850°C. The H isotope exchange rates for the min.-water pairs exam. were very slow. In most cases it was necessary to use an interpolation method for the det. of the H isotope equil. frac. factor. (From the authors' abstract)

SVERJENSKY, D.A., 1973, Calcium-rich bustamite from the Broken Hill Lode N.S.W.: Unpublished B. Sc. (Hons.) thesis, Sydney Univ., NSW Australia.

Two types of fluid inclusions have been found in calcium-rich bustamite. One type is associated with rod-like inclusions of hedenbergite and shows a range in homogenization temperatures of 246-352°C, and a range in freezing temperatures of -5 → -28°C. The second type of fluid inclusions shows corresponding temperature ranges of 254-281°C and -34 → -39°C. A second generation of hedenbergite has exsolved from the bustamite. Hedenbergite also characteristically rims and replaces bustamite in association with garnet. (From the author's abstract).

SWANENBERG, H.E.C., 1976, Fluid inclusion bubbles in a thermal gradient (abst.): International Geol. Congress, 25th, Abstracts, p. 814. Abstract published in Fluid Inclusion Research, v. 8 p. 177 (1975).

TAKENOUCHI, Sukune and IMAI, Hideki, 1976, Fluid inclusion study of the Santo Tomas II porphyry copper deposit, Philippines (abst.); International Geol. Congress, 25th, Abstracts, p. 815. Abstract published in Fluid Inclusion Research, v. 8, p. 180-181 (1975).

TALANTSEV, A.S., 1976, Dolomite-calcite geological thermobarometer: Akad. Nauk SSSR, Doklady, v. 228, no. 3, p. 701-704 (in Russian). Author at Inst. of Geol. Geochem. of Urals Sci. Center Acad. Sci. USSR, Sverdlovsk.

TALANTSEV, A.S. and TALANTSEVA, R.M., 1976, P-T-conditions of formation of the rock-crystal-bearing veins in the Urals, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 44 (in Russian; translation by A. Kozlowski).

1. Quartz veins occur obsequently* in metamorphic rocks, with lens-like shape up to 50 x 15 x 2m. Rock crystal formed in a narrow range of P-T conditions. *i.e., cross cutting metamorphic foliation.

2. (...)

3. T_H of fluid inclusions in quartz are given in table:

Place in the vein	Description of quartz	T_H, °C	P, kbar
Upper end	Fine- and medium-grained, milky	540-470	-
Upper part and sides of the middle part of vein	Medium- and coarse-grained, milky, sometimes with smoky tint	490-410	1
Central parts of vein	Coarse- and very-coarse grained, milky and semitransparent slightly smoky	400-340	1
Parts adjacent to druses	Very-coarse-grained, semitransparent, sometimes with large fluid inclusions	350-300	1 - 0.7
Druses	Euhedral, sometimes zonal crystals	290-240	0.8 - 0.4
Same	Reentrants on big crystals and minute crystals	250-210	0.5 - 0.1
Clayey filling of the central cavity	Minute (1-2cm) bipyramidal transparent crystals in the filling	T_D = 280-160	-

(From the authors' abst.)

TAYLOR, H.P., Jr. and MAGARITZ, M., 1976, An oxygen and hydrogen isotope study of the Idaho batholith, (abst.): Amer. Geophys. Union Trans., v. 57, p. 350. Authors at Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125.

D/H and $^{18}O/^{16}O$ anal. of 130 min. and rocks from various plutons within the Idaho batholith indicate widespread meteoric-hyd. alt. in certain areas. (From the author's abstract).

TAYLOR, H.P., Jr. and TURI, Bruno, 1976, High-^{18}O igneous rocks from the Tuscan magmatic province, Italy: Contrib. Mineral. Petrol., v. 55, p. 33-54. First author at Div. of Geol. and Plan. Sciences, California Inst. of Tech., Pasadena, CA 91125.

THEODORE, T.G., BATCHELDER, J.N., and BLAKE, D.W., 1976, Stable isotopes and geology of the Copper Canyon porphyry copper deposits (abst): Econ. Geol., v. 71, p. 703. First author at U.S. Geol. Survey, 345 Middlefield Road, Menlo Park, CA 94025.

Data suggest that fluid assoc. with potassic alt. here were most likely composed of magmatic water mixed with significant amounts of meteoric water. (From the authors' abstract).

THEODORE, T.G. and PRIEGO de WIT, Miguel, 1976, Potassic alteration at La Florida de Nacozari, Sonora, Mexico, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 1135-1136. First author at U.S.G.S., 345 Middlefield Road, Menlo Park, CA 94025.

Pervasive secondary biotite-rich min. assemb. char. of potassic alt. found in the cores of most commercial porphyry Cu systems, are assoc. spatially with a prominent color and geochemical anomaly at La Florida de Nacozari, Sonora. Fluid-inc. relations in the late veins suggest that their fluids were nonboiling and relatively dilute. (From the authors' abstract)

THOMPSON, P., SCHWARCZ, H.P., and FORD, D.C., 1976, Stable isotope geochemistry, geothermometry, and geochronology of speleothems from West Virginia: Geol. Soc. Amer., Bull., v. 87, p. 1730-1738. First author at Dept. of Physics, Univ. of Alberta, Edmonton, Alberta T6G 2J1 Canada.

Some speleothems (cave-deposited travertine formations) from two caves in West Virginia were formed in isotopic equilibrium with seepage waters during the interval 200,000 B.P. to the present. Deuterium/hydrogen ratios in fluid inclusions from these speleothems indicate that $\delta^{18}O$ values of waters from which they were deposited did not change appreciably during at least part of that interval. From these and other data, we infer that $\delta^{18}O$ of calcite increased with decreasing temperature of deposition. Deposition rates appear to be greatest during summer and may have fallen to zero during glacial advances. Curves of relative paleotemperature, based on secular changes in $\delta^{18}O$ of calcite as dated by the $^{230}Th/^{234}U$ method, are presented. Maxima in this record correspond to maxima in summer insolation in the Northern Hemisphere as calculated by Vernekar, as well as to high sea stands marked by raised coral reefs and to thermal maxima observed in speleothems from other regions of North America. (Author's abstract).

TIMOFEEVSKIY, D.A., GREBENCHIKOV, A.M. and ANDRYANOVA, S.I., 1976, Peculiarities of formation of gold ore deposits (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept., 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 21-22 (in Russian; translation by A. Kozlowski).

1. Deps. of Au-silicate (skarn)-sulfide-quartz, Au-albite-quartz and Au-carbonate-quartz form. originate in zones of high P by homog. and heterog. sols, sat. by CO_2 and of great chem. activity. Deps. of Au-adularia-chalcedony form. originated in shallow zones by boiling sols. of low chem. activity.

2. For deps. of Au-silicate (skarn)-sulfide form. T of beginning of min.-form. is 750-550°C; other deps. form at 550-400 to 100-50°C. T of form. of ore complexes with early Au at all deps. is 430-180°C; with late Au - 320-100°C. Main mass of Au ppted at 250-100°C, the remaining - rarely at $T > 300$°C.

3. Form. of deps. of Au-sulfide-quartz, Au-quartz and sulfide form. at early stages was from pneu.-hyd. conc. sols. of CO_2-Cl-alk. comp.; from hyd. sols. of HCO_3-hydrosilicate-halide-alk. earths (+ alk. and SO_4) comp. Conc. of sols decreased and pH changed from weakly acid to almost neutral or weakly alk. in the end of process, usually Na>K. For deps. of Au-silicate (skarn) - sulfide form. the Cl - alk. earths comp. of hyd. sol. is char. (plus HCO_3), and pH changes from alk. to neutral and weakly acid. Deps. of Au-adularia-chalcedony xlized from low.-conc. alk. hyd. sols. of HCO_3-$HSiO_3$-halide-Ca-alk. comp. (plus Mg and SO_4); also the role of F, Li, and in ore stage - of K - increases.

TODOROV, T. and KRUSTEVA, M., 1975, Fluid inclusions in minerals in the fluorite deposits from the Mikhalkovo ore field: Rudoobraz. Protsesi Miner. Nakhodishcha, #2, p. 63-74 (in Russian with English sum.).

TOLSTIKHIN, I.N., PRASOLOV, E.M., KHABARIN, L.V., et al., 1974, Evaluating the diffusion coefficient of helium in quartz crystals, in Geokhimiya radiogennykh i radioaktivnykh izotopov (Gerling, E.K., editor; et al), p. 79-90, Izd. Nauka, Leningr. Otd., Leningrad, Union of Soviet Socialist Republics. (in Russian)

TOURAY, J.C., 1976, Activation analysis for liquid inclusion studies: a brief review: Bull. Soc. Fr. Minéral. Cristallogr., v. 99, p. 162-164 (in French). Author at Laboratoire de Géologie Appliquée, Institut de Recherche sur les ressources et matériaux minéraux, E.R.A. au C.N.R.S. N° 601, Université d'Orléans - 45045 Orléans Cedex, France.

A comparison of calculated detection limits for neutron activation analysis with compositions of hydrothermal solutions (Wairakei, Salton Sea, etc.) shows that for 10^{-3} gm of fluid (total sample in the gm range), Na, K, Cl, As, Rb, Cs, I, Si, Br, Cu, Mn, Zn, W and Dy should be determinable, while Mg, Ca, Fe, F, SO_4, HCO_3, HBO_2 and Li should not be detected. Proton activation has not generally been used, mainly because of calibration problems. The following detection limits have been calculated by Barrandon, et al (1974), for non-destructive analysis of industrial rhodium: Ca, 0.15 ppm; Ti, 0.06 ppm; Fe, 0.25 ppm; Zn, 0.09 ppm; Br, 0.2 ppm. One non-destructive analysis of quartz from Roc de France, Spain by Delmas (1975) indicated 7.5 ppm Li, 230 ppm Ca, 17 ppm Fe, 14 ppm Br, 32 ppm Sr, and 2.5 ppm Ge. The method seems particularly useful for analysis of Ca and Fe which are poorly detected by neutron activation. (Abstract by Arthur Barabas).

TOURET, J., 1975a, Fluids in metamorphic rocks; the data of fluid inclusions [abstr.]: Geol. Soc. S. Afr., Congr., Abstr., no. 16 (Mineralization in metamorphic terranes), p. 142-144.

TOURET, Jacques, 1975b, Review of Fluid Inclusion Research, v. 5, 1972: Econ. Geol., v. 70, p. 1412.

TOURET, Jacques, 1976, A model for a distribution of fluids in the continental crust and the upper mantle (abst.): Sciences de la Terre, Paris, 4th annual meeting, p. 383 (in French). Author at Lab. de Pet., 61 rue de Buffon, 75005 Paris, France.

The distribution of fluid inclusions in the minerals of rocks of the mesozone and the catazone implies the existence of a fluid phase, the abundance of which seems to increase with increasing grade of metamorphism. Comparison of the densities of fluid inclusions and PT conditions of the metamorphism (obtained independently from the solid phases) underlines the representative nature of the inclusions, and, for the older ones, their synmetamorphic character. On the basis of these data, a model derived from Thomson's model (fluids circulating in open fissures under the influence of P gradients or of chemical potential; $P_{tot.}$ of fluids = lithostatic P to a first approx.) is retained. Large variations in P_{H_2O} relative to the lithostatic P are detected by the presence of other volatiles, in particular CO_2 and hydrocarbons. It seems that, with the exception of large dislocation zones where percolation is important, the possibilities for fluid movement are limited and their composition is controlled locally by the solid assemblages. This is conceivable only if, at a given level, fluids of different composition have the same density. The constancy of density seems effectively to be the rule in numerous petrogenetic processes.

At the scale of the continental crust, the distribution of deep fluids is dominated by the disparate behaviors of water, the surface fluid, and of CO_2 (+ hydrocarbons), the fluid at depth. The importance of CO_2 increases abruptly at the level of migmatites, and CO_2 becomes almost exclusive in the deep crust and the upper mantle. The origin of the CO_2 is mainly juvenile (upper mantle).

Several mechanisms, differing according to the dpeth, control this distribution: fluid-solid equilibria in metamorphic reactions, the preferential solubility of water in magmas, and the control of the mobility of water by partial hydration of anhydrous intrusions originating in the mantle. (Author's abstract, translated by Chris Eastoe).

TROMMSDORFF, Volkmar, and EVANS, B.W., 1976, Antigorite phase relations in the $CaO-MgO-SiO_2-CO_2-H_2O$ system, (abst.): Geol. Soc. Amer., Abstracts with Programs, v. 8, no. 6, p. 1145-1146. First author at Institut für Kristallographie and Petrographie, E.T.H., Sonneggstrasse 5, 8006 Zürich, Zwitzerland.

TROSHIN, Yu.P., 1976, Zonal distribution of volatile components in apical parts of granitoid intrusives (based on example of central part of E. Transbaikal'ye): Geol. Rudn. Mest., v. 18, no. 4, p. 11-21 (in Russian). Author at Inst. Geochem. of Sib. Branch of Acad. Sci. USSR, Irkutsk.

Differences in soly. of volatiles in silicate melt result in form. of zones enriched in individual volatiles in apical parts of intrusives. The metals (in parentheses) are assoc. with volatiles: at the highest level Cl and CO_2 (Zn,Pb,Au) prevail; lower zone is enriched in OH (W), partly B, and P; and the lowest - in F (Sn, Li) and partly in P; S may conc. with CO_2 and Cl as well as with F. Above considerations are supported by data (see table) on chem. comp. of fluid incs. from ore-bearing quartzes at Kukulbey and Khapcheranginsko-Lyubavinskiy ore regions (Abst. by A.K.).

Type of dep. (No. of deps./No. of samples)	Conc. in % equiv. F	Cl	HCO_3
Mo (2/6)	0.9 ± 0.0	63.6 ± 23.0	35.5 ± 24.0
W (6/6)	17.1 ± 6.1	30.7 ± 19.3	52.2 ± 24.8
Sn (6/15)	25.6 ± 30.1	18.7 ± 15.3	55.7 ± 26.4
Zn, Pb (5/12)	5.3 ± 7.5	29.3 ± 21.3	65.4 ± 28.2

TRUESDELL, A.H., and FOURNIER, R.O., 1976, Geothermal systems - mixing model geothermometry (abst.): U.S. Geol. Surv. Prof. Paper 1000, p. 185-186.

TRUFANOV, V.N., 1976, Fluid regime of metallogenic province of N. Caucasus, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept., 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst of Geol., p. 14-15 (in Russian; translation by A. Kozlowski).

Studies of melt and sol. incs. in mins. prove two main modes of generation of fluid prevailed. The first - regional P-T-gradient activization of immobile dispersed sols. in mass of rocks, with separation of transtelluric fluid streams into tectonic zones. The second - following immiscibility and emanation differentiation of local magm. chambers (...) The two modes are interconnected, sometimes they developed separately, and sometimes interferred, causing form. of peg., skarn, hyd. etc. types of ores. Boiling occurred frequently, with separation to form heterogenous media. T and P intervals of these phenomena were det. from inc. studies.

TRUSHNIN, A.V., LITVIN, O.N., and GONCHAROV, V.I., 1976, Features of temperature and gas regime in the formation of gold-silver deposits of Chukotki: Soveshch. Molodykh Uchenykh Mineral., Geokhim., i Metodam Issled. Mineral (Tezis. Dokladov), Primor. Otdel., Vses. Mineralog. Obshch., Dal'nevostoch. Geol. Inst., Vladivostok, p. 15-16 (in Russian; translation courtesy of Michael Fleisher). Authors at Northeast Complex of the Sci-Research Inst., D.V. N.Ts (Far Eastern Sci. Center? M.F.), Acad. Sci. U.S.S.R., Magadan.

The deps. are located in terrigenous Triassic forms. Nevertheless, it is in comp. of min. assoc., textural-structural features of the ore body, and character of spatially assoc. intrusive magmatism a typical representative of volcanogenic Au-Ag deps. In character of productive assoc. the dep. is referred to the complex Au-sulfide-stibnite type. The dep. was formed in three stages: arsenopyrite, gold-sulfide, and stibnite.

Conds. of form. of the ore body were det. by study of gas-liquid inc. in quartz of all stages of min. form. For comparison, data are given on inc. in meta. quartz, widely devel. within the region studied and preceding the form. of the ore field dep. The method of homog. fluids was used to det. T. The gas comp. was det. by anal. of individual inc. T_H was taken as equal T_F, because the corr. for P is not significant for a near-surface dep. The results are in table 1.

In the table are given neutralized (= normalized, averaged ? M.F.) data on the results of study of inc. in quartz of the main min. assoc. of diff. areas of the dep. CO_2 and H_2 were identified but not det. On the basis of these studies, it was found that T_F of the dep. decreases steadily from the early to the late stages. The dep. were formed in a rather wide T interval, 330-130°C, and can be referred to the medium-T Au-Ag type. Comparing gases in the min. assocs., acid gases were in solution in considerable amounts during form. of the stibnite assoc. The absence of oxygen in the ore and post-ore stages is probably connected with the high sat. of the sol. of this phase with sulfide sulfur (oxygen is consumed in its oxidation). In distinction from quartz of other bodies of the ore body, the meta. quartz formed under diff. conds. It is char. by large zoned xls, indicating a higher stability during min. form. and by sat. of the xliz. sol. by CO_2. In the meta. quartz, part occurs in inc. containing liquid CO_2. In the process of form. of the ore bodies of the dep., the meta. quartz was acted on by ore-forming sol., as indicated by the gas comp. of the S inc. and their T_H.

Min. Assoc.	T_H, °C	HCl, HF, H_2S, and others	CO_2	O_2	CO	N_2+r.g.**
Meta. quartz*	354-195	0	57-72	0	0	28-43
Arsenopyrite	330-210	0	36-44	0-7	0	56
Gold-sulfide	310-130	0	43	0	0	57
Stibnite	280-200	14	44	0	0	42

* data on S incs. ** r.g. = rare gases? Note - units not stated M.F.

TSONG, S.T., MCLAREN, A.C. and HOBBS, B.E., 1976, Determination of hydrogen in silicates using the ion beam spectrochemical analyzer: application to hydrolytic weakening: Amer. Min., v. 61, p. 921-926. First author at Dept. of Physics, Monash Univ., Clayton, Victoria 3168, Australia.

The ion beam spectrochemical analyzer (IBSCA), which utilizes the emitted radiation from sputtered atoms, has been used for the quantitative analysis of hydrogen content in a number of silicate samples. An attempt is made to interpret the role of hydrogen in the process of hydrolytic weakening in these materials. (Authors' abstract).

TSUI, T.-F. and HOLLAND, H.D., 1976, The Cu content of fluid inclusions in three epithermal ore deposits, (abst.): Amer. Geophys. Union Trans., v. 57, p. 1014. First Author at NASA-Ames Research Center, Moffett Field, California 94025.

A laser microprobe was used to study the Cu content of large (D > 100μ), single, P fluid inc. in quartz from the Finlandia vein, Colqui, Peru; the Ag-Pb-Zn-Cu dep. at Casapalca, Peru; and the OH vein at Creede, Colorado. At Casapalca and Creede the quartz xls containing the anal. fluid inc. grew late in the ore paragenesis; at Colqui the quartz was dep. prior to the main stage of sulfide dep. Cu was not det. in most of the inc. fluids. The upper limit of the Cu con. in these fluids was between 1 and 40 ppm at Colqui, between 1 and 50 ppm at Casapalca, and between 1 and 25 ppm at Creede. Small amounts of Cu det. in the spectra from some inc. fluids was probably due to contamination. The very low upper limits to the Cu conc. in most of the inc. fluids is in good agreement with the predicted Cu conc. of 1 to 10 ppm based on Crerar's sol. meas. of chalcopyrite and the min. of the dep. at Colqui and Creede. It seems likely that Cu conc. in this range are typical of epithermal ore sol. near 250°C. (Authors' abstract).

TURI, Bruno and TAYLOR, H.P., Jr., 1976, Oxygen isotope studies of potassic volcanic rocks of the Roman Province, central Italy: Contrib. Mineral. Petrol., v. 55, p. 1-31. First author at Istituto di Geochimica, Universita di Roma, 00100 Rome, Italy.

TVALCHRELIDZE, A.G., YAROSHEVICH, V.Z. and KERDZAYA, T.E., 1976, Geological and physico-chemical conditions of formation of stratiform copper-pyrrhotite deposits (exemplified by Mountainous Abkhaziya): Geol. Rudn. Mest., v. 18, no. 1, p. 64-75 (in Russian). Authors at Caucasian Inst. of Mineral Raw Materials, Tbilisi.

T_H of incs. in quartz and calcite from quartz-pyrite-polymet. ores ranged from 155 to 200°C. (A.K.).

UCHAMEISHVILI, N.Ye. and MALININ, S.D., 1976, Temperature conditions of barite formation, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 61 (in Russian; translation by A. Kozlowski).

(....) 2. Fluid inclusions in barite always bear Ca ions in concentration 0.1 - 1 M. At high T in chloride solutions bearing Ca, Ba and SO_4, anhydrite and barite may appear. Barite crystallizes at low T; at T > 200°C anhydrite is stable. Association barite + anhydrite may be the temperature criterion, since the latter is not preserved in low-T stage. (From the authors' abstract).

U.S. GEOLOGICAL SURVEY, 1976, Geothermal resources: U.S. Geol. Survey Prof. Paper 1000, p. 39-46.

Covers various aspects of research on geothermal fluids (ER).

UVAD'YEV, M.D., 1976, Typomorphism and conditions of formation of quartz from sub-surface gold ore deposits of E. Uzbekistan: Zapiski Vses.

Mineral. Obshch., v. 105, no. 1, p. 30-39 (in Russian). Author at Exper. - Methodic Expedition, Tashkent.

Gold deps. in E. Uzbekistan occur in volcanogenic rocks of trachyandesite-dacite form. of Middle/Upper Carboniferous age. Char. T_D for quartz from Au-bearing ores varies in a wide range from 100 to 700°C, but intensive decrep. occur in several types of ores at T = 200-350°C. (Abst. by A.K.)

VACHER, Andre, 1976a, On fracture healing in crystals: Bull. Soc. Fr. Minéral. Cristallogr., v. 99, p. 91-94 (in French). Author's address: 26, rue des Déportés - 92700 Colombes, France.

Observations on fracture-healing in fragments of topaz from Minas Gerais (Brazil). A description of cavity evolution after unmixing of H_2O - CO_2, resulting in the formation of inclusions with quite variable H_2O/CO_2 ratios, but without quantitative data. (Author's abstract modified by M. Pagel.

VACHER, A., 1976b, Summary study of fluid inclusions in a topaz from Montbelleux (Ille-et-Vilaine): Bull. Soc. Fr. Minéral. Cristallogr., v. 99, p. 131-133 (in French). Author at 26, rue des Déportés - 92700 Colombes, France.

Two-phase aqueous inclusions (15-20% vapor) and three-phase inclusions containing CO_2 were formed at an early stage in topaz from the Montbelleux tin-tungsten deposit (Brittany, France). Later two-phase and multiphase (halite daughters) aqueous inclusions trapped in the same fracture have highly variable vapor/liquid filling ratios suggesting boiling. Multiphase inclusions have equivalent salinities of 30-40% NaCl and filling temperatures above 400°C. It seems likely that these filling temperatures are higher than the trapping temperatures since the fluids were two-phase when trapped. (Abstract by Arthur Barabas.)

VALERA, Roberto, 1976, Some considerations on the role of fluid inclusions in crystal growth: Bull. Soc. Fr. Minéral. Cristallogr., v. 99, p. 78-79 (in French). Author at Instituto di Giaciamenti Minerari della Facolta di Ingeneria dell'Universita, 091000 Caglari, Italy.

Fluid inclusion patterns and surface structures in phosgenite point out the behavior of crystallization phenomena. It may be that fluid inclusions play an active role, not just a passive one, in crystal growth. (Author's abstract, revised by Chris Eastoe).

VAN ALSTINE, R. E., 1976, Continental rifts and lineaments associated with major fluorspar districts: Econ. Geol., v. 71, p. 977-987.

Major fluorspar districts are localized chiefly along and near continental rift zones and lineaments. Evidently large volumes of fluorine leaked upward from the lower crust or mantle along and near the rifts. This assocn. of major fluorspar districts and continental rifts and lineaments is regarded as a regional guide in the search for new fluorspar districts. The fluorspar may be accompanied by commerical quantities of barite, Zn, Pb, Mo, U, Th, Nb, Sn, Be, or RE min. (From the author's abstract)

VASIL'KOVA, I.V. and NIKOLAEV, V.A., 1976, Conditions of deposition of fluorite in ore deposits of the Maritime Province according to data from the study of gas-liquid inclusions: Soveshch. Molodykh Uchenykh Mineral., Geokhim., i Metodam Issled. Mineral (Tezis. Dokladov), Primor. Otdel., Vses. Mineralog. Obshch. Dal'nevostoch. Geol. Inst., Vladivostok, p. 70-71 (in Russian; translation courtesy of Michael Fleisher). Authors at Moscow Gos. Univ., Geochem. Branch.

1. Mica-fluorite dep. on the margin of the Khankaisk middle massif in the zone of the junction of old structures (P_{Z1}) with the region of Mesozoic folding were studied. The form. of these dep. is connected with the devel. of the Caledonian granitic complex (380-480 my.). The country rocks are limestones ($R-E_1$) and schists (t_1), cut by small bodies of alaskitic granites of high alkalinity. Both bodies were formed as the result of hyd. metasom., which led to the replacement of limestone by mica-fluorite ores. One of the dep. is a metasom. pipe-like dep. in limestone, char. by the maintenance of the fluorite min. to 300-400 meters without any notable zonin's. The other ore bodies form zoned sheet-like dep. in limestone. The main ore min. are fluorite, sericite, mica of ephesite-type, tourmaline, and quartz.

2. For the study of the thermobarometric cond. of ore dep. fluorite samples were selected from open pits and drill cores. Meas. T_H (117 samples) were made on P gas-liquid inc. Est. of the P of the process of ore dep. (8 samples) were based on complex meas. of T_H of gas liquid inc. and the T of partial homog. of essentially CO_2 inc.

The T_H results indicate that the T_F of fluorite from the dep. studied were rather similar. The process of fluorite form. proceeded in a wide T interval; it began at 360-370°C (fluorite from the apophysis of granite); most of the ore in this dep. formed at 140-290°C, and epigenetic veins of fluorite, containing usually predominant calcite, formed at 60-140°C.

4. The dist. of T_H values of ore fluorite showed that the spatial T zoning during the dep. of fluorite in the dep., having the form of a column, is not significant. Temperature leveling was aided by the presence of a shielding bed of shale, cutting the limestone and impermeable to hyd. sol. In the dep. with sheet-like ore bodies, T zoning was noted. Fluorite from the upper block of the ore has T_H of 135-165 °C, whereas in the lower block, $T > 192-229°C$.

5. The P est. of fluorite form. are uniform; metasom. of limestone occurred in the interval 500-1300 bars.

VETÖ, É., 1975, Thermo-optical examination of inclusions in fluorite from Kápolnásnyék: Relationes Annuae Inst. Geol. Publici Hungarici, 1975 (in Hungarian with English abstract).

The well Kápolnásnyék - 1 recovered dolomites which, on the basis of petrography and structural position, cannot be older than Middle Triassic in age. In the fissures and cavities of these dolomites, 5-mm fluorite crystals can be seen. The fluid-gas inclusions in these crystals were subjected to homogenization temperature- and cryoscopic measurements.

From the latter measurements, the fluid phase contains only a very low quantity of dissolved salts.

The study suggests that the fluorine content of the carbonate rocks was mobilized by heated karst water, and that fluorite would then precipitate with the establishment of proper physico-chemical circumstances. (Author's abstract)

VILLEMAIRE, Claudine, 1976, Glass inclusions in quartz grains from Devonian formations (Rhenan schist massif): C.R. Somm. Soc. Géol. Fr., fasc. 5, p. 222 (in French). Author at Lab. Géol. Struct. et Appl., Univers. Paris Sud, 91405 Orsay, France.

Biphase glassy inclusions (glass + shrinkage bubble) were found in quartz fragments from sandstones of upper Siegenien and lower Emsien age (380 m.y.). (Abstract by M. Pagel, translated by A. Barabas).

VISSER, W., and van GROOS, A.F.K., Liquid immiscibility in the system Na_2O-K_2O-FeO-Al_2O_3-SiO_2 (abst): Amer. Geophy. Union, Trans., v. 57, no. 4, p. 340.

VITVITSKIY, V.V. and SHAPENKO, V.V., 1976a, Temperature conditions of catagenesis of sediments and genesis of calcium chloride brines (Paleozoic deposits of the Volgo-Urals area), (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 55-56 (in Russian; translation by A. Kozlowski).

P two-or three-phase inclusions (5 to 40 vol.% of G phase) were found mainly in dolomite; T_H varied from 400 to 160°C. The high-temperature solutions caused metasomatic dolomitization and anhydritization of carbonate rocks, as well as appearance of authigenic garnets, rutile, albite, tourmaline, barite and sulfides of base metals in the underlying Devonian rocks. The source of brines is probably the pore solution, being buried marine water. (From the authors' abstract).

VITVITSKIY, V.V. and SHAPENKO, V.V., 1976b, New data on paleotemperatures in carbonate rocks of Paleozoic age from SE Russian platform: Akad. Nauk SSSR, Doklady, v. 228, no. 4, p. 936-939 (in Russian). Authors at Moscow State Univ., Moscow.

Mins. of Lower and Middle Carboniferous dolostones and limestones from boreholes from Volgo-Urals area (depths 753-2160 m), mainly dolomite and calcite, bear one-, two- (G 5-40 vol. %) and three-phase ($G \leq 25$ vol. % and some dms) fluid incs. T_H of two-phase incs. ranges from 150 to 400°C, T_H of three-phase incs. usually exceeds 300°C, but complete homog. was not achieved for this type. Dolomitization is probably connected with action of sols. at T 200-400°C; these rocks contain also authigenic albite, garnet, rutile, tourmaline, and barite. (Abst. by A.K.)

VOCHTEN, R. and ESMANS, E., 1976, Study of the solid and gaseous inclusions in some varieties of fluorite by microprobe and high resolution mass spectrometry (abst.): International Geol. Congress, 25th, Abstracts, p. 815. Abstract published in Fluid Inclusion Research, v. 8, p. 188-189 (1975).

VOGEL, T.A. and WILBAND, J.T., 1976, Coexisting acid and basic melts in a composite dike (abst.): Geol. Soc. Amer. Abstracts with Programs, v. 8, p. 1155. Authors at Geol. Dept., Michigan State Univ., East Lansing, MI, 48824.

The REE data indicate that the granitic portion of the dike could not be derived by partial melting of the adjacent wall rock and also could not result from fractional crystallization of the basic melt. It is possible that the two magma types are independent of each other, or they may have an immiscible relationship. (From the authors' abstract).

VOROB'EV, E.I., and LOZHKIN, V.I., 1976, The identification of daughter minerals of fluid inclusions by means of X-ray coloration: Ezhegodnik Sibirsk Inst. Geokhim. (Yearbook Siberian Inst. Geochemistry) for 1975, p. 281-283 (publ. 1976; in Russian). See translations.

VOZNYAK, D.K., and KALYUZHNYI, V.A., 1976, Use of decrepitation of inclusions to reconstruct PT-conditions of mineral formation (using quartz from Volyn pegmatites as an example): Min. Sbornik, v. 2, no. 30, p. 31-40 (in Russian).

On the basis of a theoretical consideration of the decrepitation of inclusions, the possibility of using them for reconstruction of PT-conditions of the mineral formation are substantiated. The morphology of decrepitated inclusions in quartz, and the time of their appearance in the process of crystallization of the Volyn pegmatites are studied. (Authors' abstract).

VYNAR, O.N., and GIGASHIVLI, G.M., 1976, The Republic conference: "Carbon and its compounds in endogenic mineral-forming processes (according to data from investigation of fluid inclusions in minerals): Mineral. Sbornik, v. 2, no. 30, p. 106-107 (in Russian).

A report on the conference on carbon in inclusions at L'vov, Sept. 30 - Oct. 1, 1975. Most abstracts from this conference were translated in Fluid Inclusion Research, v. 8, 1975. (ER).

WATSON, E.B., 1976a, 2-liquid partition coefficients - Experimental data and geochemical implications: Contrib. Min. and Pet., v. 56, p. 119-134.

Pertinent to any melt inclusion study involving possible immiscibility (ER).

WATSON, E.B., 1976b, Glass inclusions as samples of early magmatic liquid: determinative method and application to a South Atlantic basalt: Jour. Vol. Geothermal Research, v. 1, p. 73-84. Author at Dept. of Earth and Plan. Sci., Mass. Inst. Tech., Cambridge, Mass. USA

Silicate melt inclusions in phenocrysts are not directly representative of trapped magmatic liquid because chemical interaction between inclusions and host crystals usually occurs after melt entrapment. However, if more than one phenocryst type in a suite of rocks contains melt inclusions, the original trapped-liquid composition can be accurately fixed by the intersection of host-mineral fractionation lines in a triangular oxide plot of inclusions analyses. When plotted on a CaO-MgO-Al_2O_3 triangular diagram, analyses of inclusions in plagioclase, olivine, and clinopyroxene from a basalt dredged off Bouvet Island fall along crystal fractionation lines that intersect at a single point. This point represents an initial trapped liquid composition rich in CaO and MgO, and low in TiO_2 and total alkalies. The composition is transitional between tholeiite and basaltic komatiite, and may be indicative of extensive melting of clinopyroxene in the mantle. (Author's abstract).

WEGNER, M.W., JONES, R.E., and CHRISTIE, J.M., 1976, Exsolution in plagioclase revealed by chemical etching, (abst.): Amer. Geophys. Union Trans., v. 57, p. 1019. Authors at Dept. of Earth and Space Sciences, Univ. of California, Los Angeles, CA 90024.

This technique permits easy optical identification of fine-scale exsolution over relatively large areas and is therefore complementary to other techniques.

WEIBLEN, P.W., and ROEDDER, E., 1976a, Comparative compositional studies of silicate melt inclusion, bulk chemical, and experimental data on mare basalts (abst): Lunar Science VII, p. 927-929, The Lunar Science Inst., Houston.

Essentially same as following entry (ER).

WEIBLEN, P.W., and ROEDDER, E., 1976b, Compositional interrelationships of mare basalts from bulk chemical and melt inclusion studies: Proc. Lunar Sci. Conf. 7th, p. 1449-1466. First author at Dept. Geol. and Geophy., Univ. Minn., Minneapolis, MN 55455.

Petrographic and electron microprobe data (355 new analyses) are presented on melt inclusions and their host phases found in a re-examination of the Apollo thin section collection. In addition, occurrences of early armalcolite (?) and ilmenite are described and new data are presented on quench-pyroxene compositions and melt inclusions in chromian ulvöspinel.

Compositional differences between mare basalt types and their melt inclusions are illustrated with plots of compositions normalized to a terrestrial lava composition, that of the 1965 Makaopuhi lava lake. The plots emphasize the fact that mare basalts are not significantly differentiated relative to the compositions that are possible as defined by the melt inclusion data.

Distribution coefficients for Fe and Mg partitioning between trapped melt and host olivine and ilmenite are calculated and show a range about probable equilibrium values. It is suggested that the crystallization sequence olivine-ilmenite-plagioclase-pyroxene defined by the melt inclusion data may be the actual sequence which obtained generally for Apollo 11 and 17 mare basalts just prior to eruption. (Authors' abstract).

WEISBROD, Alain, POTY, Bernard and TOURET, Jacques, 1976, Fluid inclusions in geochemistry and petrology: present trends: Bull. Soc. Fr. Minéral. Cristallogr., v. 99, p. 140-152 (in French). First author at Centre de Recherches Pétrographiques et Géochimiques, Case officielle n° 1, 54500 Vandoeuvre-les-Nancy, France.

A summary of the application of fluid inclusion studies to non-metallogenetic petrological-geochemical problems, including a review of the available analytical methods and techniques, the basic hypotheses of these studies and the application of experimental data ($NaCl-H_2O$, CO_2-H_2O) to the interpretation of inclusion measurements. Examples discussed in detail include : mechanism of metamorphism (granulite facies and metamorphism of the upper oceanic crust); geothermometry - geobarometry (low pressure hydrothermal processes in pegmatites, and metamorphism of intrusive complexes in the French and Swiss Alps);+ quantitative computations in mass transfer processes The paper includes a particularly useful discussion of the variables

limiting the use of K^+/Na^+ ratios fluids in equilibrium with feldspars at low pressures. Most of the studies cited have been published. (Authors' abstract modified by A. Barabas.)

WENNER, D.B. and TAYLOR, H.P., Jr., 1976, Oyxgen and hydrogen isotope studies of a Precambrian granite-rhyolite terrane, St. Francois Mountains, southeastern Missouri: Geol. Soc. Amer. Bull. v. 87, p. 1587-1598. First author at Dept. of Geol., Univ. of Georgia, Athens, Georgia 30602.

WHITE, S., JONES, M., and KNIPE, R., 1976, Micro-fluid inclusions in quartz--a transmission electron microscope study (abst.): Geological Society-Mineralogical Society (Britain) Symposium on fluid inclusions, Univ. of Durham, Abstracts of meeting (unpaginated), to be published in Trans. I.M.M. Sect. B.

Recent transmission electron microscopy studies have revealed that quartz crystals and grains contain a much greater number of bubbles than previously indicated in optical studies. The bubbles have diameters less than about 1 μm and cannot easily be resolved with an optical microscope. Most bubbles in quartz grains are surrounded by dislocations and many occur along dislocation walls or at the junctions of these walls. Recent calculations indicate that bubbles may have a profound influence on the rheology of quartz.

Bubbles can be formed in quartz during the annealing of both natural and synthetic quartz crystals. They develop preferably along existent dislocation structures and may contain solid inclusions. This indicates that many bubbles in metamorphic quartzites may develop by solid-state processes long after the quartz itself was formed. (Author's abstract)

WILKINS, R.W.T., 1976, Fluid inclusions of the metamorphosed stratiform Pb/Zn orebody at Broken Hill, New South Wales, Australia (abst.): International Geol. Congress, 25th, Abstracts, p. 816. Abstract published in Fluid Inclusion Research, v. 8, p. 195 (1975).

WILKINS, R.W.T. and BARKAS, J.P., 1976, Fluid inclusions in the granitic rocks of the Lachland Fold Belt (abst.): Bull. Aust. Soc. Explor. Geophys., v. 7, no. 1, p. 45-46. First author at CSIRO Div. of Mineralogy, PO Box 136, North Ryde, NSW 2113, Australia.

Very little is known of the complex history of fluid interaction with the rocks of the Lachland Fold Belt. In this survey we have examined the nature and abundance of the fluids trapped as inclusions in the granitic rocks of southeastern NSW and Victoria. Some hundreds of specimens have been examined in thin section, embracing examples of Vallance's (1969) Bathurst, Murrumbidgee and Cooma granite types, together with leucogranites and other distinctive variants. Selected doubly-polished thick sections were used in homogenization temperature measurements and salinity determinations, using heating and freezing stages, respectively.

Fluid inclusions were found in the quartz grains of all granitic rocks examined. Six compositional types are distinguishable: (1) liquid only; (2) two-phase liquid/vapor; (3) low-density gaseous; (4) CO_2-rich; (5) multiphase of low salinity; and (6) highly saline. Inclusions of types 1, 2, and 3 are ubiquitous, but types 4 to 6 are restricted to certain granites. Inclusions of glass and devitrified glass are uncommon.

Although occasional inclusions larger than 100μm in length were observed, the vast majority are smaller than 10μm in the longest dimension. The mean inclusion size appears to give an indication of depth of emplacement. Fewer fluid inclusions are found in the quartz grains of the more mafic rocks (diorites and tonalites) than in their leuocratic associates. Inclusions range in shape from stumpy negative crystals to those with ragged or irregular outlines, but most are more or less rounded. The most irregular are the type 1 variety, which represents the lowest temperatures of formation. The overwhelming proportion of all types homogenize at less than 300°C, and, in general, the more regular the inclusions shape, the higher the homogenization temperature. Pressure corrections of up to +250°C may be appropriate for homogenization temperatures measured from deeper-level granites, but, for type 2 inclusions in the Icely Granite (part of the Bathurst Batholith) that homogenize at 280 ± 5°C, this correction is only of the order of +30°C.

Salinities of the fluids in inclusions of types 1,2 and 5 are low to moderate, in the range 0-10% equivalent NaCl. However, a few granites contain highly saline (type 6) inclusions with NaCl daughter crystals and occasionally KCl as well. These highly saline inclusions are not characteristic of any granite composition or emplacement type. An examination of the areal distribution of distinguishable fluid types reveals that type 4 inclusions are particularly characteristic of the Bathurst type granites. They are also common in the high-level granites of central Victoria and the Mt. Wills area of northeastern Victoria. These granites may also be of the Bathurst type.

It is not possible to prove that any of the fluid inclusions had a primary magmatic origin, but some, especially the irregularly dispersed higher-temperature inclusions, are related to initial cooling, as distinct from crystallization, of the host quartz grains. Most, however, are demonstrably secondary in origin, as they lie along curved fracture planes or along the traces of such planes that have now healed. By studying cross-cutting relationships between these planes as well as various textural characters of the rock, it is possible to infer relative times of origin of the inclusins. The usual situation is that the fluids now observed were trapped after the development of mature textures. In samples of the deformed granites, particularly the Burrinjuck-Young, Murrumbidgee and Wyangala Batholiths, most of the inclusions occupy fracture planes formed after the deformation of the quartz. In the deformation parts of the Barry and Wondalga Granites, however, where recrystallization is well advanced, some fluids were obviously included after deformation but before recrystallization.

A magmatic source seems most likely for the highly saline and CO_2-rich types. The abundant low-salinity inclusions could well be due to influx of meteoric waters at some later stage. Possibly some inclusion fluids may have exsolved from the solid phases in the cooling granitic bodies. Distinctive fluid inclusion assemblages characterized by high salinity and gas-rich inclusions are typical of Bingham-type porphyry copper host rocks. However such assemblages have not yet been observed in the Lachlan Fold Belt, even from mineralized granites. (Authors' abstract).

WINKLER, H.G.F., 1976, Petrogenesis of metamorphic rocks, 4th ed., New York, Springer-Verlag, 334 pp.

Includes discussions of various volatile-bearing systems (ER).

WISE, J.A., 1976, Liquid-in-glass thermometry: Nat. Bur. Stds. Monograph 150, 26 pp.

Detailed information on methods of calibration and problems encountered in the use of thermometers. (ER)

WOLF, K.H. (Ed.), 1976, Handbook of strata-bound and stratiform ore deposits: Amsterdam, Elsevier Sci. Pub. Co., 7 vols., in English.

Numerous individual articles include refs. to fluid inc. data, but generally not unpublished data, with one exception (Roedder, 1976, this volume). The volumes contain many excellent reviews of individual ore deps. or types of ore deps., and several chapters of general interests to inc. work (e.g., Duursma and Hoede on diffusion; Hitchon on fluid circulation and chem.; Saxby on org. matter; Fritz on C & O isotopes; Sangster on S isotopes, etc.) (ER)

WOOD, Cynthia, 1976, A study of fluid inclusions in quartz veins associated with the Octoraro Phyllite in southeastern Pennsylvania: M.A. thesis, Bryn Mawr College, Bryn Mawr, Pa.

Three mappable lithologies occur along the Octoraro Creek section of the Coatesville 15' quadrangle, Pennsylvania: 1. a quartz-muscovite-chlorite-albite phyllite, 2. a muscovite-chlorite-quartz-chloritoid-albite phyllite, and 3. a carbonaceous-muscovite-quartz phyllite. Quartz veins found with these rocks formed before any deformation; no evidence was found that their growth was structurally controlled. The first metamorphism was synchronous with the first deformation. This deformation, an isoclinal folding, produced a strong foliation which strikes east-west and dips 40°-60°SE. A second deformation gave rise to a slip cleavage orietned N50°E and dipping 20°SE and produced a tight crinkle lineation (L_1) on the early foliation surfaces. A second higher grade metamorphism (300-500°C and 3-4 kb) occurred after the second deformation. A third deformation produced a north-south trending, tight crinkle lineation (L_2) on the early foliation surfaces.

Information about the fluid and pressure conditions during metamorphism was obtained through a fluid inclusion study which included a crushing stage analysis and a microthermometric investigation using a heating and cooling stage. Four types of inclusions are present in the vein quartz: H_2O+NaCl, CO_2+H_2O+NaCl, CO_2 and CH_4 inclusions. These can be divided into two groups: 1. high pressure (3-4 kb), high density (.913), H_2O-rich inclusions and 2. low pressure, low density (0.05), CO_2-rich inclusions.

The first group possibly represents two immiscible fluids, one aqueous, the other CO_2-bearing trapped during the second metamorphism. The second inclusion group was entrapped during a later low temperature-low pressure growth of quartz which may have occurred during and/or after uplift of these rocks. Large, primary H_2O+NaCl 4.5% [NaCl] inclusions are found in a later growth of quartz crystals in open fractures. (Author's abstract).

WOOD, J. R., 1976, Thermodynamics of brine-salt equilibria - II. The system NaCl-KCl-H_2O from 0 to 200°C: Geochim. Cosmo. Acta, v. 40, p. 1211-1220. Author at Department of Geology, University of Wyoming, Laramie, Wyoming 82070.

WYLLIE, P.J., and HUANG, W.L., 1976a, Carbonation and melting reactions in the system CaO-MgO-SiO_2-CO_2 at mantle pressures with geophysical and petrological applications: Contrib. Min. Pet., v. 54, 79-107.

WYLLIE, P.J. and HUANG, W.L., 1976b, High CO_2 solubilities in mantle magmas: Geology, v. 4, p. 21-24.

Phase diagrams for the assemblage forsterite + enstatite + CO_2 in MgO-SiO_2-CO_2 show that a subsolidus carbonation reaction intersects the solidus near 44 kb-1530°C and stabilizes the carbonate molecule in the liquid, causing CO_2 solubility to increase from about 5 to 10 wt percent to about 40 wt percent. A similar increase occurs in the system CaO-MgO-SiO_2-CO_2 near 25 kb-1200°C for the liquid coexisting with forsterite + orthopyroxene + clinopyroxene. The CO_2 solubility in diopside and enstatite liquids remains relatively low, because these are not involved in carbonation reactions at this pressure. This accounts for contrasted CO_2 solubilities in silicate melts reported in recent experimental studies. Magmas generated in a CO_2-bearing mantle below a depth of 80 km may contain up to 40 wt percent dissolved CO_2. CO_2-rich, SiO_2-undersaturated magmas can coexist with mantle peridotite through a wide temperature range. These could represent either primary carbonatite and kimberlite magmas or the carbonated alkali ultrabasic magmas cited by many petrologists as parents for the derivation of continental volcanic and plutonic associations of highly alkalic rocks. (Authors' abstract).

WYLLIE, P.J., and HUANG, W.L., 1976c, Petrogenetic grid for siliceous dolomites extended to mantle peridotite compositions and to conditions for magma generation: Amer. Miner., v. 61, p. 691-698.

WYLLIE, P.J. and HUANG, W.L., 1976d, Carbonation and melting reactions in the system CaO-MgO-SiO_2-CO_2 at mantle pressures with geophysical and petrological applications: Contrib. Mineral. Petrol. v. 54, p. 79-107.

WYLLIE, P.J., HUANG, W.L., STERN, C.R., and MAALØE, S., 1976, Granitic magmas: possible and impossible sources, water contents, and crystallization sequences. Can. Jour. Earth Sci., v. 13, no. 8, p. 1007-1019.

YEATS, R.S. and MATHEZ, E.A., 1976, Decorated vesicles in deep-sea basalt glass, Eastern Pacific: Jour. of Geophys. Research, v. 81, p. 4277-4284. First author at Dept. Geol., Ohio Univ., Athens, OH 45701.

Microprobe and scanning electron microscope (SEM) examination of small vesicles found in glassy selvages of tholeiitic basalt shows that some vesicle walls are decorated with evenly spaced spherules 0.5-4 µm across. Some are iron sulfides with high concentrations of Cu and Ni and are set in hemispherical pits in vesicle walls. Other spherules are not sulfides and appear to be aggregates of plates in microvesicular vesicle walls; these may be oxidized spherules accompanied by palagonitized glass. Other decorations includes plates, grooves, and whiskers; the chemical nature of these features is not known. The spherical shape of sulfide spherules is distorted by secondary crystal growth into the vesicle, presumably due to reequilibration during cooling or to alteration. Loss of sulfide spherules during degassing may be an additional mechanism by which metals enter seawater near a rise crest. (Author's abstract).

YEN, C.-C., 1976, Trapping temperature and pressure of the fluid inclusions in the gangue minerals of gold-silver-copper deposits at Chinkuashih mine, Taiwan: Proc. of the Geol. Soc. of China, no. 19, p. 127-133 (in English). Author at Inst. of Geology, National Taiwan Univ.

Fluid inclusion studies of twenty-four samples of barite, quartz, and alunite collected from gold-silver-copper deposits at Chinkuashih Mine revealed the presence of very dilute, sometimes CO_2-rich fluid with calculated densities ranging from 0.87 to 0.91 gm/cc. The freezing temperatures of the fluids are above -9°C, less than 14 weight percent in salinity if the $NaCl-H_2O$ system is used. Homogenization temperatures appear in a wide range from 160° to 300°C. The highest trapping temperature was about 375°C, after a pressure-correction. Estimated load pressure was 600-1000 bars at early fissure-filling stage and 31.2 bars or less at late-stage of mineralization, corresponding to ore formation at depth of 2400-3500 meters to a change into a few hundred meters due to enormous upheaval in the late stage. (Author's abstract).

YPMA, P.J.M., 1976a, Fluid inclusion characteristics of low temperature near-surface ore deposits. Example from the Beltana willemite ore body, South Australia (abst.): International Geol. Congress, 25th, Abstracts, p. 816-817. Abstract published in Fluid Inclusion Research, v. 8 p. 199 (1975).

YPMA, P.J.M., 1976b, Fluid inclusion study of copper deposits of the W. margin of the Mt. Painter Block, South Australia. Porphyry copper characteristics of stratabound sulphides (abst.): International Geol. Congress, 25th, Abstracts, p. 817. Abstract published in Fluid Inclusion Research, v. 8, p. 200 (1975).

YUSUPOV, S. Sh., 1976, Fluctuation of temperature during the hydrothermal stage of mineral-formation in the chamber pegmatites in Kazakhstan, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 43-44 (in Russian; translation by A. Kozlowski).

Zones of T change were recognized on plots of T_H of P inclusions in quartz and fluorite vs time of deposition, from the Kent, Akzhailiausskiy etc. granite massifs. Each large cycle consists of four parts: T decrease - no change - T increase - no change. During the decreases reticulate quartz and violet fluorite formed. The minimum T (400°C) appeared at the boundary of the reticulate quartz and rock crystal. Under the succeeding stable T, rock crystal, amethyst and colourless fluorite formed. During the T increase, light-smoky quartz and pink fluorite crystallized. Subsequent stable T period gave the deep-smoky quartz, morion and the green fluorite (pegmatites of Kent and Bektauata). Microfluctuations of T over a range 1-5°C presumably are necessary for the normal growth of crystals (Author's abst.)

YUSUPOV, S.Sh., KHAIRETDINOV, I.A., and CHUPINA, L.Yu., 1976, Temperature conditions of formation of agates in Kazakhstan, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol. p. 49-50 (in Russian; translation by A. Kozlowski).

Agate deposits occur in intermediate and acid effusives. (...) Fluid inclusions were studied in quartz, fluorite, calcite and barite from the center of the agate nodules from the deposits Sartmolla, Katu-Tau, Kyzyl-Tugan and Pavlodarskoe. In the external chalcedony layers only gas inclusions were found. In the center of the nodules inclusions in the base of the crystals bear from < 10 to 40-70% of gas, and in the periphery - from 10-3% of gas to none. T_H of fluid inclusions in quartz and fluorite ranged from 450 to 90°C, in calcite from 200 to 90°C, in barite 130 to 50°C. In quartz from Sartmolla and Zhastar II deposits there are clear T fluctuations: early quartz T_H = 100-150°C, late quartz = 200-250°C. Amethyst quartz bears inclusions with T_H 130-180°C, amethyst plus smoky zoned quartz - 250-300°C. Maximum T_H (350-450°C) was found in pale and deep smoky quartz in the upper parts of crystals; the root parts of crystals yield T_H 95-200°C. Similar fluctuations were found in fluorite: the internal zones of crystals have T_H 200-100°C, the external zones - 450-300°C. (From the authors' abst.)

ZAKHARCHENCHO, A.I., 1975, Pegmatite-forming melt-solutions and main paths and stages of formation of granitic pegmatites, Collected Papers on Experimental and Geological-Mineralogical Studies of the Process of Ore Formation, v. 2, A.I. Zahkarchenko, ed.: Leningrad, VSEGEI, p. 65-88 (in Russian).

A review of previously-published studies - see, e.g., Fluid Inclusion Research, v. 7, pp. 241-245. (E.R.)

ZAKHARCHENKO, A.I., 1976a, The transition of granite melts to fluids, their characteristics and metal content from minerals and inclusions, in Internat. Geol. Congress, 25th Session, Reports of Soviet Geologists (Tugarinov, A.I., et al., eds.), p. 261-274: Moscow, Izd. Nauk (in Russian with English summary).

This paper was not given at the 25th I.G.C. and the abstract is not present in the volume of abstracts of the 25th IGC (E.R.).

ZAKHARCHENKO, A.I., 1976b, Transition of melts into fluids, evolution of content of metals, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 12-13 (in Russian; translation by A. Kozlowski).

Essentially same as Zakharchenko, 1976, see Fluid Inclusion Research - Proceedings of COFFI, 1975, vol. 8, p. 200-201 (A.K.)

ZAKRUTKIN, V.V., TRUFANOV, V.N., and DUDAKOV,V.K., 1974, New method of determination of primary nature of basic metamorphites: Acad. Sci. USSR, Doklady, v. 217, no. 2, p. 446-448 (in Russian). Authors at Rostov State Univ., Rostov.

Essentially the same as given under same title by Zakrutkin, Trufanov, and Dudakov, 1973, in Fluid Inclusion Research - Proc. of COFFI, v. VI, 1973, p. 173, but with addition of a figure showing 6 decrepigraphs. (A.K.)

ZAPATERO, Luis, 1976, Fluorescent inclusions in quartz: Inst. Gemologico Español, Bol., 1976, no. 13, p. 15-21 (with 6 color photos) (in Spanish).

A short discussion of the various kinds of incs. in quartz from the fluorite dep. of Berbes (Asturias). Phases found include bitumen, fluorescent yellow oil, gas, aq. sol., and wax (?). (ER)

ZAREMBO, Yu.G. and ANDRYANOVA, S.I., 1976, Relation between gold and tungsten mineralization in W. Uzbekistan (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept., 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 32-33 (in Russian, translation by A. Kozlowski).

Quartz-scheelite and quartz-sulfide veins formed from pneu.- hyd. and high-T. hyd. sols. bearing CO_2. Role of CO_2 decreases from early ore to late barren stages. Scheelite-bearing quartz contains 80-90 cm^3 CO_2/kg (0.8-2.8 arbitrary units on IR absorption, hereafter called simply IR), and quartz with Au and sulfides - 150-160 cm^3 CO_2/kg (IR 1.5-3.9). Au and scheelite ppted at T = 260-220 and 240-220°C, respectively. Late Au-low quartz-sulfide veins xlized from hyd. sols. with lower CO_2 conc. (IR 0.9-0.78). Post-ore quartz- carbonate veins ppted from CO_2-poor colloid sols. (30 cm^3 CO_2/kg; IR 0.1-0.8). Amount of water in quartz increases from early to late stages (from IR 0.5-3.5 to 5-11). Veins formed at T= 440 to 50°C with abrupt T changes (intervals 150-280°C); stages of pption of quartz (440-290°C), ore mins. (270-220°C) and carbonates (140-50°C) may be distinguished. CO_2 occurs in incs. with T_H - 320-290°C. (...)

ZHARIKOV, V.A., 1976, Some actual problems of experimental mineralogy: Zapiski Vses. Mineral. Obshch., v. 105, no. 5, p. 543-561. (in Russian). Author at Inst. of Exper. Mineralogy of Acad. Sci. USSR.

List of discussed problems: equil. with min. of unstable comp., and problems of stimulation of mineral. reactions; systems with completely mobile components and buffering of regime of these components; studies of model fluid and problem of its generations; mass transport in porous sols., their physico-chemical features and interaction with finely porous wall matter; studies of extrahigh Ps and problems of Earth's depths; and magm. systems with completely mobile components. (Transl. by A.K.)

ZINCHUK, I.N., 1976, Mineral-formation of hydrothermal veins at N. anticlinorium of Donbass, (abst.), Abstracts of Fifth All-Union Conference on Thermobarogeochemistry, Ufa, USSR, 20-23 Sept. 1976: Ufa, Bashkir Section, Acad. Sci. USSR, Inst. of Geol., p. 38-39 (in Russian; translation by A. Kozlowski).

Two-phase hydrothermal fluids were recognized in veins at N. anticlinorium. In quartz of Pavlovskoe T_H of early secondary inclusions bearing L CO_2 (12% at 20°C) equal 237 - 230°C. Heterogenization was at 193-192°C and 480-450°C atm at late stage of mineral-formation; last generation of inclusions have T_H 174-148°C, free of CO_2.

Veins in the slope of the N. anticlinorium bear syngenetic gas-liquid inclusions (T_H = 150 - 147°C) and inclusions of "dry" gases with CO_2 (T of partial homogenization in gas = 40°C; T_{Frz} = 57°C; nitrogen becomes gaseous at -150.5 to -150°C). L N_2 occupies 35-40 vol. % at -185°C, and CO_2 about 12 to 15 vol. % at T of melting. Calculated P at

T_H of syngenetic gas-liquid inclusions at 150°C equals 85 atm.

Similar inclusions were found in quartz-carbonate veins of Bobrikovskoe Au-polymetallic deposit (Nagol'nyi complex). N_2 vaporizes at -158°C; at -185°C it occupies 20-25 vol. %. CO_2 vaporizes at +19°C; at -54.5°C it makes up 25-28 vol. %. Calculated P at T_H of syngenetic G/L inclusions (180°C) equals 90 atm.

By mass spectrometry the following composition of gases was found: N_2 - 63.78%, CO_2 - 32.70%, CH_4 - 3.51%. Low P in the moment of heterogenization testifies to rapid opening of fractures. Low solubility of CH_4 in water permits the determination of P in the system; values found in veins from Central Donbass equal 440-350 atm. (Author's abst.)

ZOLOTAREV, B.P., VOITOV, G.I. and CHEREVICHNAYA, L.F., 1976, Gases in young basaltoids of some islands in SW part of Pacific: Akad. Nauk SSSR Doklady, v. 229, no. 3, p. 721-724 (in Russian). First author at Geol. Inst., Acad. Sci., USSR, Moscow.

Gases (several cm^3 per 1 kg of rock) from ground basalts, andesitic basalts, andesites, gabbro-diabases and calcite gave following ranges (cm^3 per 1 kg): H_2 0.2-2.2, CH_4 0.016-0.16, C_2H_6 0.0016-0.032, C_3H_8 0.001-0.01, C_2H_4 0.001-0.0056. CO_2 and N_2 were not determined. (A.K.)

ZOLOTUKHIN, V.V., 1976, On droplet shape of sulphide phenocrysts from Norilsk ore-bearing intrusions: Akad. Nauk SSSR, Sib. Otdel, Geol. i Geofiz., 1976, no. 5, p. 114-119 (in Russian with English abstract).

The presence of droplet-like sulphide phenocrysts in the rocks of ore-bearing Norilsk intrusions is one of the principal arguments in favour of liquation genesis of sulphides. Detailed examination of the structural pecularities and phenocryst distribution as well as causes of droplet shape of sulphides suggest rather their metasomatic genesis because it is typical of the nonore metasomatic rocks of the same intrusions. (Author's abstract).

ZUBKOV, V.A., BRYZGALOVA, G.S., DEMIN, Yu. I., et al., 1974, Genesis of magmatic rocks of the Leninogorsk District, Rudnyy Altai, as shown by their mineral inclusions: Acad. Sci. USSR, Dokl., Earth Sect., v. 207, no. 1-6, p. 163-165.

Translations

Items presented here are selected on the basis of (1) availability of a translation that has not been published elsewhere; (2) significance to inclusion research; and (3) date of publication. Thus older items may be included when particularly significant. The Editors would welcome suggestions from readers as to other papers that should be translated, and would particularly appreciate copies of privately-made translations not here-to-fore published.

CHEPIN, A.I., and DOLOMANOVA, E.I., 1976, Determination of the chemical composition of deposits in opened vacuoles of minerals by the electron microprobe method: Sbornik Nauchn. Trudov, Mosk. Otdel., Vses. Mineralog. Obshch., March 1974, p. 199-201 (in Russian; publ. 1976). (Additional title page reads: New Mineralogical Studies, Ministry of Geol., All-Union Sci. Research Inst. of Min. Resources (VIMS), and Moscow Section, All-Union Mineralogical Soc., Acad. Sci. USSR.)

The chemical composition of crystalline phases in inclusions in various minerals (quartz, tourmaline, cassiterite, and others) had been determined previously by the electron microprobe method (Dolomanova and others, 1966, 1968; Troneva and others, 1971). Nevertheless, the studies were qualitative, without detailed explanation of the features of the analysis. More thorough studies were subsequently completed by the author (Dolomanova and others, 1974).

The present work was done to explore the possibilities of microanalysis of solid deposits1/ in opened inclusions in minerals. Features of microanalysis of the deposits are considered, factors influencing the quality of the analysis, and methods of analysis are proposed. The method was developed for the electron microprobe MS-46 and is the first attempt at qualitative, semi-quantitative, and partially quantitative studies of the composition of solid deposits in vacuoles.

The studies were made both in sections and in transparent polished sections. At first qualitative analyses were made of a large number of inclusions (20-60) open to the surface of the section, considering the data of spectrographic analyses of analogous samples. In view of the small size of most of the deposits, the analyses were made very carefully and over the entire area of the inclusion.

Inclusions richest in deposits were photographed in a current of absorbed electrons2/ and in the characteristic X-ray radiation of each element found. The size of the area scanned was chosen in correspondence with the size of the inclusion. The sample current photograph reflects the distribution of the phases in the area scanned, and also to some degree the topography of the surface. The photographs in characteristic X-ray radiations show the character of the distribution of the studied element in the scanned area, so that from the density of the points one can judge the distribution of the concentration of the element. Nevertheless one must have in mind that the map of distribution obtained depends on the size of the beam and its localization. At large beam size and poor resolution, taking place with high working voltage and with material of low density, the images of separate, closely located grains merge with one another and small particles of deposit located close to one another appear to be a single larger deposit.

In the map of the distribution of the element an additional distorting effect is brought in by the excitation by the beam of a lower-lying deposit (if there is one). The depth of penetration of the electrons into the sample is directly proportional to the energy of the incident electrons (i.e., of the operating voltage) and inversely proportional to the density of the studied mineral. For material of low density the depth of penetration can attain rather large magnitudes. For example, for Ca at $V = 20$ kV it is 6.3 microns. Consequently, in order not to distort the real picture of the distribution of the elements when the deposit is small, one must lower the working voltage to a limit close to the potential of excitation of the element studied. However, at low voltages, sensitivities are decreased; it is hard to focus the beam, and the size of the beam is increased. It was found from experiments that a working voltage of 10-20 kV is optimum.

The quality of the micro-analysis is affected by the "edge effect", which can lead to false notions as to the presence of the element analyzed in the deposit (increased intensities of radiation from the rims of inclusions facing the spectrometer), or which can create conditions under which one cannot find an element present (radiation from two walls closest to the spectrometer of a deep inclusion, partly or completely absorbed in the sample). In avoiding this during study of the deposit, the analyses were carried out at different positions of the same inclusion. The total map was determined by superposition of the partial distributions. Usually two positions were sufficient, one of which differs from the other by turning the sample 180°.

Polishing the sample has a negative influence on the results of studies of the chemical composition of deposits in inclusions. The layer of polishing paste clogs the opening of the inclusion, obstructs the excitation of low-lying deposits, and to a considerable degree weakens the X-ray radiation from the sample. This is especially true for the light elements (N, F, Na, Mg, Al, Si) having large wavelengths. Increase of the strength of the current during the scanning for these elements leads to a decrease of resolution. Besides, as the result of polishing, many solid deposits break out of the inclusions, and easily soluble compounds are dissolved during repeated washing of the sample. This is confirmed by the absence in many inclusions of such soluble elements as Cl, Na, and K.

On the basis of the experimental work and analysis of interfering factors, the following procedure is proposed for study of the composition of solid deposits in inclusions in minerals:

1. The chemical composition of solid deposits in inclusions are better studied on chips or slices of the mineral, without polishing or sectioning. Such studies, carried out by the authors, permitted obtaining information, not only on the compositions of the solid phases, but also of the liquid ones. Liquids spilled during the opening crystallized around the vacuole in the form of small (1-2 microns) isometric precipitates.

2. During the studies, one must turn the sample to eliminate the "edge effect".

3. For accurate identification of elements present in low concentration and to take account of the "edge effect", one must determine the background distribution in the area of the studied elements.

4. Reconstructions were carried out of the contained inclusion. Small, clearly visible deposits were divided according to their composition by means of superposing maps of the distribution of individual elements, photographed at two positions of the section, and comparing them with sample current photographs. For powdery deposits, comparisons were additionally made with data on the background distribution over the area of the inclusion.

5. For semi-quantitative estimation of the composition of solid phases the "reference element" method was used (Bykov et al., 1972), which is also very useful in resolving closely located deposits according to composition.

6. Large deposits (larger than 10 microns) were analyzed quantitatively, for which they are extracted from the vacuole, pressed into a polystyrene mold, polished and studied, using the usual methods of quantitative micro-analysis.

Unambiguous solutions to the problems of determining the qualitative composition of small deposits can be achieved only by combining data from the scanning electron microscope with data from the electron microprobe (Boyarskaya et al., 1973). For convenience of the work one ought to make a photographic map of the distribution of the elements in color film. Using for each element studied its light filter, one can in a single frame obtain the distribution of several elements, which is very important in distinguishing very similar deposits. Knowing the size of the inclusions and separating them on the replica, one can calculate their quantitative composition.

This method of study was used for the study of solid deposits in inclusions in cassiterite, quartz, tourmaline, and gold. Data from these studies have been published (Troneva et al., 1971; Dolomanova et al., 1974). The figure shows a generalized view of a reconstructed inclusion in quartz. In it one can separate several varieties of deposits; pyrite or pyrrhotite (Fe + S); chalcocite or covellite (Cu + S); sphalerite (Zn + S) with a small amount of Fe; ilmenite (Fe + Ti); corundum (Al); and deposits of complex composition, containing Ni, Fe, Cu, S and Cu, Fe, Zn, As, which might actually be intergrowths of minerals of simpler composition. Besides the distinct deposits of small size, all the bottoms of the inclusions are covered by finely dispersed sediment, containing K, Cl, Ca, Al, Na (lined region in figure). This can be either a deposit of a single species having complex composition, or an aggregate of sediments of simpler composition.

On the basis of the experiments one can say that the electron microprobe of type MS-46 can be used successfully for the analysis of the composition of solid deposits in opened inclusions of various minerals.

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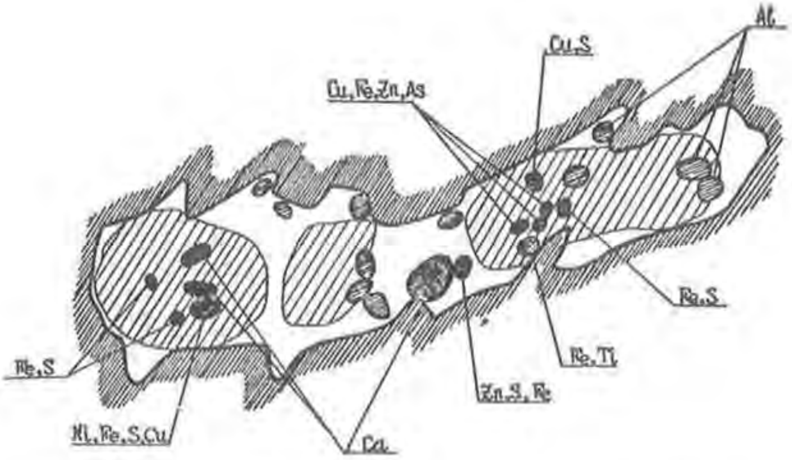

Figure (p. 201). Scheme of location and composition of deposits in an inclusion in quartz.

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[1] This term presumably includes both daughter minerals and material precipitated on opening. (Ed.)

[2] This presumably refers to a picture taken in terms of the sample current, a procedure rarely used in the West, and which yields a photograph (i.e., an oscilloscope image) that is the reverse of the normal back-scattered electron image, in that concentrations of high average atomic number will appear darkest. (Ed.)

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DOLOMANOVA, E.I., 1976, The chemical composition of gas-liquid inclusions in minerals of tin-ore deposits: Sbornik Nauchn. Trudov, Moskov. Otdel., Vses. Mineral. Obshch., March, 1974, p. 176-177 (in Russian; publ. 1976). (Additional title page reads: New Mineralogical Studies, Ministry of Geol., All-Union Sci. Research Inst. of Min. Resources (VIMS), and Moscow Section, All-Union Mineralogical Soc., Acad. Sci. USSR.)

Hydrogen, CO_2, N, H_2S, noble gases, and rarely methane and oxygen were found by gas analysis in the vacuoles of vein quartz of tin-ore deposits. The amount of gas in the quartz varies within wide limits. The composition of the gas and its amount depend on the genetic type of the deposit, the time of deposition of the quartz (quartz of the first stage of mineralization is richer in gas), the composition of the country rock in which the deposit is formed, the composition of the hydrothermal solution, its temperature, pressure under which it occurs, and on the change of pressure under the influence of various factors (Dolomanova et al., 1972).

Infra-red spectroscopy has shown gaseous CO_2, CH_3X (where X = F, Cl), and compounds of fluorine and the OH group, associated with Na^+, Li^+, and H^+ in the structural canals of quartz (Dolomanova et al., 1972_2).

Emission microspectrographic analysis of the liquid phase has shown C, Cl, B, S, Na, K, Li, Ca, Mg, Al, Ti, Fe, Cr, Mn, Zn, and more rarely F, Be, Ni, Ga, Sn, and cyanogen. The determinations were made in microaqueous extracts under normal conditions. Thereby one can assume that all these components form easily soluble compounds (Dolomanova et al., 1972_1).

Electron microprobe studies of the composition of the solid deposits in the vacuoles of quartz, cassiterite, and tourmaline have shown Fe, Mn, Ta, Nb, W, Ti, Sc, Zn, Ca, Mg, Al, Si, K, Na, Cl, F, P, S, N, Ag, Cd, Bi, Pb, Sn, Ni, Co, Cr, Cu. Starting from the distributions of the elements over the area of the vacuole, one can assume that most abundant in the deposits are silicates and aluminosilicates, halides, single and complex oxides; less abundant are sulfides (or sulfates), nitrates, phosphates. Among the powdery sediments, widely distributed are aluminosilicates of Fe, K, Ca and K, rarer are silicates of Al and Mg, mixtures of chlorides and sulfides (?) of K, Na, Ca, Mg, Fe (Dolomanova et al., $1974_{1,2}$). With a high degree of confidence one can identify among the daughter minerals rutile, corundum, gahnite, halite, sylvite, zincite, sphalerite, cobaltite, greenockite, cassiterite, hematite, ilmenite, sulfides (or sulfates) of Cr, Na; tantalo-niobates of complex composition, apparently of tapiolite with admixtures of W, Sc, and Ta; wolframite, scheelite, fluorite, and quartz.

The micro-X-ray diffraction method has been used to identify among the daughter minerals in vacuoles of one of the samples of cassiterite: sylvite, muscovite, jacobsite, sulphohalite, and the composition of the recrystallized liquid phase ejected under pressure from the opened vacuole corresponds to hauyne. Calcite and tourmaline were determined optically.

Comparison of the composition of the mineral paragenesis, constituting the ore body, and the deposits in vacuoles of the minerals widely distributed in the tin deposits, permits one to confirm to a large degree the probability that the chemical composition of the solution trapped in the vacuoles corresponds to that of the hydrothermal solution from which the deposit was formed.

This is indicated by the list of daughter minerals given above, among which are found even some rarely met among ore minerals, such as corundum, spinel, cobaltite, rinkolite (i.e., mosandrite), hematite, and ilmenite. It must also be emphasized that the chemical composition of deposits in vacuoles supplements our concepts on the composition of the hydrothermal solutions, because amidst these deposits are present easily soluble compounds, for example chlorides, usually not preserved in ore bodies.

Attention is also called to the fact that in the vacuoles of minerals that crystallized in the "sulfide" stage, sulfides are also more abundant among the daughter minerals. Thus, in the vacuoles of tourmaline are found galena, bismuthinite, argentite, greenockite. In the vacuoles of quartz were found cobaltite, zincite, a sulfide or sulfate (?)

of chromium, and in vacuoles of cassiterite -- sphalerite.

The first studies made of the chemical composition of deposits in vacuoles of cassiterite from deposits of various formations (Smirnov, 1937) showed similar and differing features. The similarity was that in vacuoles of cassiterite of different genesis, lithophile elements were the most abundant among the deposits. Iron was the usual siderophilic element. Chlorides predominated over fluorides.

Differences were that in vacuoles of cassiterite from pegmatitic deposits of cassiterite-feldspar-quartz and cassiterite-quartz formations there were often found tantalo-niobates of Fe, Mn, Ti, sometimes with admixed Sc and W. In vacuoles of cassiterite from deposits of the cassiterite-quartz-sulfide formation, sulfides or sulfates of lithophilic elements and sulfides of chalcophilic elements are more usual. There is also similarity between the compositions of the deposits in the vacuoles and that of the micro-mineral admixtures in the cassiterite.

In conclusion, one can note that the chemical composition of the deposits in the vacuoles reflects specifics of the solutions from which cassiterite crystallized.

Beginning the studies of the chemical composition of the solutions included in vacuoles of minerals indicates that we still know little about the conditions of crystallization of the solutions, of the chemical processes leading to the formation of the deposits and possibly accompanied by the escape of gas, water, etc., of the change in composition of the solution in the process of its recrystallization and during the formation of even individual zones of growth of a single mineral, and of the influence of the lithological composition of the country rocks on the composition of the solutions.

These and much other information can be obtained during systematic and complex study of liquid-gas inclusions in minerals, containing information on the genesis of the deposit.

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KUZ'MINA, T. M., ZAGORSKII, V. E., AND MAKAGON, V. M., 1976, Temperatures of formation of zones of exocontact alteration around veins of rare-metal pegmatites: Ezhegodnik Sibirsk Inst. Geokhimii (Year Book Siberian Inst. Geochemistry) for 1975, p. 78-82 (publ. 1976; in Russian).

There are many papers in the literature concerned with the study of the composition and structure of aureoles of altered rocks around rare-metal pegmatites (1, 2, 5, and others), but directly determined temperatures on these processes are completely lacking. Below are given the first results of studies of gas-liquid inclusions in minerals of altered rocks around veins of three fields of pegmatites of the sodium-lithium type, with different rare-metal mineralization. The fields studied were formed under different tectonic and physico-chemical conditions.

For field I, formed under conditions of high pressure in zones with varying tectonic regimes, are characteristically unzoned spodumene-bearing pegmatites with pollucite and (or) tantalite. In the process of their formation, two states are clearly distinct: (1) magmatic crystallization, and (2) post-magmatic, including hydrolysis of feldspar and albitization.

The pegmatites of fields II and III, carrying mainly tantalum mineralization, were formed under conditions of relatively low pressures with varying tectonic regime. In field II there were studied bodies of lepidolite-albite pegmatites with zones of quartz-muscovite complex, albitic pegmatite, quartz core, and albite-quartz-lepidolite areas. Spodumene is absent in them, but amblygonite is present in the quartz core. In field III there is developed microcline-albite, sometimes with petalite in asymmetrically zoned veins or unzoned essentially albitic bodies, formed by means of the crystallization of albite from the melt-solution parallel to the autometasomatic albitization of previously separated microcline and petalite. In some areas of the pegmatite body, later processes of "greisenization" appeared.

The most typical exocontact process in field I is the recrystallization of biotite in schists, holmquistization, and tourmalinization. The biotitization of amphibolite and the recrystallization of the biotite of schists lead to the formation of cesium-bearing mica-rich rocks.

Closely associated spatially with pegmatites of field II are tourmalinites and mica-rich rocks, formed as the result of the reaction on amphibolites of fluids separated from the pegmatitic melt-solution in the final stages of the pegmatite process. The principal minerals of these rocks are respectively tourmaline and lithium-iron-magnesium micas enriched in rubidium and cesium. A characteristic mineral of the mica-rich rock is also fluorite.

In the exocontact pegmatites of field II the amphibolites have undergone replacement by holmquistite, micas, chlorite, and sometimes tourmaline. Of these, the most characteristic are the replacements by micas leading to the formation of fluorite-containing protolithionite-zinnwaldite mica-rich rock containing rubidium and cesium, and by chlorite, as the result of which the amphibolites are transformed into specific plagioclase-chlorite rocks, sometimes with fluorite. The chlorite is developed both after amphibole and also after secondary mica. Besides the exocontact alteration, the amphibolites in this field have also undergone a slightly apparent pre-pegmatite silicification parallel to the biotitization.

The formation of the exocontact zone of altered rocks is connected with a specific stage of the formation of the pegmatite, mainly with the stage of the formation of the albite paragenesis in the pegmatites.

Gas-liquid inclusions occur in the following minerals of the altered rocks around the veins: quartz, tourmaline, fluorite, and holmquistite. In quartz and fluorite, these are usually isometric or oval inclusions; in tourmaline they have tubular form. Inclusions are very rare in holmquistite. The size of the inclusions is a few microns; the inclusions in holmquistite are especially small.

The abundances in minerals of the altered rocks of different fields are different. In minerals of the exocontact rocks of field I they are very rare and occur far more frequently in the newly formed minerals around the pegmatites of fields II and III. The inclusions are usually two-phase, consisting of an aqueous solution and a gas phase; in tourmaline there is sometimes a solid phase present also.

Gas-liquid inclusions in minerals enclosing pegmatite rocks of field III have been studied in most detail. Homogenization of primary inclusions in minerals of the exocontact of the pegmatites occurs in the liquid phase. Inclusions in fluorite from homogeneous mica-rich rocks and in tourmaline of exocontact borders are homogenized at 350-405°C, and in quartz from augen mica-rich rock at 360-380°C. In quartz from the essentially chlorite-rock the inclusions are homogenized at 305°C, which indicates the relatively low-temperature of this process, although because of the limited number of samples studied, one cannot be confident that these numbers are an upper temperature limit of formation of these rocks.

Comparison of the temperature of homogenization of the inclusions in minerals of the mica-rich rock and the albitic zone of the pegmatites show that they are very similar. Later and lower in temperature of formation than the albitic zone is the process of greisenization in the pegmatites (temperature of homogenization of inclusions in quartz 295-315°C), which is accompanied by the bleaching of the mica-rich rock, in which the fluorite contains inclusions homogenizing at 220-270°C. Such agreement between the temperatures of homogenization of inclusions in minerals of pegmatites and those of the surrounding altered rocks indicates the close connection between the processes of formation of the pegmatites and of the exocontact altered zone around them.

The homogenization of gas-liquid inclusions from amphibolites that have undergone pre-pegmatite alteration occurs at higher temperatures than in the zones of exocontact alteration around the pegmatite vein. These inclusions are homogenized in the liquid phase at temperatures of 420-450°C and in the gas phase at temperatures of 450-520°C. If in these rocks there was a superposed alteration around the veins, then in that quartz most inclusions homogenize at 345-400°. Thus, the process of regional alteration of metamorphic rocks of the fields occurs at higher temperatures than the alteration around the vein.

The albite-lepidolite pegmatites of field II, judging from the results of study of gas-liquid inclusions in the minerals, were crystallized mainly in the temperature interval 600-290°C. The crystallization of the albitic cleavelandite zone of the pegmatite was at temperatures 390-410° (4). Gas-liquid inclusions in the minerals of the mica-rich rock are homogenized at temperatures 350-400°C. From this it follows that the process of formation of the mica-rich rock probably occurs simultaneously with or somewhat later than the crystallization of the albitic (cleavelandite) zone, but before the formation of the area of late albite-quartz-lepidolite complex, formed at temperatures 290-330°C.

In the altered rocks around the veins of field I we have been able to find two-phase gas-liquid inclusions only in tourmaline and a single inclusion of CO_2 in holmquistite. The temperature of homogenization of the inclusions in tourmaline is 550-450°C. These data indicate a higher temperature of formation of the exocontact zone around a pegmatite of this type. The beginning temperature of formation of spodumene-containing pegmatite is not less than 550°C (3). It is seen that the maximum temperature obtained of homogenization of inclusions in the rocks around the veins corresponds to the beginning of the stage of post-magmatic alteration of the pegmatite.

Thus, the data obtained indicate: (1) different temperatures of the process of exocontact alteration in different pegmatitic fields; (2) similarity of the temperatures of processes occurring in pegmatitic veins and processes of exocontact alteration of their country rocks; (3) higher temperatures of formation of the zone of pre-pegmatite alteration of metamorphic rocks as compared to zones of alteration of rocks around the veins.

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LE BEL, Laurent, 1976, Preliminary note on the mineralogy of solid phases in quartz phenocryst inclusions in the porphyry copper from Cerro Verde/Santa Rosa, S. Peru: Soc. Sc. Nat., no. 350, v. 73, p. 201-208 (Lab. de Geol., Min., Geophy., et du Musés Geol. de L'Univ. de Lausanne, Bull. 220) (in French; translation courtesy of Prof. LeBel). Author at Univ. de Lansanne, Inst. de mineralogie, Palais de Rumine, CH-1005 Lausanne, Switzerland; current address Service Geol. National, BRGM, B.P. 6009, 45018 Orléans Cedex France.

Daughter minerals in decrepitated fluid inclusions in quartz phenocrysts from phyllic (quartz-sericite) and propylitic alteration zones were studied by scanning electron microscope equipped with dispersive energy analyzer and with the electron microprobe. Microthermometry data suggest trapping at about 400°C with pressures varying from 1100 to 200-300 bars (presumably related to passage from lithostatic to hydrostatic pressure conditions). Preexisting minerals believed to have been trapped during inclusion formation include a platey K-Al-Si-Fe mineral (possibly muscovite or ferriferous phengite), an oxide or carbonate

mineral containing Fe, Mn, Zn and Al, and oligoclase. Minerals believed to have formed from the fluids after trapping include halite, sylvite, chlorides containing Fe, Fe-Mn, Fe-Mn-K, Fe-K-Na-Al, anhydrite, sulfochloride complex containing Na-Fe-K-Cu-Ba, manganiferous ilmenite, chalcopyrite, and pyrite. In particular, these results indicate that the fluids were poor in Mg and rich in Ca and Mn. A precipitation mechanism for anhydrite by pressure reduction at constant temperature (380-400°C) is proposed. The data suggest transport of copper in solution as chloride complexes. (Abstract by A. Barabas).

I Introduction

Over a period of several years there have been attempts to determine the solid phases contained in the fluid inclusions of crystals since study of the mineralogy of these microphases and the chemistry of the fluids with which they may be in equilibrium supply geochemical and thermobarometric data on the growth media in which the host mineral formed and the phenomena of transformation, metasomatism or "alteration" which the mineral and the paragenetic rock group of which it is a part may have undergone.

Scanning electron microscope (SEM) techniques coupled with electron microprobe analysis techniques make it possible to study the mineralogy of microphases whose sizes are generally measured in micrometers.

The first work was performed with the electron microprobe on closed inclusions which were brought near the crystal section surface by polishing (in Roedder, 1972) or by decrepitation (Eadington, 1974). The best areas to study are inclusions opened by a mechanical process (grinding, thermal shock) in which the mineral phases have been preserved. Inclusions of this kind are located with the SEM and the quantitative analysis is carried out using an energy dispersive system connected to the microscope. The morphology and quantitative analysis of the phase are often sufficient for identification. Much work of this kind is being performed and can be followed mainly in abstracts in the "Proceedings of COFFI" (1968-1973). The entry is under "daughter minerals" or under the mineral name. In the last volume published, Volume 6 (1973), the following phases were identified: albite, ankerite, calcite, columbotantalite, cryolite, elpasolite, fluorite, halite, hauyne, hematite, ilmenite, mica, quartz, rutile, sylvite and topaz. The most recent note published in French is by J.P. Saintives (1976) which discusses the origin of the inclosed microcrystalline phases.

II Material Studied

During the systematic study of fluid inclusions in quartz phenocrysts of the subvolcanic complex of Cerro Verde/Santa Rosa, S. Peru, linked to a porphyry copper type mineralization, many multiphase fluid inclusions were noted (type A of the author, Plate I, photos 1 to 4). These inclusions, which are sometimes "negative crystal" dipyramids, have sizes of between 8 and 20 micrometers. There can be about ten mineral phases. The objective here is not to describe the thermo-optical study which was made but to indicate that there are two types of inclosed phases. Certain minerals seem to be in equilibrium with the fluids in which they are immersed (this appears during homogenization tests). These are real "daughter minerals." In the latter case, study of the relations between solid phases and liquid phases determines the thermodynamic conditions for trapping. On the other hand, others are not in equilibrium with the fluid phase (in most cases the chemistry is very different) and their crystallization preceded that of the host mineral, leading to growth cavities in the latter which were then filled by the chronological sequence of various fluids which determined the nature of the rock.

These inclusions were studied in the alteration zone called "sericite quartz" or "phyllite" and sometimes in the "propylite" zone of the deposit where the paragenetic development for the original mineral assemblage is:quartz-sericite-calcite-epidote-muscovite-chlorite-hematite-pyrite-chalcopyrite. Thermo-optical study makes it possible to define the pressure-temperature combination establishing this paragenesis: approximately 400°C for the pressure range 1100 bars to 200-300 bars (interpreted for the moment as a passage from lithostatic to hydrostatic pressure).

III Methodology

A) Preparation and Observation: Cracking.

The quartz phenocrysts extracted from the rock by grinding are broken into fragments either by crushing or by thermal shock on the heating stage (decrepitation). The submillimetric fragments are mounted directly on a specimen holder and metallized with gold by means of a cathode anodizing treatment under low argon pressure. The specimens are then examined with the SEM and attempts are sometimes made to remove doubts by means of the microprobe. At the present time, the most complete instrument for this kind of study is the scanning electron microquantometer (SEQM) which combines the advantages of the SEM and those of a microprobe (study of elements lighter than sodium, and focusing of X-rays).

The present study was carried out partly with the SEM Jeol-SM 35 of the electron microscope center of the University of Lausanne and partly with the SEM Jeol-03 of the BRGM at Orleans, the latter instrument being equipped with a Nuclear Conductor diode and a Tracor treatment device NS 880 PDP 8K, and sometimes with the ARL ESMQ of the electron microanalysis center of the University of Lausanne.

B) Problems Involved in the Method

These are directly linked to the limits of the energy dispersive analyser and the nature of the object observed. The analyser does not detect elements whose atomic number is below that of sodium and incorporates to a considerable extent into the microspectrum elements making up the inclusion matrix (walls of the host mineral except when the microphase extends well above the cavity) and elements making up the neighboring phases. The microprobe makes it possible to detect F, C, and B and to improve focusing of the analysis. The latter remains, however, qualitative since the geometry of the crystal analyzed and the absence of polishing have a very great effect. In the most favorable cases quantitative analyses can be made for around 60% of the weight (plagioclase, Plate II and anhydrite, Plate IV, photo 4).

C) Perspectives

It seems very probable that developments in ionic analyser technology will soon lead to a very complete instrument for this type of study (light elements, degree of oxidation, isotopes, etc.) (Clocchiatti, 1975).

IV Results

The results are presented in the form of remarks on the photographic plates (Plates II to V). Photographs of microspectra are superimposed on photos of inclusions with the mineral content. Firstly, the constancy of the Si peak can be distinguished which can be attributed to the silicon contained in the microphases and/or to the silicon of the matrix quartz. Immediately to the right of this peak the Au peak due to metallization can always be found. It is found practically in the same place as the S and the presence of this element is indicated only by a shoulder on the right. The other Au peak is located at the end of the spectrum (most often cut off by the framing of the photo). This metal is not the ideal metallization metal for a study of this kind even if it gives excellent SEM images.

A) Plate II†: Silicates

The inclosed minerals are thought to have been trapped as solid phases. There are two possibilities for them: 1) there was cocrystallization (are the trapped phases compatible with silica expressed in the form of quartz?) and 2) the minerals preexisted and induced the growth cavities of the host mineral during crystallization.

Photo 1. Santa Sosa, 510-36, 462 m

There are two crystals in the cavity: a) A platelet whose monoclinic appearance is reinforced by solution figures without characteristic shapes. The pseudo-hexagonal habit and microspectrum suggest mica. The absence of Mg can be observed but the Fe content estimated with the microprobe (2.2% FeO) is not sufficient to make it ferriferous biotite. Could it then be muscovite or ferriferous phengite? b) For this crystal, the Si of the microspectrum can be attributed to the matrix as the microprobe study seems to show. It would then not be a silicate but rather Fe, Mn, Zn (and Al) oxide of the spinel group (franklinite?) or a carbonate.

Photos 2,3,4 Santa Rosa 510-36, 462 m

The crystals have a triclinic appearance. Photo 3 shows two, twinned. The microspectra which are all identical (that for photo 3 is not shown) are not influenced by the matrix since the minerals extend above the cavities to a considerable extent. The shape and the microspectra make them plagioclase and the microprobe determines the ratio Na_2O/CaO which is about 2.5:1. This puts the crystals in the oligoclase region. With respect to this point it should be noted that the peak ratio given by the energy dispersive analyser Na/Ca is inverse. The Na does not respond well to the electron beam.

B) Plate III: Chlorides*

It is probable that for this plate all the mineral phases are in equilibrium with the fluids.

Photos 1 and 2 (2 is an enlargement of 1). Santa Rosa 510-36, 460 m

The three crystals A, B, and C are chlorides.

A) Fe, Mn chloride. Hexagonal or monoclinic appearance.
B) Fe, Mn and K chloride.

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† Ed. note - it is indeed unfortunate that these 16 excellent SEM photos cannot be reproduced here

*Without systematically continuing work with the microprobe (study of B and F which are often associated with chlorides) it is not possible to identify these often complex chlorides. The literature speaks of chlorocalcite, hydrophylite (Eadington, 1974) but here we observe no Ca in the chlorides. This author indicates $FeCl_2.2H_2O$, without a name, which could be our phases III, -3C and IV-3A.

C) Fe, Mn and K chloride.

Microprobe studies were not made for boron or fluorine (which cannot be detected with the energy dispersive analyzer). It is still difficult to identify these phases.

Photo 3. Santa Rosa, 510-36, 462 m

This is an instructive example for showing the limits of the possibilities of the diode analyser. There is a definite interaction between the different phases. A is probably halite, B sylvite and C an Fe (and K) chloride.

Photo 4, Santa Rosa, 510-36, 462 m

There is a halite cube showing solution shapes (solution begins on the crystal edges).

C) Plate IV: Chlorides* and sulphates

Minerals in equilibrium with the fluids.

Photo 1. Santa Rosa, 510-36, 408 m

Na,Fe,K, Cu and Ba sulphochloride complex.

Photo 2. Santa Rosa, 510-36, 247 m

Fe, Mn and Na chloride.

Photo 3. Santa Rosa, 510-36, 247 m

A) Fe chloride.

B) Fe, K, Na and Al chloride.

Photo 4. Santa Rosa, 510-36, 408 m

Orthorhombic anhydrite crystal.

D) Plate V: Oxides and sulphides

The determinations are not ambiguous since the minerals extend considerably above the cavities.

Photo 1. Santa Rosa, 510-36, 247 m

The following coexist in this cavity: a crystal a) of magnesium-bearing ilmenite and a crystal b) of chalcopyrite.

Photo 2. Santa Rosa, 510-36, 247 m

There is crystal of chalcopyrite in each cavity.

Photo 3. Santa Rosa, 510-36, 247 m

Chalcopyrite crystal.

Photo 4. Santa Rosa, 510-36, 247 m

Pyrite crystal with solution shapes tending to round out the form (isometric).

V Interpretations

A. Petrology

The relict ferromuscovite-oligoclase-spinel is a classical granitoid paragenesis. The low Mg and the albite content of the plagioclase show the acid character of the fluid which is in agreement with the SiO_2 supersaturation of the rock expressed at the surface.

However, the high Ca^{++} activity indicated by the anhydrite crystals and the presence everywhere of Mg suggest affinities with more basic fluids and systematic study of the relict minerals trapped in the growth cavities which they have induced might supply data on the origin of these acid fluids, i.e., are they products of magmatic differentiation, mixture of magmas or do they result from originally acid fluids?

B. Metallogeny

This is the field in which the largest number of applications can be supposed. Future work could concern the following subjects: 1. Hypogene sulphates. It has been thought for a long time that sulphates can be hypogene (Butler, 1919). Complete knowledge of the $CaSO_4$ - $NaCl-H_2O$ system (Blount and Dickson, 1969) makes possible discussion of the presence of anhydrite. It can be seen, for example, that a solution saturated with $CaSO_4$ can at a constant temperature (380-400°C) and in an environment of NaCl 7 moles/kg H_2O deposit, during a pressure fall of about 700 bars (between 1000 and 300 bars, of above under II) 2.3 kg $CaSO_4$ per m^3. 2. Early mobilization of Cu in the form of complex chlorides. 3. The probable mineralization sequence: chlorides-sulphates-sulphides + oxides with the implied redox reactions.

VI Conclusions and Acknowledgements

This preliminary study confirms the interest of further knowledge of the mineralogy of multiphase inclusions. In addition to the fact that the question of the origin of supersaturated rocks is posed, these observations coupled with thermo-optical observations make it possible to determine more closely the thermodynamic systems which are essential for understanding the genesis of hydrothermal deposits.

This note is part of the author's work for a thesis on certain genetic aspects of porphyry copper type deposits and the material was supplied by the Cerro Verde/Santa Rosa complex in S Peru. Thanks should be given to the following: the DGRST which covered the field trip expenses, Mr. Z. Johan and Mr. P. Jeanrot of the BRGM, Orleans and Mr. G. Burri and Mr. T. Jalanti of the University of Lausanne for their various friendly contributions.

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POTY, Bernard, LEROY, Jacques and JACHIMOWICZ, Léon, 1976, A new device for measuring temperatures under the microscope: the Chaixmeca microthemometry apparatus: Bull. Soc. Fr. Minéral. Cristallogr., v. 99, p. 182-186 (in French; translation courtesy of Maurice Pagel, Arthur Barabas, and Chris Eastoe). Authors at Centre de Recherches Pétrographiques et Géochimiques - Case Officielle n°1 - 54500, Vandoeuvre-les-Nancy, (France).

The major limitation to the study of fluid inclusions is their small size. In the past, this has limited and continues to limit to a certain extent the analysis of inclusion contents by normal chemical methods. This explains why mineralogists have always tried to characterize the fluids using physical methods. One of the most frequently used methods is microthermometry, the measurement of the temperatures of phase transformations under the microscope.

Utilization of microthermometry methods requires an instrument for precisely and accurately measuring temperatures, as well as some knowledge of the relevant chemical systems based on experimental data.

Today we have a considerable body of experimental data bearing on the physical chemistry of the system H_2O, CO_2, CO_2-H_2O, H_2O-NaCl, CH_4 and H_2O-CH_4. Although these systems are certainly much simpler than those found in nature, they nevertheless give an acceptable basis for interpreting most geologically occurring fluids (see Weisbrod, Poty and Touret, 1976)(see this volume of Fluid Inclusion Research).

At the same time that these experimental data were being gathered mineralogists were working on the problem of temperature measurement under the microscope. Following the apparatus conceived by Ermakov (1950) a large variety of original instruments have been constructed (see Roedder, 1972). However, no instrument directly applicable to the study of fluid inclusions was available commercially; existing devices (e.g., the Leitz 350 heating stage) had to be modified for inclusion work (Poty, 1967). Beginning in 1968, the rapid growth of fluid inclusion studies at Nancy necessitated major modifications of the existing devices (Poty and Stalder, 1970, Leroy, 1971) and led to the construction of 5 prototype models of the present installation.

In 1972, Chaixmeca Ltd* constructed a microthermometry installation based on our design. In 1974, the device was patented by the A.N.V.A.R. and commerical manufacture began. The Chaixmeca microthermometry installation has subsequently been delivered to 36 different organizations (university laboratories, research centers, and mining companies) in 12 countries on three continents.

Major features of the Chaixmeca microthermometry installation

The following specifications for the functioning of apparatus were supplied to the constructor:

1 - The ability to measure temperatures rapidly between -180° and +600°C without moving the sample. The measurement of high temperatures (between 400° and 600°C) was felt to the particularly necessary in studies of late-stage magmatic phenomena at low pressures (porphyry coppers, for example). The upper temperature limits of 600°C is certainly insufficient, but it does not appear that the same technology could cover the range -180° to +1000°C.

2 - Attainment of a homogeneous temperature in the heating-cooling stage with vertical and lateral temperature gradients as small as possible within the sample chamber.

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* Chaixmeca, Boîte Postale 3312, 54014 Nancy Désilles.

3 - Attainment of an optimal thermal inertia. This inertia must be low enough that the temperature of the stage stops increasing when the energy input into the heating resistance is reduced, or that the temperature stops decreasing when the flow of cooling gas within the stage is stopped. On the other hand, the inertia must be high enough to permit good measurement reproducibility. A compromise must be found between these two contradictory requirements.

4 - Incorporation of an optical condenser in the stage. This condenser is necessary in the study of fluid inclusions because of the large differences in index of refraction between the inclusion contents and the host mineral. This lens should be fixed so that temperature measurements are not affected by variations in its position. Temperature variation is obtained, as in the prototypes built at the CRPG, with an electric resistance for the healing, and by the circulation of a gas cooled in its own liquid for the cooling.

The commercially available Chaixmeca microthermometry installation consists of a combination heating and cooling stage, an electrical measurement and regulation package, and a temperature exchanger (fig. 1).

Figure 2 shows a cross section of the heating and cooling stage, with the following principal parts: heating resistance (H_r), passages for the circulation of the cooling gas (R_c), silica condensers (L_1 and L_2), position of the temperature measurement probe (S), sample location (Sa), infrared filter (F).

The utilization of this stage is characterized by great flexibility. The thermal inertia appears to be optimal and the condenser illumination permits the study of inclusions as small as 2 μm in diameter.

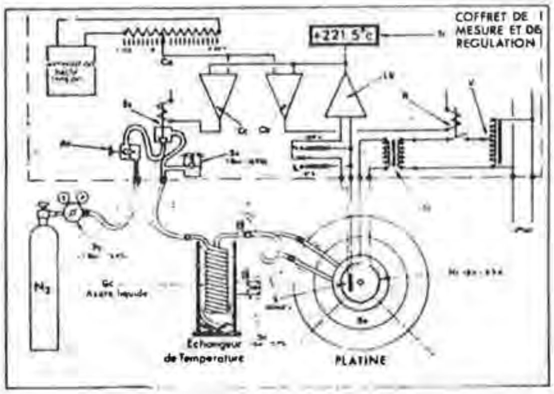
Temperature measurements using the resistance probe in the stage, a linear bridge, and a digital voltmeter are made with a resolution of 0.1°C. Automatic temperature regulation by means of an electric switch at low temperature and by a relay at high temperature, allows long duration experiments (several hours to several days) which are sometimes necessary in order to dissolve minerals trapped in fluid inclusions.

Measurement reproducibility and calibration

The reproducibility of measurements made with an apparatus should be tested using phenomena which are reproducible under completely controlled conditions. The Chaixmeca installation was tested using fluid inclusions: inclusions with three fluid phases (liquid CO_2, aqueous solution and CO_2 vapor) in quartz from Calanda (Grisons, Switzerland) and two-phase fluid inclusions (aqueous solution and H_2O vapor) in quartz from a porphyry copper deposit (Tyrone, New Mexico, U.S.A.).

Figure 3A shows a histogram of 26 replicate measurements of the meltings point of CO_2 in a single fluid inclusion in the Calanda quartz. The distribution of 15 homogenization temperature measurements for a single inclusion in the Tyrone sample are shown on a histogram in figure 3B. It can be seen that 90% of the measurements fall within ±0.1°C of the mean in both cases. This seems to be sufficient for fluid inclusion work, at least at present.

The calibration of this device poses more severe problems. Calibration of heating and cooling stages is generally performed by measuring melting points of pure substances under conditions as close as possible to those routinely used for sample measurement. The temperature difference between the accepted melting point of the pure solid and that measured by the temperature probe (Δt) gives the correction which must be applied to the temperature indicated by the voltmeter in order to arrive at the true sample temperature. Unfortunately, our experience



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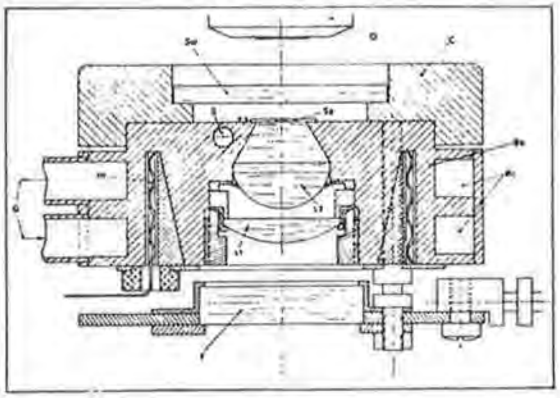

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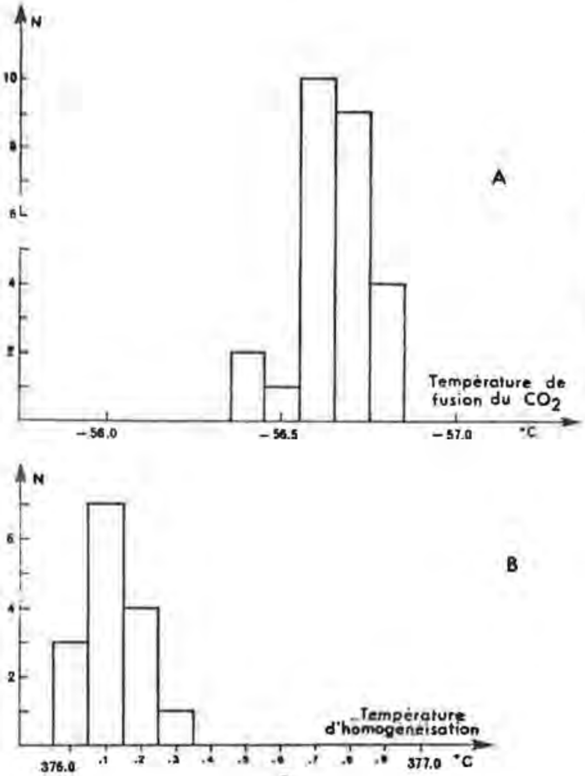

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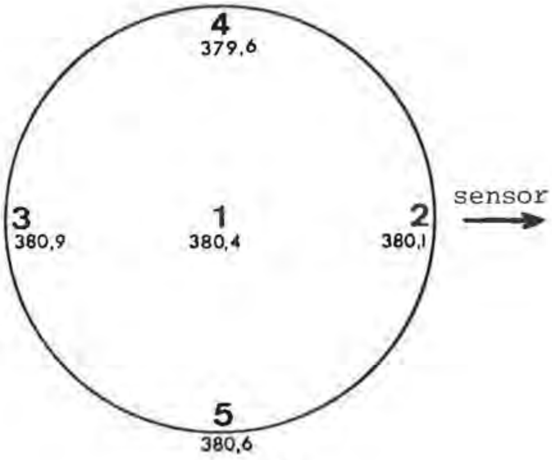

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Fig. 1 - Schematic diagram of the Chaixmeca microthermometry apparatus showing the heating-cooling stage, temperature exchanger, measurement and regulation package containing the linear bridge (Lb) and regulators (Cc, Ch, Co).

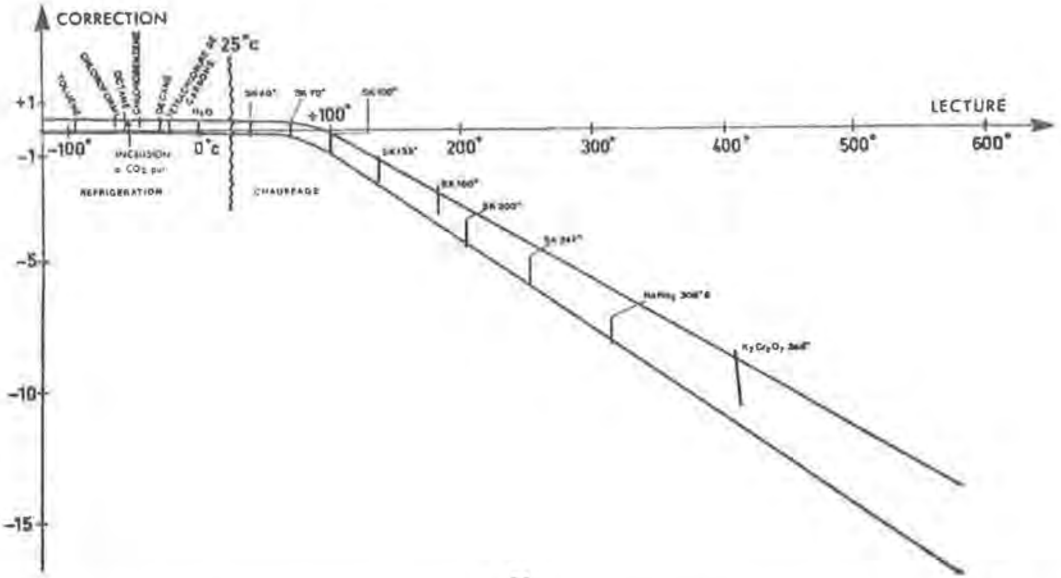
Fig. 2 - Cross section of the heating and cooling stage.

Fig. 3 - An example of the reproducibility of measurements with the Chaixmeca microthermometry apparatus.

A - Three phase fluid inclusions from Calanda (Grisons, Switzerland). The peak corresponds with the triple point of CO_2 (− 56.6°C).

B - Two phase fluid inclusions in quartz from quartz monzonite porphyry (Tyrone porphyry copper, New Mexico, U.S.A.).

Fig. 5 - Determination of the lateral gradient across the optical field of the heating-cooling stage. Numbers 1 - 5 with their corresponding temperatures refer to the different positions in which the homogenization temperatures for the same inclusion were measured.



4

Calibration curve for a Chaixmeca apparatus made at the C.R.P.G. July-August 1974 (in JEHL, 1975). SK refers to Merck Co. melting point standards.

shows that the melting of the microscopic grains of the supposedly pure compounds does not always occur at a well-defined temperature. Often melting takes place over an interval of several degrees. These variations in melting point may be due to the compositional heterogeneity of the grains, to variations in grain size or surface properties, or to other phenomena.

The calibration curve (fig. 4) shows that a total uncertainty of (2.3°C) is associated with the measurement of the homogenization temperature of the studied inclusion from Tyrone, while the reproducibility is 10 times better (0.2°C). It must be concluded that the problem of calibration of a heating and cooling stage has not been satisfactorily resolved. If it is necessary to obtain measurements with greater precision, it might be possible to calibrate the stage using fluid inclusions in synthetic quartz, grown under precisely known temperature and pressure conditions and from precisely known solution compositions. The precision of measurements depends on the individual inclusion (size, visibility, etc.) as well as on the microscope objective used. If objectives with large working distances are used (e.g. 3.5 x, 10 x, or special objectives such as the Leitz UMK 50 universal stage objective) measurements are hardly affected. However, this is not the case for normal high power objectives supplied with most polarizing microscopes. If these objectives are used a calibration curve must be determined for each and the measurements must be made with great care. The development of high quality objectives with large working distances is one of the areas where progress would greatly aid the practice of microthermometry.

Measurement of temperature gradients in the sample chamber

Temperature variations within the sample chamber are important characteristics of any heating-cooling stage. As we have seen, this cannot be determined precisely by melting pure compounds but must be measured with fluid inclusions.

The vertical temperature gradient for the Chaixmeca stage was measured using two-phase inclusions in a quartz crystal from the Mayres pegmatite (Andrèche, France). These inclusions were located 200 µm from the surface of a polished section 1.4 mm thick. After determining the homogenization temperatures of the inclusions just below the upper surface the section was turned over and the homogenization were repeated. The results obtained on these inclusions in positions differing by 1 mm vertically are shown in table 1.

	Measured homogenization temperatures	Differences
Ist inclusion (homogenization in liquid phase)	in upper position : +380.6, 380.6, 380.6 in lower position : +379.5, + 379.6, +379.6	1.0 to 1.1°C
2nd inclusion (homogenization in vapor phase)	in upper position : +388.8, +388.9, 388.9 in lower position : +388.0, +388.0, +388.0	0.8 to 0.9°C

Table 1 - Homogenization measurements at different vertical positions of two inclusions in quartz from the Mayres pegmatite (Ardèche, France).

Inclusion Position	Mean of homogenization temperature	Number of measurements
1	380.4 ± 0.2°C	8
2	380.1 ± 0.0°C	4
3	380.9 ± 0.1°C	8
4	379.6 ± 0.1°C	5
5	380.6 ± 0.1°C	7

Table 2 - Means of homogenization temperatures for the same inclusion at different positions in the optical field of the heating-cooling stage (see fig. 5).

CONCLUSIONS

The Chaixmeca microthermometry installation permits the relatively precise measurement of temperatures of small objects under the microscope (2 to 1,000 µm) over a large range of temperatures. Thus this device is of interest in physics, chemistry, and earth sciences and biology for temperature measurement of any object visible under the microscope in transmitted light.

This installation was nevertheless specially conceived for mineralogists, petrologists, and economic geologists who need a device allowing the easy and precise study of fluid inclusions. By its ease of utilization the Chaixmeca microthermometry installation should find a place in every mineralogy, petrology and economic geology laboratory.

ACKNOWLEDGEMENTS

The authors would like to thank Chaixmeca Ltd, and in particular Mr. Kreel and Mr. Dasse for accepting the severe (design) constraints

based on the utilization of this device. These constraints presented problems which were difficult to resolve, in particular the behaviour of the materials at high temperature.

Once the microthermometry installation was constructed, it benefited from the use by many permanent and temporary workers in the Research Team Dealing with Equilibrium between Fluids and Minerals at Nancy. We would like to mention in particular A. Barabas, J. Bossi, B. Charoy, M. Cuney, M. Denis, C. Eastoe, H. Etminan, L. Hollister, V. Jehl, R. Kreulen, J. Mullis, F. Noronha, M. Pagel, J. Touret and A. Weisbrod. Finally, numerous discussions of microthermometry techniques with E. Roedder were especially helpful.

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The devel. of methods of exper. study at high P and general advances in the geol. sci. have permitted discussions of problems of the form. of magmas in the Earth's core and mantle.

As has been shown by exper. and theor. studies, the process of melting mantle olivine-containing rocks depends first of all on the conc. of water, and this problem is now discussed in many papers. Because the content of water in the original magma cannot be judged from the content of water in the rock, criteria for est. the amount of water in the melt can in most cases be only indirect. One of the criteria is the det. of the T of the magma, because the participation of water is the most important factor det. the T of melting of silicate rocks. It is known that all other additional components, lowering the T of melting, can be directly calc., starting from the chem. and min. comp. of the rock.

One of the most reliable methods of direct det. of the T of xliz. of a magma (which is always lower than the original T of the melt) consists of the study of fused glassy or rexliz. incs., first of all in phen. of volcanic and subvolcanic rocks, which has become possible thanks to the construction of high-T stages (3,6,9).

As the result of thermobarogeochemical studies of incs. (5,8, and others) many data have been obtained, permitting many petrological conclusions. First of all, there is the conclusion as to the very low content of water during the form. of andesitic magmas, and, consequently, as to the impossibility of their generation at high Ps at the expense of olivine rocks of the mantle. Other important results of the study of incs. include the direct evidence of the xliz. of apatite from alkalic nepheline syenites (1), evidence of the magmatic origin of granite in the outer zone of granitic pegs. with graphic and aplitic structure (5), and others. Along with this, the method of study itself of P-T cond. of magmatogenic xliz. is still not generally accepted, and publications have appeared in the literature which essentially negate the possibility of obtaining accurate information of this kind. One of these is the paper by Volokhov (2), to which these remarks are a reply.

The author of the cited paper bases his criticism on the following two assumptions:

(1) In the devel. of the method adequate attention was not paid to the possibility of diffusion through the lattice of H ions (protons) originating in the incs. as the result of the dissoc. of water and other H-containing cpds. during their heating to T_H; (2) the method does not take into account that the melt incs. originate in mins. of rocks that are mainly effusive and partly of the clearly hypabyssal depth facies, i.e., in a setting of intense dehydration (and degassing) of magma (p. 13).

First, let us note that the second assumption is in contradiction to the first. Actually, in connection with the second assumption he notes correctly that such "melted incs. ... char. not all systems, but only the dehydrated silicate parts". Consequently, during homog. of these inc., one cannot speak significantly of factors introduced in assumption 1, and the information on T_H is objective.

Along with this, there is no doubt (and this is recognized by Volokhov) that during boiling there does not occur an increase of the T of the melt and thus we do not obtain increased T_H by the process of boiling.

Data on the comp. of the silicate part of the inc., obtained by their anal. by electron microprobe, are also objective. No direct det. of the amount of water by the method of thermobarogeochemistry is foreseen, and judgment as to the original amount of water is made only on the basis of the T_H.

In those cases where boiling of the melt occurs during the xliz. of the phen., study of the inc. permits one to obs. directly the results of this process by the appearance of bubbles; thereby it has even been det. that such bubbles consist mainly of CO_2 (7, 8, 10). Regrettably, the appearance of inner reflections does not permit one in most cases to observe directly the presence of water in the outer rim of such gas bubbles. Thereby, judging from the high T_H of the inc., one can only assert that the portion (of water) here will be very small.

An even more interesting case has appeared recently in anorthite olivine-anorthite (sic) nodule amidst basalts of Kamchatka, where the gas phase is N_2, and in inc. of elongated form, a distinct rim of water has been found, so that boiling occurred at T > 1100°C and P ~ 1-7 kbar.

Let us note a misunderstanding on p. 14 of Volokhov's paper, where he speaks of the fact that during the oxidation of iron-containing mins., the source of the oxygen "is not the atm., but the incs. themselves". Everyone who has carried out obs. during homog. can be satisfied that in this case there occurs darkening, not of the wall of the inc. (vacuole), but of the entire surface of the preparation at the expense of oxidation by O_2 of the air, but by no means at the expense of increased oxidation potential in the inc. after the dissoc. of water and the outward loss of H_2. Regrettably, even our heating stage, filled by an inert medium, does not give the possibility of obtaining P_{O_2} below the corresponding buffer. Nevertheless, oxidation here proceeds far more slowly than in air, which permits one to carry out the necessary meas.

The reply to the main thesis of the critical paper is first of all a specially conducted exper. (4) with aqueous-gas incs. in natural quartz, having a low degree of filling. This permitted obtaining considerable superheating of the contained incs. without the appearance of decrep. Heating was carried out to 1200°C for some hours, which exceeds by many times, the true T_H of these incs. and the time of normal exper. with melt incs. Repeated exper. showed that the T_H of heated incs. occurs within the same limits, i.e., no noticeable leakage of water occurred during the exper. Similar exper. with superheating were carried out for other mins. having higher T_H.

Far greater worry is caused for us by a problem that is not touched upon by Volokhov, and that is the problem of the preservation of the tightness (hermeticity) of the incs. at the time of the slow cooling of the melt during decreasing P. The absence of substantial leakage of water from mins. of magmatic rocks is indicated by many facts; we refer the critic of our interpretation to obs. of the lower Ts of S melt incs. and incs. in the outer zones of mins. Finally, the lowering of T_H of the melt in such incs. can be obtained artificially, not only by the addition of water, but also of F and alkalies, but in the studied cases, there is no substantial increase of the contents of F or alkalies (which was caused by the agpaitic character of the xliz.). Therefore the only factor lowering the T of the later incs. ought to be water, accumulated in the trapped residual melt.

The absence of leakage of water from incs. in mins. of nepheline syenites, urtites, and nephelinites is rather clearly confirmed by the presence of complex water-containing melt incs. with T_H up to 1000-1100°C, studied by Bazarov, Shashkin, and Panina (5). After the appearance of the paper by Volokhov, new data were obtained in the lab. of min.-forming sols. of the Inst. of Geol. and Geophys., Sib. Branch, Acad. of Sci, U.S.S.R., dealing with the direct obs. of the aq. phase in rexliz. incs. in quartz of granitic chambered pegmatites (incs. at low Ts, down to 570°C).

Summarizing what has been said, let us note: confirmation of the loss of H ions in the process of homog. is completely refuted by the available exper. data (including results of anal. of the gas phases of incs.); boiling of the melt with separation of a gas phase does not by any means hinder the det. of Ts, i.e., does not change the process of homog. (naturally, one speaks of normal, not composite incs.).

Along with this one must account completely for the fact that interpretations of data obtained during work with high-T incs. are very complex, require many exper., and that confusion and gaps exist in the methodology making difficult the solution by means of exper. For example, one cannot, in fact, calc. the T corr. connected with the est. of P. For the present, starting only from general considerations, it is stated that this correction is comparatively small; in any case it has a positive sign. In other words, the T of the melt ought to be higher than T_H of the melt incs.

There are also many other problems, which ought to be solved together with experimenters; nevertheless, there is no doubt that high-T melt incs., preserved in the min. of magmatic rocks, are sufficiently tight, both under the conds. of exper., and also in nature, and that the information obtained during their study is sufficiently objective to be used as the basis for petrological conclusions.

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CHAPTER 3

APPARATUS FOR INVESTIGATING INCLUSIONS OF MELT IN MINERALS

Inclusions of mineral-forming melts carry information about the physicochemical conditions of crystallization of minerals and enable us to estimate the temperature, pressure, composition, and properties of natural magmas. In order to clarify these parameters, a special apparatus has been developed, intended for thermometric investigations, and the determination of the chemistry, pressure, and other properties of melts.

1. APPARATUS FOR MINERAL-THERMOMETRIC INVESTIGATIONS OF MELT INCLUSIONS

General surveys of the mineral-thermometric methods of investigation and apparatus from the earliest period have been made by Yermakov (1950), Smith (1953), Khitarov (1965), and others. A qualitatively new stage in the investigation of gas-liquid inclusions began in the early 'forties, when N.P. Yermakov and P.V. Tsybyshev constructed a free-air chamber for observation of inclusions under the binocular microscope at temperatures up to 300-400°C (Yermakov, 1950). Further refinement of the mounting has led to the creation of a microthermochamber, the best-known being that of Yermakov (1950). It should be noted that a completely new heating principle was employed in this construction, convective transfer of heat in a closed atmospheric medium. The chamber has been used for heating preparations in an atmospheric medium to 650°C.

Later new microthermochambers were constructed and various improvements in experimental technique carried out (Bailey, 1949; Tsurinov & Vol'nova, 1952; Lemmlein, 1953; Kormushin, 1960; Lesnyak, 1964; Kalyuzhnyi, 1960; Anikin & Ishbulatov, 1970; etc.).

The work, starting with inclusions of salt brines, melt-brines, and melts, required the creation of even higher temperature microthermochambers. These could be obtained with the high-temperature apparatus, described by Kalyuzhnyi (1965, 1973) and the modifications of the high-temperature chamber of the Dolgov-Bazarov System, a two-stage chamber with an additional small loop (Bazarov, 1968c) and a one-stage chamber with a spiral platinum-rhodium heating element of smaller diameter (Bakumenko, 1970). Chambers were prepared with laminated heaters of platinum (Chepurov & Pokhilenko, 1972) and silite (Mikhailov & Shatsky, 1974). These microthermochambers, used for investigation of melt inclusions, will be considered in greater detail below.

[70] The Quenching Method

The quenching method (the traditional method of experimenters) has also been applied during the investigation of inclusions of magmatic melts. It has been used both abroad and in the USSR. The essence of the quenching method involves heating the preparation to the prescribed temperature and subsequent rapid cooling (quenching) in an aqueous, atmospheric, or some other medium. Quenching may be achieved by removal of the preparation from the heated space or in another way.

Roedder and Weiblen (1970b) have placed the preparation, enclosed in an ampoule with evacuated atmosphere, into the heating element. At the appropriate moment the ampoule is rapidly extracted with the aid of a platinum wire. The time of chilling (1-2 sec) assumed by Roedder in the atmospheric medium is somewhat underestimated (sic.). In other experiments an aqueous medium was used for cooling (Roedder & Weiblen, 1970b).

In Naumov's experiments (1969), the preparation is placed over a hole in a platinum ribbon bent into a loop and is heated in an atmospheric medium. At the appropriate moment, the preparation is removed with the aid of tweezers. The time of cooling is 2-3 seconds. In this case, cooling and chilling of the preparation are undoubtedly achieved more rapidly than the atmospheric cooling used by Roedder.

In the method of quenching, the type of heating device is of no consequence. It is only necessary that the heater make it possible to obtain the necessary temperatures in the item being investigated. The heating element is usually a vertical tube, with a coiled platinum, platinum-rhodium, or other wire on it. The ampoule with the preparation is set in the central portion of the heating element or the sample is arranged on a preparation-carrier. Such constructions are characteristic of the high precision of the temperature measurements on the heated sample and make it possible when necessary to carry out lengthy experiments (over many hours). The application of the quenching method to melt inclusions enables us to examine extremely small inclusions and, moreover, contributes to obtaining qualitative photographs at various stages in the phase transformations in the heated inclusions. The simplicity of construction is also important, as is the possibility of conducting experiments *in vacuo*, in atmospheric and in an inert medium, and the achievement of practically any desired temperatures for heating the sample. There is also the possibility of conducting experiments 'side-by-side with other work'.

The principal deficiency in using the quenching method in mineral-thermometry of melt inclusions is the impossibility of making continuous visual observations on the phase transformations during the experiment, thus leading to errors in determining the temperatures of homogenization. The method is not applicable to inclusions that contain additives yielding low viscosity. At the same time, the quenching method may turn out to be very effective when used in parallel with the method of visual observation of the homogenization of inclusions in microthermochambers.

B. High-Temperature Microthermochambers for Investigating Inclusions for Magmatic Melts.

In mineral-thermometric investigations of melt inclusions, microthermochambers are usually employed which consist of heating devices combined with a microscope. They allow us to conduct continuous observations on the processes that take place in the inclusions during heating and cooling, and to define the various phase transformations, including the moment of homogenization.

[22] The necessity to construct a more efficient apparatus had already become apparent during the initial experiments with melt inclusions, since the apparatus available did not enable us to examine inclusions up to the state of homogenization (Bakumenko, 1965). A demand developed for microthermochambers, distinguished by simplicity in construction and manipulation, operating in a wide range of heating temperatures from normal to 1600°C, having a high precision in measuring the homogenization temperatures of inclusions, and making it possible, when necessary, to conduct experiments in an inert medium or *in vacuo*. Such chambers have been devised.

The heating systems which could be used in thermometry, may be constructed using four principles of initial heating of the object investigated: convection, conduction, direct radiation, and induction.

In microthermochambers described up until now, the first two principles have been used: transfer of heat to the object by means of convection and conduction (with a sample holder having a low coefficient of conductivity); or transfer of heat to the object by means of conduction through solid materials with high conductivity (contact heating). All the widely-used high-temperature microthermochambers have been devised on the basis of resistance heaters (the release of heat occurs during
[23] the passage of an electric current through the conductor). There has been only one chamber with induction heating of the objects investigated by super-high frequency currents.

Microthermochambers using convection and conduction of heat.

The best known microthermochamber for investigating inclusions of magmatic melts and high-temperature gas-liquid inclusions is that built by Dolgov & Bazarov (1965). The fundamental work on the thermometry of melt inclusions, presented in this monograph, was carried out in modified microthermochambers of this type. The body of the original model (the Dolgov-Bazarov chamber) is amde of asbestos-cement (Fig. 6). Caps with inspection openings are fixed to the body by means of bolts. On the body there are terminals, to which the outlets of the ends of the heating element are joined.

The heating element is made up of two tubes (silica - internal, and porcelain, external). The tubes are inserted one into the other. Along the outer surface of the inner tube is coiled a spiral of ÉI-19 high-temperature wire, with a diameter of 0.8mm. Within the heating element is placed a short porcealin tube, in which the sample-carrier (a circular plate of silica glass, 3-4mm thick) is set. A hole has been drilled in the plate for insertion of a two-hole tube with the thermocouple. The junction of the thermocouple is located in a special depression in the silica glass. For heat insulation, an ultra lightweight firebrick was used, as a result of which the external surface of the chamber heats up to only 60°C after 1.5 hours of continuous work at high temperatures.

The microthermochamber constructed by Dolgov & Bazarov is distinguished by its simplicity in preparation and use, and the possibility

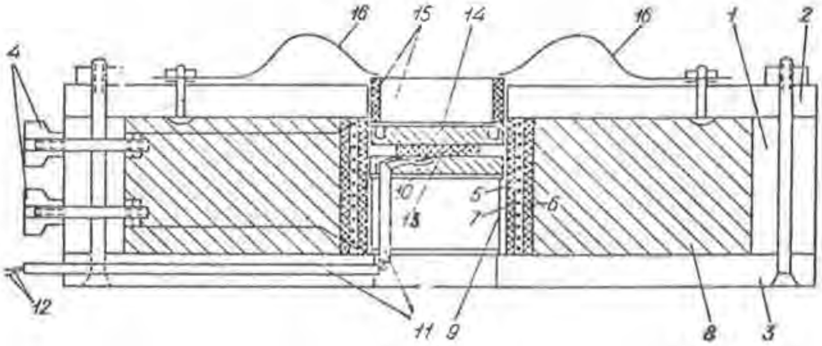

Fig. 6. Section through microthermochamber constructed by Dolgov & Bazarov (1965). 1) cylindrical body; 2,3) caps (1-3 made of asbestos-cement); 4) screw terminals; 5,6) porcelain tubes; 7) spiral of high-temperature wire EI-19; 8) heat-insulation ring; 9) circular frame of EI-19 wire; 10) plate of silica glass; 11) two-hole porcelain tube; 12) themocouple; 13) sample; 14) upper plate of silica glass; 15) porcelain ring; 16) springs.

of making observations on the processes that take place in the inclusions throughout the entire experiment, using normal short-focus objectives. The thermochamber operates over a temperature range from +20 to 1200°C. On the basis of this device, a temperature of the order of 1400°C may be reached, using a platinum or platinum-rhodium wire, 1 mm in section, as a heating element, coiled on a silica or alumina tube about 15 mm in diameter and 25 mm high (Bakumenko, 1970). We now use single-stage chambers with a heater of greater diameter.

Somewhat earlier a two-stage thermochamber (Fig. 7) was prepared by Bazarov (1968c) for the investigation of melt inclusions at ultra-high temperatures. The working range of this portable chamber was from 20 to 1650°C. The heating element is complex and consists of two parts: 1) an external heating stage (wire of EI high-temperature steel, coiled on a quartz tube); 2) an additional platinum heating coil, set on a sample-carrier of silica glass. The junction of a platinum - platinum-rhodium thermocouple is welded to the coil. The supply of current for the heating elements is achieved by two separate transformers. The chamber has been designed for both long- and short-focus objectives. The precision in temperature measurement is ± 10°C at 1450°C.

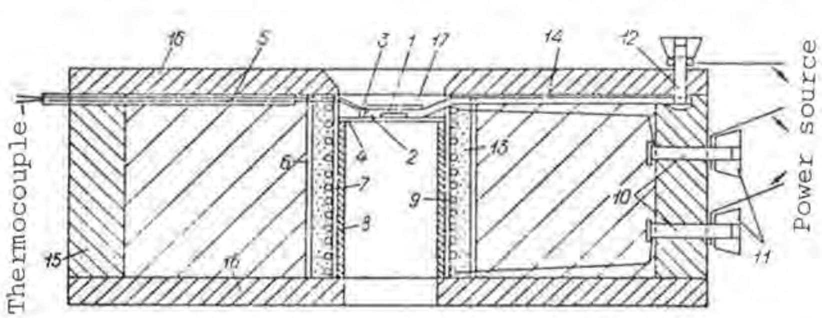

Fig. 7. Section through high-temperature microthermochamber constructed by Bazarov (1968). 1) sample; 2,14) platinum hearing loop; 3) thermocouple junction; 4) plate of silica glass; 5) two-hole porcelain tube; 6-8) silica tubes; 9) heating spiral of high temperature steel EI; 10-12) screw terminals; 13) ceramic filler; 15) body; 16) caps (15 and 16 made of asbestos-cement); 17) plate of silica glass.

An analogous solution to the problem of obtaining high temperatures has been indicated by Piznyur (1973), in describing the two-stage microthermochamber of I.V. Popivnyak, devised on the basis of the Dolgov-Bazarov chamber. In it, two toroid spirals were employed, which created: 1) an outer temperature stage (nichrome spiral, up to 800°C); 2) an inner temperature-stage (platinum spiral, up to 1400°C). In some constructions, a ribbon spiral has been used in place of wire.

The microthermochambers with heat transfer by convection and
[24] conduction along with their range of merits, are not free of deficiencies. The achievement of high temperatures (above 1200-1250°C) is complicated by a number of technical factors. During the high-temperature experiments, frequent replacement of the silica glass is necessary as a consequence of turbidity or near-melting of the samples. The principal deficiency in the high-temperature chambers of this type during examination of melt inclusions is the significant temperature drop from the heating element to the object of investigation, located in the center of the observation stage. However, a decrease in the diameter of the chamber simultaneously excludes the possibility of

using short-focus objectives (X 20). The introduction of a second heating coil considerably complicates the construction and the use of the chamber.

Microthermochambers With Contact Heating. The idea of using a contact heater and, in particular, ribbon (and flat) resistance heating elements is not new. The latter have been employed for various purposes in experimental investigations (Roberts & Morey, 1930; Keith & Roy, 1954; etc.). Fitton & Neal (1964) have described a staged (with a central section of higher resistance) platinum and platinum-rhodium ribbon heating elements for the study of the formation of bubbles in drops of aluminosilicate melts and have suggested the possibility of using similar heating elements for a heating stage on the microscope.

Kalyuzhnyi's microthermochamber (1965) was one of the first high-temperature vacuum devices with a flat metallic heater used in mineral-thermometry. It has been mounted on the stage of an EVP-2 electro-vacuum instrument and consists of a vacuum hood, a brass sleeve with glass window, a molybdenum heating element, and a thermocouple mounting (Fig. 8). The sleeve is cooled by circulating water. The heating element is made of molybdenum foil and is fixed on current-conducting clamps. The shape of the heating element is a strip with a narrower central portion. Temperature has been measured on a platinum-platinum-rhodium thermocouple, the junction of which has been fixed to the lower surface of the heating element.

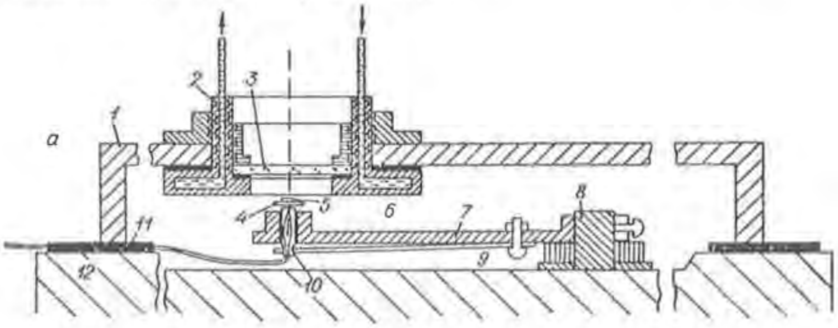

Fig. 8. Section through Kayuzhnyi's high-temperature vacuum microthermochamber (1965). 1) vacuum hood; 2) brass sleeve; 3) glass window; 4) molybdenum heating element; 5) sample; 6) thermocouple junction*; 7) thermocouple mounting; 8) clamps; 9) spring; 10) porcelain insulator; 11) resin packing; 12) stage of EVP-2 vacuum instrument. *Presumably there should be a line from 6 over to the center of the stage (Ed. note).

Lighting is provided by the incandescent heating element itself. It is possible to heat samples up to 1600°C. The vacuum (about 1 x 10^{-4} mm mercury column) enables us to conduct experiments with minerals which oxidize on heating in air. In this thermochamber, Kalyuzhnyi (1965) conducted homogenization of glass inclusions in hyalodacite phenocrysts from Transcarpathia. Deficiencies in Kalyuzhnyi's thermochamber must include the awkwardness of construction, features of lighting which do not permit observations during the initial phases of
[25] the experiment, and the impossibility of using short-focus objectives with large magnification. The molybdenum heating element may operate only in a vacuum or an inert medium. It is likely that, as a result of these shortcomings, this chamber will not be employed in the future.

On the principle of Kalyuzhnyi's chamber, a heating design has been constructed in the microthermochamber for high-temperature investigations in an inert medium, suggested by Chepurov & Pokhilenko (1972). The body of this microthermochamber (Fig. 9), made of asbestos-cement, does not differ fundamentally from all the previous models of the Dolgov-Bazarov chamber. In the body, there are openings for clamps, the thermocouple, and the tube through which the inert gas is introduced. The heating element is a platinum strip, inserted into the terminals of wider platinum strips, which in turn are fixed by bolts between brass plates, joined to the clamps. In order to illuminate the object being examined throughout the entire experiment, there is an opening up to 1 mm in diameter in the platinum strip heating element. Into this opening, the sample is placed on a thin glass plate (in order to avoid melting near the heating element). The heating element enables us to achieve temperatures up to 1500°C and more.

Sealing of the chamber is achieved using resin and asbestos. Observations on the processes, which take place in the inclusions, are conducted with the aid of short-focus objectives (X 20), with a system of water cooling. A resin collar and an asbestos packing are slipped onto the objective, and these are pressed against the end of the alumina tube during insertion of the objective into the inspection opening into the chamber, creating the necessary seal for the working space of the microthermochamber. The precision of the temperature measurements during completion of all the requirements of the technique used with the chamber is ± 15°C.

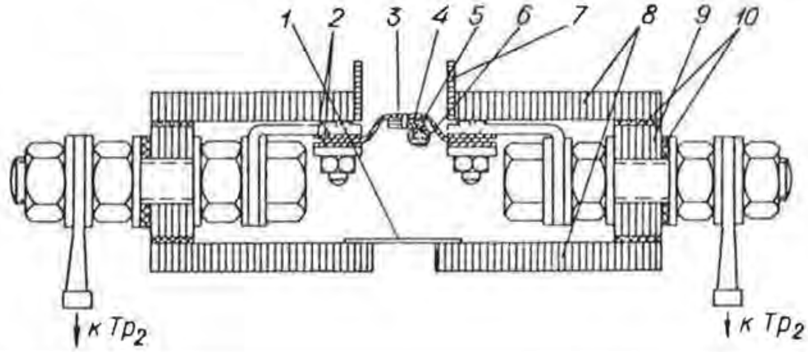

Fig. 9. Section through microthermochamber with inert medium and platinum strip heating element (Chepurov & Pokhilenko, 1972). 1) Silica glass plate; 2) platinum clamps; 3) platinum strip heating element; 4) thermocouple; 5) alumina strip-support; 6) two-hole porcelain tube; 7) alumina (or other material) tube; 8) cap; 9) body (8 and 9 made of asbestos-cement; 10) resin packing.

This device has also not been widely used by investigators into melt inclusions. The principal deficiency in the platinum heating-element of such type is its over-small (thermal) inertia and the inevitable deformation of the surface of the strip during heating, and also the ease with which the platinum recrystallizes at high temperature. The 'relief' of the strip may change after each experiment, that is, the contact between the glass plate and the heating element is disturbed each time. This deficiency involves a decrease in the precision of measurement of the homogenization temperature.

Simplicity and economy of preparation are to be found in the
[26] modification of the high-temperature chamber, suggested by Mikahilov &

Shatsky (1974), where instead of the platinum (molybdenum or other metal) heating element, silite (i.e., silicon carbide or "Globar", Ed. note) rod (designed for a muffle furnace) was used. The facing portion of the rod used has in the center the shape of a ribbon (thinner portion), which is heated during the passage of the current (Fig. 10). In order to fix the heating element, special contact clamps were used, set in combination with the silite rod. The clamps are joined through the brass leads to the corresponding clamps on the body of the chamber. The heating element permits us to obtain temperatures up to 1600°C with a precision in temperature determination of 1-2%. This construction provides stable temperatures with repeated calibrations and possesses the necessary (thermal) inertia. The surface of the heating element is not deformed during heating, and being a ground surface ensures a good, and fundamentally stable contact between the sample and the heating element. Recently, this construction has been used by almost all the Novosibirsk investigators. It is not difficult to set up the chamber with this heating element for work in an inert gas. The deficiencies of the silite element are its brittleness and unreliable contacts with the current-conducting clamps.

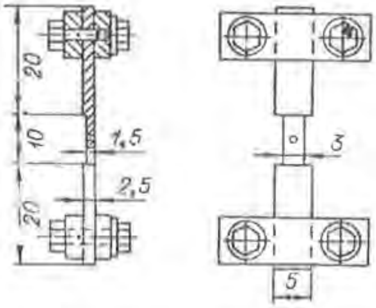

Fig. 10. Diagram of silite strip heating element.

Summarizing the above, we may note that during the development of techniques for high-temperature investigations, a significant step was achieved. The high-temperature microthermochambers have been tested and work, permitting us to investigate melt inclusions in minerals from the most varied rocks. However, the goal of creating a completely satisfactory apparatus has still not been totally achieved. Where local and uniform heating is the objective, a heating element, based on the conversion of energy from an electromagnetic high-frequency field into heat has still not been widely approved in practice. A heating element, based on the use of focussed heat radiation, would enable us to obtain any temperature up to a few thousand degrees.

Measurement and errors in measuring temperatures of homogenization of inclusions. The measurement of temperatures in high temperature thermochambers is achieved with the aid of a platinum - platinum-rhodium thermocouple. The thermocouple junction is placed as close as possible to the heated sample and must certainly be rigidly secured. Since the temperature of the thermocouple junction normally does not correspond to that of the heated sample, each thermochamber has its own calibration of temperature vs. EMF of the thermocouple. The latter is achieved by standardization based on clearly defined melting points of several chemically pure salts and noble metals, placed in the working space of the chamber. For this purpose, we used NaCl (800°C), Ag (960°C) Au (1063°C), Mn (1250°C), Pd (1552°C), etc., during the high-temperature investigations; Cu (1083°C) and Fe (1539°C) may be used only *in vacuo* or in an inert medium. As an electrical measuring instrument, it is possible to use any sufficiently sensitive milli-voltmeter (18mV full range) calibrated at a small emf.

We must dwell somewhat on the estimation of errors when measuring temperatures (Chepurov, 1973d; Chupin, 1973a), which come from errors in instrument readings and random errors. The class of precision of the measuring instruments, used in mineral-thermometric investigations, is usually 0.5, that is, errors in reading the instrument do not exceed [27] 0.5% of the whole scale. The error in constructing the temperature-emf graph and the calculation of the homogenization temperature derived from it, do not exceed ± 2°C (ed. note - this is graphical error only). The random error in measuring the temperature of homogenization depends on a number of construction features in the set-up and technique of the measurements: the thickness and the horizontal dimensions of the silica plates and the samples plates, the position of the inclusion in the plate, the position of the sample with respect to the opening in the strip heating element, the strength of the current of inert gas, the working distance of the objective, and other reasons. The random errors, as indicated, are eliminated by a strict observance of the rule of working under conditions as close as possible to those used for the standardization of the thermochamber. In existing high-temperature microthermochambers, the overall error in measurement is usually estimated as ∿ ± 10-15°C.

C. An Auxiliary Apparatus for Thermometric Investigations of Inclusions in Minerals.

The mineral-thermometric set-up, besides the microthermochamber, consists of a microscope, a regulated power source, a light source, and measuring instruments; sometimes a vacuum pump, a cylinder with inert gas, etc., are additionally required. The most widely used in practice in mineral-thermometric investigations is the MBI-6 microscope with an AU-13 stanton tube, which possesses a good light-source system and optics. Only minor re-equipping is required: replacement of the stage by a metallic plate (or special stage) and fitting of the appropriate long-focus condenser (Bazarov, 1965). Other types used are the MKU-1, MBI-3, and -4, MIN-8 and -9, and metallographic and certain imported microscopes. For observations on the processes taking place in the inclusions, long- and short-focus objectives are employed. The long-focus objectives (OSF) enable us to create a well-isolated space in the thermochamber and lower the temperature gradients in the sample, but they have a low resolving capacity. The short-focus objectives provide good definition, although their direct application is complicated by the small working distance; the application of a water-cooling system has proved useful in this case (Chepurov, 1971; Fig. 11).

There are two cameras in the outfit of the MBI-6 microscope: broad format and 16 mm. The use of the photo-tube and ciné-camera enables us to make ciné pictures of the processes that take place in the inclusions during heating.

The power supply to the existing high-temperature microthermochambers comes from a variable current circuit through a step-down transformer and voltage transformer of the RNO-250, RNO-250-5, and other types. The capacity of the transformer is selected according to the construction of the heating element and is usually close to 0.2-1 kW. The maximum voltage, taken from the secondary, is 5-30 volts, and [28] the current 10-150 amp. In addition to that mentioned above, the set-up may include such measuring instruments as an ammeter, and when working with minerals that oxidize in air, a vacuum pump or a cylinder with inert gas is attached to the thermochamber.

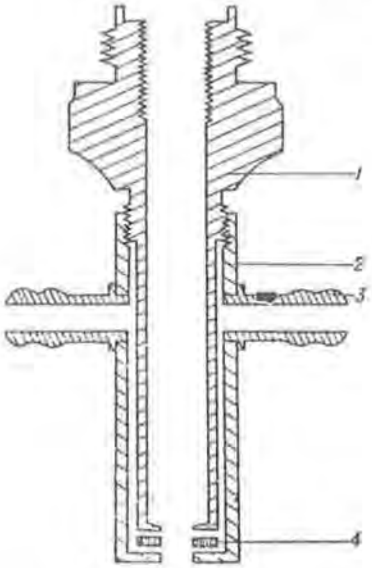

Fig. 11. Diagram of system for water-cooling microscope objective. 1) body of objective; 2) outer wall of body; 3) copper tube; 4) polyfluorethylene resin packing.

2. THE PRESENT APPARATUS AND POSSIBILITIES OF USING IT FOR CLARIFYING THE CHEMISTRY OF HIGH-TEMPERATURE INCLUSIONS.

Investigations on high-temperature inclusions of melts and melt-brines in magmatic minerals also provide, in addition to information on temperatures, data on the chemistry of the magmatic processes. Here, a significant aspect is the possibility of obtaining direct data both on the composition of the volatile components, and also the silicate and salt components.

The determination of the silicate components (of glass and its crystallization products) is currently and most precisely made by the "x-ray spectral" (i.e., electron microprobe) method. Some idea of the chemistry of the melt inclusions may also be given by indirect methods, for example, by determining the refractive index of glass and solid phases via interferometric or immersion methods (Kalyuzhnyi, 1954, 1965; Bazarov *et al.*, 1969; Roedder, 1972; Reif, 1973*a*, *b*).

Besides the study of one-, two-, three-phase carbon dioxide and aqueous inclusions, the cryometric method is used for clarifying the features of the gas and salt compositions of multi-phase inclusions of brines and melt-brines, and also for determining the amount of carbon dioxide in the fluid or gas phase of melt inclusions. Additional information on the salt composition of the inclusions may be obtained with the aid of analyses of individual inclusions and bulk analyses of aqueous extracts by methods of chemistry, electron diffraction, X-ray measurement, etc.

In order to examine the chemistry of the volatile components, methods of ultramicrochemical analysis of the gas phase of individual inclusions are widely used, and also methods of chemical, chromatographic, and mass-spectrometric analysis of bulk gas samples. Extraction of the gases from inclusions in minerals has been achieved by crushing the samples in vacuum ball-mills or by disintegration of the inclusions when heating in evacuated systems, and also during decomposition of individual inclusions by setting them between two glasses or in special presses with an inert liquid. Of the methods listed, we consider it necessary to dwell in detail only on those that give us the most valuable, complete, and achievable information about the chemistry of the environment during the phase of magmatic mineral-formation.

A. THE ELECTRON MICROPROBE METHOD FOR DETERMINING THE COMPOSITION OF GLASS AND CRYSTALLINE PHASES.

The principle of the method of local analysis with the aid of the electron microprobe. The electron microprobe method of investigation and analysis of the chemical composition in micro-quantities of material has received widespread application. In a number of countries, modern equipment has been constructed for the analysis of micro-quantities; in France, the Ms-46, in Japan, the JXA-5, in the USA, the Mac-400, in Great Britain, the EMMA-4, in the USSR, the MAR-1, and corresponding types in other countries.

[29] The essence of the method is as follows. The sample being investigated is set up in a vacuum chamber. During analysis, observation is carried out with an optical microscope and the sample may be shifted with fine adjusting screws without disturbing the vacuum. A special electron optical system, consisting of an electron beam and electromagnetic lenses, creates a beam of electrons focussed on the sample. The electrons excite the atoms of the material examined and cause X-ray radiation. The radiation is broken up into a spectrum in X-ray spectrometers with curved monocrystals. The intensity of the spectral lines is measured by counters with appropriate electronics for recording the impulses. From the values of line intensity, we may calculate the amount of a particular element in the sample as compared with those for corresponding standard samples. The electron microprobe enables us quantitatively to determine almost all the elements in the periodic table (from B to U), with localization down to one micrometer, from a mass of material of the order of 10^{-13} g. The latter is of exceptional importance for examining microportions of melts, retained in the most varied minerals.

Sample preparation and conduct of analysis on an electron microprobe. In order to carry out an electron microprobe analysis, we usually employ cartridges, prepared from an epoxide resin with standards and the sample being examined, mounted in them (Lavrent'ev *et al.*, 1974; etc.). The method of preparing the cartridges for analysis of the composition of inclusions of magmatic melts in minerals is briefly as follows (Chepurov *et al.*, 1974): an organic glass is coated with a thin layer of resin, in which the sample is mounted (plates polished on both sides), which enables us to set the plates at one level. A mold is placed above the samples, and into this the resin is poured. After hardening of the resin, the cartridge is readily removed from the organic glass and hollows are prepared in the immediate vicinity of the samples. In them are mounted the standards, the grains of which stand out above the plane of the cartridge. Both sides of the cartridge are polished. In order to identify inclusions that have appeared on the surface of the cartridge, and in order to determine the level at which the inclusions are arranged with respect to the polished surface, it has been found useful to use a combination of methods of observation in reflected and transmitted light. Komatsu and Yajima (1970) mounted their samples in a slide and polished it on one side. The grains that contained inclusions of glass on the polished surface, were separated on the binocular microscope. Roedder & Weiblen (1970*a*, *b*) used thin sections, prepared with the aid of resin, to analyze the inclusions.

An analysis of the composition of the inclusions in minerals has been carried out under the following conditions: accelerating voltage 12-20kV, current 0.01-0.07 μA, diameter of beam 3-10μ, counting time 10-25 sec, sometimes 5 sec, depending on features of samples analysed. As a rule, 1-5 points in the inclusions are analysed, with not less than three repeat determinations for each point. During the analysis of crystallized inclusions, consisting of an aggregate of grains, a probe with a defocussed (∿20μm) beam is used (Komatsu and Yajima, 1970; Roedder and Weiblen, 1972).

As standards, artificial homogeneous glasses or minerals with precisely defined amounts of individual elements and a composition close to that of the analyzed samples, are used.

The error for determinations on the microprobe does not exceed 2%, if uniform and large samples are investigated. In determining the composition of inclusions in minerals, the precision of analysis diminishes. Roedder & Weiblen (1970*a*, *b*) have pointed out an error arising as a result of a difference in background between the analysed [30] glasses and the standards. In our determinations we have corrected for background (Lavrent'ev *et al.*, 1974). The analysis of the composition of inclusions of mineral-forming media has turned out to be complicated owing to a number of features: 1) the inhomogeneity of the samples; 2) the dimensions of the analyzed objects; 3) errors that accompany the breakdown of the samples for analysis into different elements; 4) the removal of alkali metals from the radiated volume during analysis of inclusions of glass, etc. In order to lessen the effect of the last factor, we used average maximum figures for the amount of alkalies in the glasses, which nevertheless may turn out to be somewhat underestimated. On the other hand, the amounts of Si and Al, as a result of the removal of alkali metals from the radiated volume, have turned out to be overestimated.

The sum of the oxides may serve as a control on the quality of the analyses carried out. Moreover, the sums of oxides obtained are always less than the true values owing to: 1) oxides not analyzed (MnO, Cr_2O_3, P_2O_5, etc.; 2) undetermined components (H_2O, CO_2, CH_4, etc.). Clocchiatti (1972) believes that these and others may constitute up to 6% during analysis of glass inclusions in minerals of acid volcanic rocks, + uses this to explain the low sums in the analyses. In an experimentally degassed inclusion, the sum of the oxides turned out to be close to 100%. It is natural that such errors (especially in relation to H_2O) are unlikely for inclusions in minerals of basic rocks and even more so, lunar rocks. Usually the relative error of analysis is close to 4-6% (Clocchiatti, 1971; Komatsu & Yajima, 1970), but errors in determining Na and K may exceed 10% (during the analysis of alkaline glasses using minerals as standards, the errors for Si and Al are increased.)

B. THE CRYOMETRIC METHOD AND APPARATUS FOR FREEZING INCLUSIONS

The cryometric method has been widely employed in the investigation of gas-liquid inclusions readily seen under the microscope (Lemmlein & Klevtsov, 1955; Roedder, 1962*, 1963; Mel'nikov, 1965, 1968; Bazarov, 1965, 1966; Bazarov & Motorina, 1970; Andrusenko & Mel'nikov, 1968; Dobretsova, 1968). Recently, it has also been used in the study of the

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*Not in References. Probably Econ. Geol., v. 58, p. 167-211.

gas and fluid phases of melt inclusions and inclusions of melt-brines. The cryometric method enables us to assess: 1) the concentration and composition of salts in solutions and brines; 2) the composition of crystallized salt phases; 3) the composition and density of monophase gaseous and liquid-like inclusions; and 4) the presence of carbon dioxide in inclusions.

The first attempts to observe the behavior of inclusions during cooling were made on gas-liquid inclusions in the previous century. The investigators of that time (Davy, Brewster, Sorby, Spezia, etc.) used rough-and-ready methods for cooling the samples below room temperature: ice, drops of evaporating alcohol, acetone, ether, and other cooling substances. More detailed information about this stage of development of cryometric investigations is given by Smith (1953) and Roedder (1962).

Special arrangements for the cooling and study of inclusions at low temperatures have only become available in the last 20-25 years. Cooling of the sample has been conducted in a current of cold air (Cameron, Rowe & Weis, 1952); acetone (Roedder, 1962); liquid nitrogen (Mel'nikov, 1965; Bazarov, 1966; Roedder, 1968); or carbon dioxide (Velchev & Mel'nikov, 1965; Kormushin, 1965). In 1952, a description appeared in the local literature of a universal stage for the microscope for investigations at high and low temperatures constructed by Tsurinov & Vol'nova (1952). The stage was designed for the microstructural
[31] phase analysis of organic substances. Cooling was achieved at -150°C in liquid nitrogen. This arrangement is also applicable to the cryometric investigations into minerals, but has not received wide application.

Accepting as a basis the apparatus designed by Tsurinov & Vol'nova, Mel'nikov (1965) constructed a set-up for investigating inclusions at low temperatures. Cooling was also achieved with nitrogen, which was passed into a chamber, set up on the microscope stage, from a Dewar flask through a connecting tube. The flow of nitrogen is controlled by a valve at the entry to the chamber, which permits lowering or raising of the temperature. Measurement of the temperature is done by a cryometer (copper-constantan thermocouple + mounted mirror galvanometer). This set-up operates in the temperature range from +20 to -75°C.

Several cold-temperature layouts are known that have been proposed by various authors, but have not received widespread acceptance. Kormushin (1965) used a concentrated solution of solid carbon dioxide in ethyl alcohol for cooling samples from +20 to -72°C, achieving a change in temperature by altering the concentration of carbon dioxide. As a chamber, he proposed to use an ordinary glass jar.

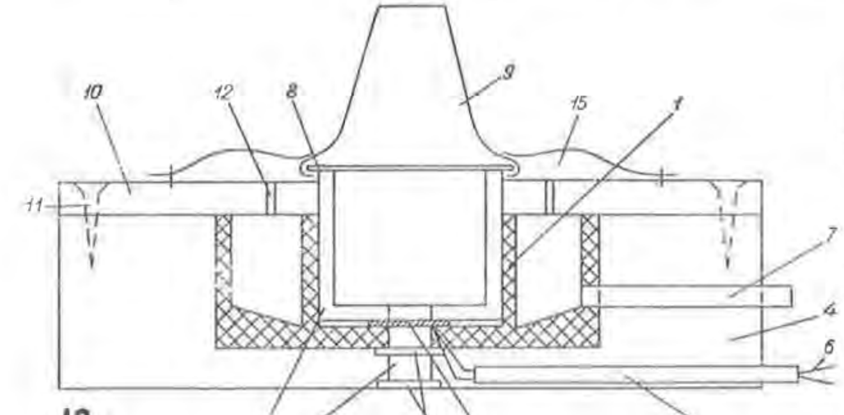
Myaz' & Simkiv (1965), in investigating carbon dioxide in inclusions, used a microtome biological cooling stage, in which the temperature can only be lowered to -10 to -12°C. Cooling is based on the principle of the Peltier effect, where, during passage of an electrical current through the successive coupling of three different metals, one layer is cooled and the other heated up. Velchev & Mel'nikov (1965), in freezing samples, used a Kofler stage, the cooling of which is achieved by the passage of liquid carbon dioxide under pressure. Cooling can be taken to -50°C.

Abroad, much of the information on freezing of inclusions has been obtained from Roedder's set-up (1962), which enables us to study samples at temperatures from -35 to +250°C (Roedder, 1965). Roedder's cold chamber has a number of significant deficiencies, and in particular, it requires a very cumbersome booster equipment and operates only down to -35°C. Therefore, for more intense cooling, Roedder suggests dis-

[32] connecting the chamber from the pump circulating the acetone, and plunging it into a large bath with acetone and dry ice at -78.5°C. Later on, in order to increase the speed of cooling and to increase the temperature range, Roedder (1972) has designed a new set-up, which is cooled by a flow of evaporating liquid nitrogen.

Nitrogen has also been used as a cooling agent in the apparatus proposed by Bazarov (1966). This apparatus, in the simplicity of its construction, has significant advantages as compared with other types and has been used for cryometric investigations in the Institute of Geology and Geophysics of the Siberian Division of the Academy of Sciences of the USSR.

The principal parts of the apparatus (Figs. 12 and 13) are: a cooling chamber with a thermocouple, a microscope, a PPTN-1 potentiometer, two Dewar flasks for nitrogen (capacity 1-2 liters) and for ice (capacity 0.5 liter), a normal heating element, a M-195/1 galvanometer, a starting battery with a voltage of from 3.6 to 4.6 V, and a regulator for cooling speed. The last not only allows us to cool the inclusions at practically any required rate, but also to regulate the speed of cooling the sample and to hold at any temperature during the course of a required time. The apparatus enables us to conduct experiments over a wide temperature range (from room temperature to -170°C). An easily rectifiable deficiency is a certain inertia during warming of the inclusions. In order to increase the speed of warming of inclusions,



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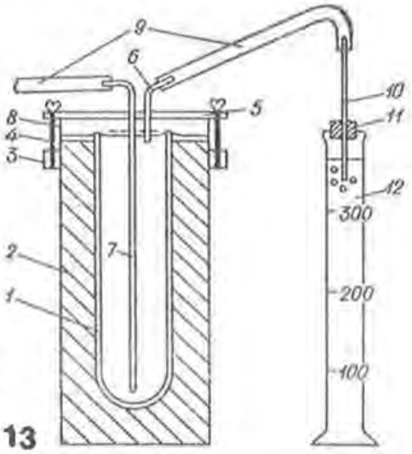

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Fig. 12. Longitudinal section through cooling chamber. 1) cooling section; 2) internal cooling sleeve; 3) glass thermal shields; 4) thermo-insulating section; 5) porcelain two-hole tube; 6) copper-constantan thermocouple; 7) tube for passage of nitrogen; 8) textolite washer; 9) plastic jacket; 10) upper lid of chamber; 11) wood-screws; 12) openings through which nitrogen is removed from the chamber; 13) sample; 14) opening through which sample is illuminated; 15) flat springs, clamping sleeve.

Fig. 13. Longitudinal section of layout for regulating flow of nitrogen. 1) Dewar flask; 2) thermo-insulation casing; 3) plastic cover-plate; 4) bolt with wing-nut; 5) upper cover; 6) short brass tube; 7) long brass tube for passing nitrogen; 8) plastic gasket; 9) plastic tubes; 10) brass tube; 11) gasket with opening for removal of excess nitrogen; 12) flask with water.

an additional heating element has been installed in the newer version, which is set either within the chamber or is placed in the tube that conducts the flow of nitrogen. In order to increase the number of experiments which may be carried out without recharging the nitrogen flask, it is possible to use standard ASD-15 Dewar flasks with a capacity of 15 liters.

A method for the ultramicrochemical analysis of the composition of the gas phase inclusions, as now used, has been developed by Dolgov & Shugurova (1966, 1968), Dolgov, Shugurova and Pogrebnyak (1969), Shugurova (1968*a*, *b*), and others, using methods previously suggested. In order to make a gas analysis of individual inclusions, less than 0.02 mm in size, the following instruments and attachments are necessary: 1) a microscope with an ocular-micrometer and triaxial micro-manipulator; 2) a special attachment (press) for crushing inclusions and releasing the gas phase; 3) a pipette for collecting the released gas bubble; and 4) flasks with absorbents and inert liquid.

At the present time, the following gas components and their groups are being determined (H_2S, SO_2, NH_3, HCl, HF), CO_2, O_2, hydrocarbons, CO, H_2, and (N_2 + rare gases). In addition, the first group of gases noted may be separated qualitatively by methods of spot test analysis.

CHAPTER IV

[33] MELT INCLUSIONS, THEIR TYPES, AND THERMOMETRIC METHODS OF INVESTIGATION

Inclusions of silicate and salt melts and melt-brines are widely distributed not only in natural minerals of terrestrial, cosmic, and cosmogenic origin, but also in artificial crystals, grown from silicate, metallic, salt, and other melts and melt-brines, known to the 'growers' as 'melt solutions' or 'fluid melts'. The best known are the terrestrial objects, among which we may primarily note the melt inclusions in various strictly magmatic minerals, in minerals of every possible xenolith captured by melts, and in minerals of rocks affected by thermal or dynamic action. Such are the inclusions associated with fulgurite and pseudotachylite formations, inclusions in minerals involved in zones of burning coal and other fires (buchites and cinder glasses), inclusions in minerals of the exocontact zones of various magmatic bodies, etc.

Melt inclusions have been found in cosmic objects by Sorby, Cohen, and others in minerals of stony and iron-stony meteorites (Smith, 1956), and recently, in lunar samples (Roedder & Weiblen, 1970a, b, 1971, 1972a, b, 1973). In the latter a portion of the inclusions is not associated with the processes of lunar magmatism, but clearly has a cosmogenic (impact) origin. A cosmogenic origin is also appropriate for specific glassy inclusions in minerals of large terrestrial crater structures (astroblemes), also formed during impact action between cosmic bodies and terrestrial material (Dolgov & Vishnevsky, 1974). Such inclusions have been formed artificially in minerals affected by dynamic action during nuclear and thermonuclear explosions and in special pieces of apparatus in which a super-high dynamic pressure is obtained with the aid of explosive substances. Further examples of melt inclusions are the lechatelierite and similar glassy inclusions, found in bediasites, indochinites, australites, and other varieties of tectites (Dana, 1962; Dolgov et al., 1969, 1971).

Finally, it is difficult to estimate the variety of melt inclusions in synthetic crystals, a serious study of which is only just beginning.

The number of new natural and artificial objects, in which such inclusions have been found, increases without a break. The range of application of all-round static and dynamic (as understood by Yermakov, 1972) studies of melt inclusions has also expanded. The most important trends concern the determination of the conditions of magmatogenic mineral-formation, the clarification of the properties of natural and artificial melts at the time of their crystallization, the solution of problems of dynamic crystal-morphology, etc. It is natural that the level of study of all the items and trends listed and the information [34] obtained with their aid are unevenly balanced. Therefore, in the present report we shall in the main present data which have the greatest petrological and informational value.

1. THE GENETIC CLASSIFICATION OF MELT INCLUSIONS

An all-embracing experimental and theoretical consideration of the problem of the primary and secondary nature of inclusions in natural and artificial crystals has been given in the works of Shubnikov (1935), Lemmlein (1973), Grigor'ev (1948), Kalyuzhnyi (1960), and in a number of papers by Yermakov. In the present report we shall adhere to the genetic subdivision of inclusions into primary, pseudosecondary (primary-secondary), and secondary groups proposed by Yermakov (1948, 1949a, b, 1950, 1971, 1972). Individual portions of early genetic classifications have been refined by Yermakov in his latest version (Yermakov, 1971, 1972). In particular, the subdivision of primary inclusions into zonal and azonal types has contributed to the identification of still clearer boundaries between the primary and pseudosecondary inclusions.

The question of the primary or secondary nature of inclusions in magmatic minerals was first clearly posed in the 'sixties of last century in connection with the widespread distribution of gas-liquid inclusions in the quartz of granitoid rocks. At this time, thanks to the work of Sorby (1858), Vogelsang (1967), Zirkel (1893) and other petrographers, there were already views held that magmatic rocks are characterized by glassy and crystallized ("stony") inclusions, and that hydrothermal and metamorphic formations had inclusions of water and carbon dioxide. In this connection, there was a dilemma whether to renounce the hypotheses on the magmatic nature of granites, or to place in doubt the possibility of using inclusions for genetic interpretations. There were supporters of both positions. But in 1869, Vogelsang put forward the first suggestion of the possibly secondary origin of these inclusions during the healing of later fractures in the presence of aqueous solutions. Unequivocal proof of the secondary nature of gas-liquid inclusions in the quartz of granitoids was presented in the works of Zirkel, Daly, Nelson, Bailey, and later investigators (Smith, 1956).

At present, there are other generally-known facts about the presence of gas-liquid and other secondary inclusions in minerals of many igneous rocks and, on the other hand, facts about the presence of melt inclusions in minerals of nonmagmatic rocks (Plate 1, figs. 5-6). In most cases, the genetic position of these inclusions is readily explicable. However, the position of certain groups of inclusions remains problematical. There are particular difficulties in many cases about the age relationships between the latest inclusions of silicate melts and the highest-temperature inclusions of silicate-salt and salt (i.e., melt and melt-brines), and other later inclusions. But the clarification of the relationships between types of inclusions and hence, a particular interpretation of these data is the key to the resolution of such cardinal problems of petrology as: 1) the relationship between magmatic and metamorphic processes in the broad sense; 2) the physicochemical conditions of generation and crystallization of magmas; 3) the physicochemical features of the boiling and liquation of melts under deep-seated and near-surface conditions (clarification of relationships between intramagmatic and post-magmatic solutions, and the possibility of liquation of melts with the separation of additional non-mixing phases - silicate melts, salt and silicate-salt melts, melt-brines, and solutions, and [35] sulfide and other melts). It is doubtful whether we can yet state that even one of the problems listed has been completely solved. Thus, the importance of an open mind on the problems of the primary or secondary nature of melt and other inclusions is evident, so that we shall dwell on this problem in more detail.

Primary Inclusions. In Yermakov's classification (1971, 1972), zonal and azonal inclusions are recognized in the class of primary inclusions of mineral-forming environments. Both kinds of inclusions are syngenetic with respect to a certain actual growth zone of the crystal-host. Such zonal inclusions are characterized by a clear restriction to the zones of crystal growth traced by them. The characteristics of primary inclusions as given in the works of Zirkel (1893) and later investigators were based on examples of this kind of inclusion. Amongst the azonal inclusions such a spatial restriction of many inclusions into a particular growth zone is absent. In order to assign isolated inclusions unequivocally to the primary azonal type, we need, in addition to morphological studies, to carry out comparative thermometric and other analyses in individual cases.

Zonal inclusions. This group includes only those inclusions that clearly emphasize the zonation of the crystal-host (Fig. 14). The features of the regular spatial distribution of zonal inclusions indicate a synchronous formation of individual groups of these inclusions with an actual, more or less clearly defined growth zone of the crystal (Fig. 14 a), that is, they indicate the mutual syngenetic nature of the primary inclusions of the given group. Two limiting cases of such synchronous formation are possible: 1) zonal inclusions of a given series characterized by a synchronous time of initiation of the cavities, independent of the time of closure; 2) zonal inclusions characterized by a synchronous time of closing of the inclusions, independent of the time of initiation (see Fig. 14 b, c). In the first case, the earlier surface of the crystal, onto which the basal facet of the zone with

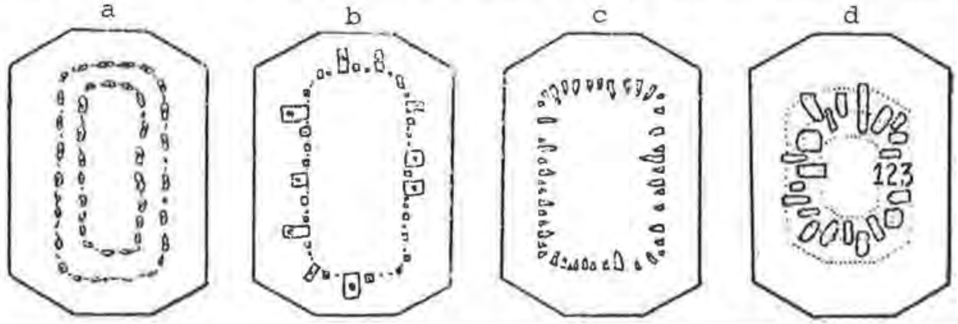

Fig. 14. Zonal primary inclusions.
a) general case (restriction of inclusions to a single growth zone), b, c) limiting cases (b - synchronous initiation of inclusions, c - synchronous closure of inclusions); d) variety of zonal inclusions, similar to azonal types.

inclusions grows, is traced out by the inclusions, and in the second case, the inclusions outline in basal facet of the next zone, which covers the zone of inclusions.

In individual cases, zonal inclusions may occur in forms like pseudo-secondary and even secondary inclusions, which develop on cleavage planes, partings, and cracks, passing along twin and other crystallographically unequivocal boundaries, and also on concentric cracks which develop during thermal shock. Such epigenetic inclusions [36] are readily recognized, if the surfaces to which they are confined, crosscut the zonation. In other cases, later inclusions, spatially combined at random with primary ones, may be recognized and excluded by carrying out additional observations on the pecularities of their filling, homogenization, and other characteristics. Zonal inclusions are mainly characteristic of the minerals of volanic and subvolcanic rocks.

Azonal inclusions. Yermakov (1972) has assigned here the isolated and unsystematically arranged primary inclusions, clearly not connected with the growth zones of crystals (Fig. 15). The random arrangement and the absence of any clear restriction of the primary azonal inclusions to actual growth zones of crystals indicate a mutual non-syngenetic nature of the inclusions. They begin to form and are finally sealed asynchronously.

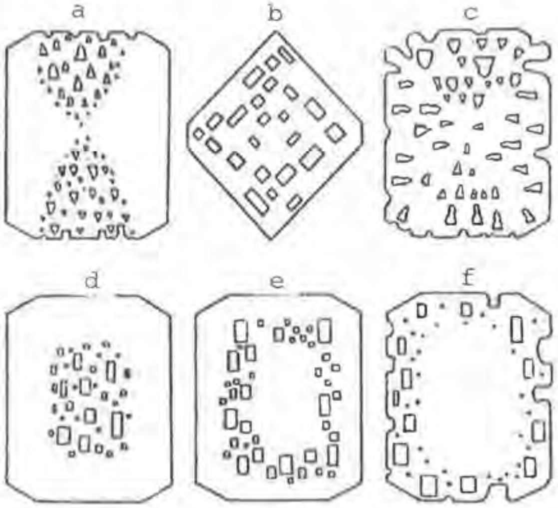

Fig. 15. Azonal primary inclusions.
a) azonal arrangement of inclusions within individual growth sectors; b) azonal arrangement of asymmetric inclusions (inclusions flattened parallel to the faces by which they were trapped); c) 'polar' azonal inclusions (the moment of closure is fixed by the presence of planes, parallel to the overlying faces; their projections have been portrayed by straight lines); d, e, f) cases of azonal arrangement of inclusions within core, intermediate and peripheral zones of roughly zonal crystals.

Isolated inclusions are frequently difficult to assign to primary azonal or to secondary and pseudo-secondary types. An important criterion for the primary nature of isolated inclusions is their morphological association with individual crystal growth sectors. For example, this association may show as a flattening of the inclusions parallel to the crystal growth faces (see Fig. 15 b), or they may be elongated normal to these faces, and it will be shown that in different growth sectors, these inclusion orientations are correspondingly altered (see Fig. 15 c). However, proof of a spatial association between inclusions and individual growth sectors (e.g., the random presence of inclusions in some growth sectors and their absence in others) is inadequate, since pseudo-secondary inclusions sometimes reveal an analogous association. These latter inclusions are sometimes preserved in cracks which arise in individual growth sectors during the release of stress, due to the anisotropy of the crystals. Such pseudo-secondary melt inclusions are particularly characteristic of synthetic crystals.

A second unequivocal criterion for the primary nature of azonal inclusions is the appearance of primary crystal growth forms on their walls, especially the appearance of a primary asymmetry (see Fig. 15 b) and polarity (see Fig. 15a, c), which frequently occurs systematically in inclusions sealed in different growth sectors. For example, in quartz phenocrysts, there are sometimes glassy inclusions with asymmetric negative hexagonal-bipyramid faces, and a tendency towards a regular change in the direction of flattening of the faces of the inclusions according to their occurrence in one growth sector or another (see Fig. 15 b). Primary polarity in the morphology of inclusions has been seen either in the presence of negative basal faces, defining the beginning of the formation of the inclusion (see Fig. 15
[37] a), or negative outer boundaries, defining the moment of complete isolation (see Fig. 15 c).

The azonal arrangement of inclusions sometimes arises as a result of migration of inclusions during transformation of the shape of the primary cavities and especially during the breakdown of primary inclusions having markedly disequilibrium faces. The artificial migration of inclusions is easily achieved if the crystal is subjected to extremely high thermal gradients. However, under natural conditions, such gradients are unlikely within a crystal even during the eruption of lava onto the surface. Azonal inclusions are more characteristic of the holocrystalline intrusive rocks.

With weakly defined zonation and in the presence of inclusions with markedly uneven dimensions and shape, the difference between the zonal and azonal primary inclusions is somewhat masked owing to uncertainty in the subdivision of the crystal into growth zones. Such difficulties arise in crystals with very rough zonation (thick zones). In fact, as the crystal is subdivided into zones, neighboring inclusions of different dimensions and different shape may turn out to be confined to one or another zone. Thus, when recognizing two different zones with boundaries 1-2 and 2-3 within a crystal (see Fig. 14 d) the inclusions may be regarded as azonal, and with the recognition of one thicker zone with boundaries 1 and 3, these same inclusions must be regarded as zonal. Since, in the present instance, all the inclusions have been formed at one time synchronously, we have assigned them to the zonal type, although some of them began to form earlier than others, and some separated later (sic.). The inclusions in the roughly-zoned crystals (see Fig. 15 d-f) have been assigned to the azonal group on the strength of lack of synchronous time of formation. Thus, even in these more complex cases, the practical possibility of subdividing primary inclusions into zonal and azonal types is not excluded.

Pseudo-secondary (primary-secondary) inclusions. These include (Plate I, fig. 4) the sub-syngenetic inclusions formed after the zones that enclose them, but prior to the termination of crystallization of the material from the given medium (Yermakov, 1950, 1972). Pseudo-secondary inclusions are secondary (non-synchronous) with respect to the growth zone in which they have been preserved, but syngenetic with respect to one of the later growth zones of the given crystal. In the classifications of Lemmlein (1959) and Kalyuzhnyi (1960), this category of inclusions is not recorded; they have been assigned in part ot the primary group (regenerated), and in part to the secondary group.

Of the three varieties of pseudo-secondary inclusions recognized by Yermakov (1971), melt inclusions are encountered under two headings. The first consists of those associated with cracks in the crystal, which formed during continuing growth and were covered by later growth zones of the crystal. The second variety consists of regenerated inclusions. They develop during regeneration of various external defects in the crystal, disturbing the natural sequence of layers deposited during the time of crystal growth. Such surface defects, for example, appear after welding, shearing, or other damage to the crystals.

Inclusions in syngenetic healed cracks. Yermakov considered those cracks that cut the internal growth zones of a crystal and are syngenetic with some of the external growth zones to be syngenetic cracks. Such syngenetic cracks in magmatogenic minerals most commonly form either as a consequence of thermal shock from a marked temperature
[38] change in the surrouding melt, or mechanical relief of stresses, associated with the anisotropy which shows up markedly in crystals with a sectorial structure. The surface of any crack, extending through a crystal, turns out to be in marked disequilibrium with the melt in it. Therefore, an interaction begins between the melt and the material in the walls of the crack. This process usually starts by the sealing of dendrites although in large cracks (Yermakov, 1971), "stepped" and "multi-headed" growth have been observed. The separation and formation of the inclusions and further transformations in their shape are the result of synchronous growth and solution processes of different sectors of the surface of the inclusions. This variety encompasses most of the glassy and crystallized inclusions encountered in magmatic minerals that are restricted to cracks (Plate I, fig. 4; Yermakov, 1971). This is emphasized by their temperatures of homogenization, which are usually lower than those of the neighboring primary inclusions and are equal to those of the later peripheral primary inclusions with which they are synchronous.

Regenerated inclusions. During the formation of regenerated inclusions, a mechanism operates to regenerate (ed. note - in the sense to grow over) defects of the crystal surface, out of equilibrium with the medium, and intersecting its former zonation. The appearance of these defects is associated either with chemical or mechanical factors. Such defects may be surfaces of welding, mechanical damage, and induction surfaces, along which separation of individuals has taken place (Fig. 16).

Primary and pseudo-secondary types are distinguished among regenerated inclusions. Inclusions that are sealed during regeneration of welding surfaces which markedly transect the primary growth zones have been assigned by us, following N.P. Yermakov, to the pseudo-secondary type. Such inclusions have been described by Lemmlein (1930) and have been observed by us in quartz from the quartz porphyries of Armenia. They are also very characteristic of plagioclase phenocrysts from certain basalts, and especially, andesites, and dacites.

The regenerated pseudo-secondary inclusions are in contact with

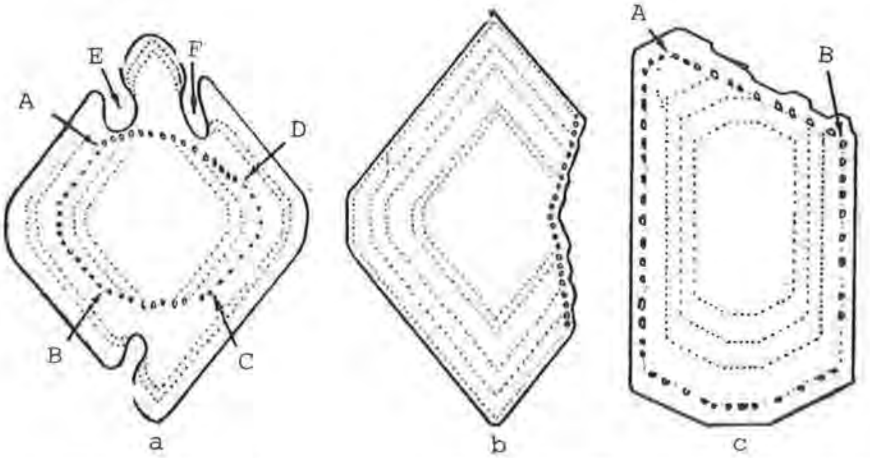

Fig. 16. Regenerated pseudo-secondary inclusions.
a) confined to surfaces of intense welding of crystal (sectors AD and BC), syngenetic with regenerated primary inclusions (sectors AB and CD), which are restricted to surfaces of weak submelting. E and F) primary spaces, associated with "multi-headed" growth; b) confined to face along induction surface (case of so-called 'one-sided corrosion'); c) associated with regeneration of mechanical surface along cleavage (sector AB).

various earlier growth zones of crystals. In this way, they are distinguished from the related primary regenerated inclusions, confined [39] to hollows in slightly submolten and later regenerated surfaces. The latter do not disturb the overall zonation and have been formed under conditions of rhythmically alternating processes of growth and weak solution. Primary and pseudo-secondary regenerated inclusions frequently form syngenetic groups (Fig. 16 a).

Another variety of regenerated inclusions is associated with the regeneration of surfaces of mechanical pitting of individual parts of crystals. The surface of mechanical fracture extends either in a random direction, or is parallel to crystallographic directions: planes of cleavage, parting, and also crystal twin boundaries. In the last cases, it is easily diagnosed only when the surface intersects a growth zone of the crystal (see Fig. 16 c).

One of the varieties of inclusions, formed during regeneration of mechanical fractures, includes those that were originally associated with regeneration of surfaces of "one-sided corrosion", the causes of which are not understood. It appears (Lemmlein, 1930, 1973) that the surfaces of such 'pseudo-fragments' of crystals represent the induction surfaces of combined growth of parallel, twinned and irregular intergrowths, along which the individuals are readily separated under conditions of sub-melting (Fig. 16 b). During the regeneration of the separate crystals, a false impression is created that prior to regeneration, the crystal, for reasons not understood, underwent very intense one-sided corrosion, or that there was a deep "embayment" in the crystal, associated with pitting of some portion of it.

Secondary Inclusions. These inclusions are epigenetic with respect to all the growth zones of the crystal: they are formed after the completion of all growth (including regenerated growth) of the crystals and are always confined to the sealed cracks cutting the zonation (Plate I, figs. 5-6; Pl. IV, figs. 1, 2, 7). In magmatic minerals, such inclusions form only in those cases when the mineral cracks open and traps a portion of melt during a phase in which it is a relict mineral, and some later mineral of the reaction series is stable with the melt. Melt inclusions, sealed into mineral cracks, which were stable with the melt under the conditions of cracking, are pseudosecondary inclusions in syngenetic sealed cracks. (Plate I, fig. 4).

Other examples of secondary melt inclusions are those of exogenous melts, confined to induction surfaces and cracks in minerals of xenoliths and individual xenocrysts (Plate IV, figs. 1, 7), and also inclusions of regenerated melts in certain contact rocks.

It should be emphasized that the phenomenon widely observed in the USSR and abroad, of the refilling of the contents of "mutually intersecting systems" of inclusions of different age, confined to cracks, has been observed not only in the case of the gas-liquid inclusions, but also in melt pseudosecondary and secondary inclusions. This phenomenon enables us to determine with confidence the age succession of the inclusions confined to the various systems of cracks.

A special group of secondary melt inclusions is that of postgenetic melts, which are not confined to cracks, but are formed in place during the local fusion of low-melting crystalline inclusions (Plate I, (Fig. 5) or during partial local melting of the mineral-host itself. An interesting study of such inclusions in an impact quartz from the Popigai crater structure has recently been made by Dolgov & Vishnevsky (1974).

In conclusion, we must stress that a good negative facetting of the inclusions is not a criterion for their primary nature. Thus,
[40] skeletal crystals are characterized by primary inclusions of irregular shape. Only one zonal boundary shape is expressed in them (Fig. 17). And, on the other hand, secondary inclusions are known with good negative facetting. Between the facetting of such inclusions and the shapes of the external boundaries of crystals there is a special antiparallel relationship (Fig. 18) (Voitsekhovsky & Mokievsky, 1965).

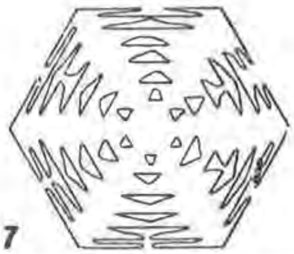

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Fig. 17. Primary inclusions captured during skeletal growth of mineral.

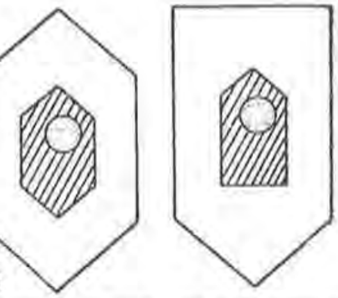

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Fig. 18. Association between shape of negative inclusions and outer boundary of crystal.

2. THE INFORMATIVE VALUE, PHASE COMPOSITION, AND PECULIARITIES OF NORMAL AND ANOMALOUS MELT INCLUSIONS

Studies of melt inclusions contribute to the understanding of the physico-chemical environments during the crystallization of melts, their composition, and properties, and also enable us to subdivide the products of the metamorphic and magmatic processes (in the broad sense of the word), clear examples of which are such complex metamorphic-magmatic rocks as the migmatites, certain pegmatites, and the carbonatites.

The most informative are the so-called normal melt inclusions, which, in contrast to the anomalous types, after equilibrium homogenization may be regarded as the equivalents of a mineral-forming melt. As a rule, the series of syngenetic normal inclusions is characterized by identical phase relationships, although a pseudo-anomalous phase relationship is also sometimes observed in them, controlled by kinetic factors (the variable degree of crystallization of a particular substance, and the absence or variable volume of the released gas phases). Dut during stabilized heating, all the syngenetic normal inclusions, in contrast to the anomalous types, are homogenized at a single temperature, because they have an identical composition (filling). The anomalous inclusions also have an anomalous ratio of phases when placed into equilibrium conditions (at the temperature of homogenization of the syngenetic normal inclusions). However, the anomalous inclusions can definitely be of interest, since they may be obvious indicators of boiling of the melts (Plate I, fig. 8) during impact processes (Plate I, fig. 5), etc. First of all, we shall dwell on the problem of the primary state of the mineral-forming and secondary magmatic media and the appropriate terminology.

The primary state of the contents of melt inclusions. There is a definite relationship between the observed phase composition of the melt inclusions and the primary state of the melt, which has been isolated in the inclusion. It is possible to judge the original state of the melt [41] in some cases by simple visual observations on inclusions in polarized light, but in more complicated cases, we may have to resort to a study of the phase transformations during the process of heating, and also to control with the aid of the microprobe.

The first generalizations concerning the primary state of the contents of glassy and crystallized inclusions were made by Sorby (1858), Zirkel (1893), and other investigators, who demonstrated that such inclusions are unequivocally associated with magmatic processes. Thus, worthwhile new criteria for understanding magmatic and non-magmatic processes were obtained. In Yermakov's early publications (1949a, 1950), the state of the magmatic environments was subdivided into melt and gas-melt groups; in his later work, Yermakov (1957) defined these series as melts and residual melt-brines.

The accumulation of new data has enabled us to give details of this scheme. In order to denote the particular original state of the melt, isolated in an inclusion, the terminology must take into account the features of the chemical composition of the natural melts: the relationships of the readily-soluble phases (mainly salts), those difficult to dissolve (mainly silicates and glass), and fluids (mainly water and carbon dioxide). The aggregate state and composition of the fluid phases in inclusions are readily determined by cryometric or thermometric methods (water, liquid carbon dioxide, or solution). The silicate phases (glass or crystals) may be distinguished from the salt phases by the temperatures for the commencement of solution or melting. The first transformations of silicates and glass are observed only at 600-700° or a higher temperature. The solution of salts usually occurs at a temperature several hundreds of degrees lower.

As a basis for the features indicated, the original state of the contents of inclusions, in which the phase of liquid water or carbon dioxide is absent (less than 10%), belongs to the 'silicate, silicate-salt, or salt melts' (in accordance with the quantitative relationships of the silicates, glass, and salts). In the presence of an aqueous brine (or carbon dioxide) in the inclusions, along with silicate and salt phases in separate significant amounts (from 10 to 50%, the state is denoted by the terms 'salt or silicate-salt melt-brines'. In the absence of salt phases in the glassy or crystallized inclusions, but in the presence of a significant phase of liquid water (or carbon dioxide), the state is defined as 'silicate melt-solution'. (Fig. 19).

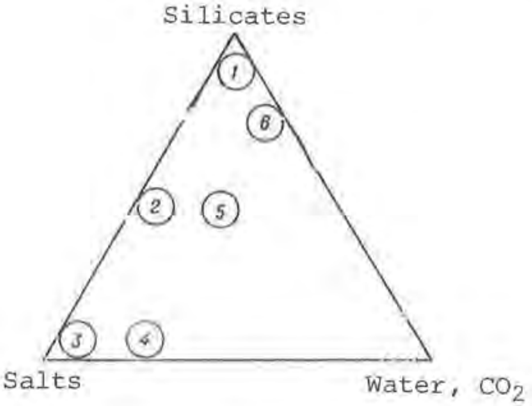

Fig. 19. Primary state of contents of melt inclusions.
1-3) melts (1-silicate, 2-silicate-salt, 3-salt); 4,5) melt-brines (4-salt, 5-silicate-salt); 6) melt-solutions.

We shall consider examples of these media in some varieties of inclusions in the order of their distribution in natural objects. Inclusions of silicate melts are the most common variety, consisting of glassy and crystallized inclusions in minerals of igneous rocks (Plates II, III, X, etc.).

The inclusions of salt and silicate-salt melts and salt-brines are typical of the minerals of the inner zones of pegmatites (blocky zone and quartz-rich nucleus), and are also known in granites and alkaline [42]rocks as late inclusions (as compared with those of silicate melts). Inclusions of silicate-salt melt-brines are known in the carbonate minerals of the carbonatites. Inclusions of salt and silicate-salt melts are encountered much less frequently than the normal multi-phase inclusions of salt-melt brines (poor in water) and even more so than the brines (rich in water).

Inclusions of silicate melt-solutions are the rarest variety. Examples are the glassy inclusions with a mineral-captive and a water phase with a samll gas bubble, which have been found in nepheline syenites of the Kurgusul'-Listvennyy Massif of alkaline syenites; crystallized inclusions with an insignificant amount of liquid phase, found in the rock-forming minerals of the alkaline rocks of the Gula pluton; and, possibly, the 'gas-liquid' inclusions, with a glass phase (?) around them, from the nepheline syenites of the Botogol Massif.

Features of the phase composition of melt inclusions. In accordance with Yermakov's generally-accepted classification (1966, 1972), all solidified melt inclusions have been subdivided into glassy (amorphous), crystallized, and crystallofluidal.

Inclusions of silicate melts and melt-solutions during hardening provide a spectrum of phase compositions from purely glassy inclusions through partially crystallized, finely crystallized with an infinite number of individual crystallites and grains, up to relatively coarsely crystallized types (with a small number of crystalline phases).

Inclusions of silicate-salt and salt melts normally provide only coarsely-crystallized aggregates with a small number of individuals and with separate gas (or gas-liquid) segregations, distributed in the intergranular spaces of the inclusions. The gas phases usually penetrate along the walls of the mineral-host. Inclusions of this type form transitions from true crystallized into crystallofluidal types.

Inclusions of silicate-salt and salt melt-solutions after crystallization consist of crystallofluidal types. The fluid component of these inclusions contains a phase of liquid water or CO_2, in which there is a gas bubble.

The phases that are observed in inclusions at room temperature Yermakov (1950, 1957, 1966, 1972) has suggested be denoted by letters and indices, indicating their composition and quantitative relationships (Table 1). This classification generalizes the results of a study of inclusions of mineral-forming media, but it may also be used when defining inclusions of specific secondary melts, which are not mineral-forming.

[43] Table 1. Classification of Solidified Inclusions According to Composition (Yermakov, 1972).

Solidified inclusions		
1. Amorphous	2. Crystallized	3. Crystallofluidal
$A_{gl} >> G, A_{gl}$	$C >> G, C_t >> C_e + G$	$(C_t > C_e) > G$
$A_{gl} + C$	$C > (A_{gl} + G)$	$(C_e > C_t) > (G > L)$
$A_{gl} > (G + C)$	$C >> A_{gl} > G$	$(C_e > C_t > C_{om}) > (L > G)$
$A_{gl} > (G + L_{CO_2})$	$A_{gl} > (C_{om} + G)$	$L_m > G_m, L_m > (C_t + G_m)$

Composition of phases: A) amorphous, C) crystalline, G) gas, L) liquid, Indices: gl) glass, e) easily-soluble salt, t) silicate difficult to dissolve, om) ore mineral, m) mixture of gases or liquid of indeterminate composition.

To avoid unnecessary repetition, more detailed observations of types and phase varieties of inclusions will be given in the sections on normal and anomalous melt inclusions.

A. Normal Melt Inclusions

As noted above, normal melt inclusions, that is, inclusions of mineral-forming melts, melt-solutions, and melt-brines, consist of three types: glassy (amorphous), crystallized, and crystallofluidal (also including crystalline-gaseous in Yermakov's earlier classification (1949a).

The glassy and partly crystallized inclusions are characterized by the presence of a glassy phase. Complete or almost complete crystallization of the entrapped essentially silicate melt is typical of the crystallized inclusions. The crystallofluidal (crystalline-gaseous) inclusions are characterized by an increased amount of volatile components in the composition of the preserved melt or melt-brine.

Glassy (amorphous) inclusions. Normal glassy inclusions are found in the form of the following varieties: single-phase (A_{gl}), two-phase ($A_{gl} >> G$), and partly crystallized [$(A_{gl} + C) > G$]. Exceptionally rare varieties are inclusions of glass without a gaseous phase with isolated mineral-captives ($A_{gl} + C$), and inclusions with a phase of liquid CO_2 ($A_{gl} > G + L_{CO_2}$), and with a phase of liquid water ($A_{gl} > G + L_w$) or with saturated brine ($A_{gl} > G + L_w + C_e$). Here, we must straight away emphasize that the anomalous melt inclusions with a phase of liquid CO_2 or solution (with and without salts), in contrast to the normal inclusions, occur much more commonly (sic.)

Glassy inclusions are known mainly in the minerals of eruptive and subvolcanic rocks, but are also frequently present in the minerals of the holocrystalline, typically intrusive rocks (in certain nepheline syenites and endocontact granites). The presence of glass and its amount depend not only on the rate of cooling of the crystallizing system, but also on its viscosity. For example, the inclusions in minerals of ultramafic rocks are always more or less crystallized.

Single-phase (non-bubble) inclusions are formed in those cases when solidification of a melt (quench) takes place prior to the appearance of a contraction bubble (or bubbles) of the gas phase. They have turned out to be very characteristic of pyroxenes from Curtis Island (Pacific Ocean). They are occasionally (together with glassy inclusions with numerous small gas bubbles) found in plagioclases and pyroxenes from the basalts of the River Nalacheva (Kamchatka). Very often, secondary single-phase glassy inclusions have been sealed in cracks in minerals of xenoliths (ultramafic and quartzose xenoliths in the basalts of Klyuchevskaya volcano and others). Primary single-phase inclusions predominate in the leucites of leucitites (Ruanda, Africa; Plate VII, fig. 10) and wyomingites (Yellowstone Park, USA; [44] Plate VII, figs 8, 9), and have been found (along with two- and multi-phase inclusions) in the pyroxenes of fergusite porphyries (Eastern Pamir) and the present-day lavas of Vesuvius, and also in nepheline from the nepheline syenites of the Central Aldan region (the Zolotoy and Tommot massifs).

Two-phase glassy inclusions with a gas + glass phase composition (with one or several gas bubbles) have been found in practically all the volcanic and subvolcanic rocks. They have been formed by quenching of the melt after the appearance of the contraction bubble (Plate I, figs. 3,4).

Partially crystallized inclusions, in contrast to the normal glassy inclusions, are characterized by the presence of newly-formed daughter crystals in the form of crystallites or well-facetted crystals of rock-forming minerals. In these inclusions, a gas phase is almost always present. Partially crystallized inclusions, along with two-phase types, are the most common varieties of glassy inclusions (Plate III, figs. 9, 10). During crystallization of the inclusions, in association with an additional volume effect arising from a difference in the densities of the melt and the crystals, a second generation of gas bubbles frequently appears, which is confined to the daughter crystals. Sometimes, specific aggregates of crystals and secondary bubbles are formed, resembling bunches of grapes (Plate III, figs. 8, 9). Such formations are interesting in the fact that they may be formed only during the crystallization of a still-liquid melt, isolated in an inclusion.

Of the rare varieties, there is interest in the glassy inclusions, in which one of the phases consists of liquid (carbon dioxide, aqueous solution, or brine) or individual crystallites of salt or their aggregate. Partially crystallized glassy inclusions with a liquid phase (water) have been found in nepheline from the nepheline syenites of Tuva (the Toskul Massif). In these inclusions, liquid with a gas bubble (occurring in a single cavity), several well-facetted crystallites, and completely translucent and fresh glass, comprising 50% and more, are contemporaneously present (Plate IX, figs. 15, 16). Glassy inclusions have also been found without crystalline phases, with an analogous gas-liquid cavity.

Glassy inclusions with salt and water-salt phases are typical of nepheline from the nephelinites of Northern Tanzania. Salt phases in the glassy inclusions of this type have been found in the form of 'globules' (Plate V, figs. 15018), similar to the 'globules' in the combined (mixed) glassy inclusions in quartz from the granitic blocks of Ascension Island, described by Roedder (1970), or confined to a bubble of the gas phase, sometimes forming a 'halo' and deforming it along the edges.

Glassy inclusions with a gas phase and with one large salt segregation of clearly spherulitic structure (Plate I, fig. 1) or several small spherical segregation (Pl. I, fig. 2) have been found as isolated examples in quartz and plagioclase from pumice in the Khangar volcano (Srednyi Range, Kamchatka). These inclusions have been found together with later numerous 'low-temperature' (ca 800°C) glassy inclusions.

A detailed study of normal and anomalous glassy inclusions (with adhesion bubbles) with salt phases has only just begun. By clarifying the conditions of their formation, we may solve the appearance of specific silicate-salt and salt melts and melt-brines, which cause so many contrasting opinions.

Crystallized Inclusions. Essentially-silicate crystallized inclusions are most often found in the form of the following varieties: completely crystallized inclusions with a gas phase ($C_t >> G$) (Plate X, figs. 1, 3, 5, 7, 8, 9, 13; Pl. III, figs. 1-3); crystallized inclusions,
[45] in the interstices of which a little glass is preserved $[(C_t >> Gl) >> G]$ (Pl. II, figs. 1-3; Pl. III, figs. 4-7); and partially crystallized inclusions, transitional to glassy $[C_t > (A_{gl} + G)]$ (Pl. II, fig. 6; Pl. III, figs. 8-10). Crystallized inclusions with a liquid-water phase $[C_t > (G + L_w)]$, liquid carbon dioxide $[C_t > (G + L_{CO_2})]$, and with a salt phase $[(C_t >> C_e) >> G]$, are very rarely found.

Crystallized inclusions are most characteristic of minerals from deep-seated and hypabyssal intrusive rocks of various compositions. They have been found in quartz in migmatites and the outer zones of pegmatites (aplitic, pegmatoid-granitoid, and graphic). They also frequently occur in phenocrysts from rocks of volcanogenic origin, especially in the form of early primary inclusions and intratelluric phenocrysts.

Among the crystallized inclusions of silicate melts, we may distinguish:

1) true crystallized inclusions (formed during crystallization of a melt, preserved in the liquid state);

2) devitrified inclusions, formed during devitrification of glass as a result of later processes, for example, during subsequent reheating of the rocks or as a consequence of spontaneous devitrification in old rocks;

3) recrystallized inclusions, formed during subsequent recrystallization of very finely crystallized inclusions.

Here we may add the transformed inclusions, formed through the action of chemical agents on non-sealed melt inclusions. The last variety is readily recognized by the presence of cracks which reveal them, and by comparison of these inclusions with other syngenetic types. The preceding varieties are in most cases difficult to distinguish from one another, because the processes that characterize them are usually manifested directly in all the inclusions of a particular group. Features of true crystallized inclusions are the above-noted 'grape-like' aggregates of crystallites with gas bubbles of first and second generation. The first-generation bubbles are associated with normal thermal shrinkage during cooling of the melt, and the cause of the formation of the second-order bubbles is the commencement of crystallization of liquid melt, as a consequence of which an additional source of free volume appears.

In contrast to the true crystallized inclusions in the aggregate of recrystallized and devitrified inclusions, a second generation of gas bubbles of spheroidal (!) shape does not appear. Unfortunately, these features may only be observed in inclusions in which a certain amount of glass has still been preserved. In the holocrystalline inclusions, it is generally complicated to study the details of phase relationships because of difficulties of observation. Therefore, in most cases there is no possibility of distinguishing the structural varieties listed and such inclusions are described under the general heading 'crystallized inclusions.'

Completely crystallized inclusions are most typical, as already noted, of various deep-seated rocks. Coarsely-crystallized inclusions of the type (with a minimum number of individuals) are found in minerals of various alkaline rocks. Examples are inclusions in nepheline from the theralites of the Kuznets Alatau and in pyroxene from the theralites of the Canary Islands. For such inclusions in pyroxene from the monchiquites of the Inagli Massif (Central Aldan region), we have used the microprobe to identify the mineral composition of the grains forming the inclusions (nepheline, K-feldspar, and biotite).

In genetic respects, it has been very useful to discover and to make a thermometric study of completely crystallized inclusions in quartz from deep-seated granitoids (Plate X, figs. 1, 3,5) and [46] pegmatites from the Aldan Shield in connection with the problematic nature of their origin. The inclusions are characterized by exceptionally small dimensions (down to 5-10 microns). Inclusions of rounded shape predominate, sometimes with crystallographically regular facets of hexagonal quartz. These inclusions consist of an aggregate of grains of feldspar and quartz (preliminary diagnosis on the basis of similarity in optical properties) and an interstitial gas phase, possibly with a rim of liquid phase, but the dimensions of the inclusions do not permit its recognition.

Examples of finely crystallized inclusions are those in nepheline from the ijolite-urtites of the Chika Massif (Sangilen), in pyroxene from the monchiquites of Cape Dezhnev, in olivine from the meimechites of the Gula Pluton, and in pyroxene from biotite peridotite-porphyry dikes (the Yakokut Massif, Central Aldan region). The last example is interesting in that, in spite of near-surface crystallization of the mineral, the low viscosity of the ultramafic melt has resulted in total crystallization of the inclusions.

Various types of partially crystallized inclusions are characteristic of almost all the igneous rocks examined, excepting the deep-seated granitoids, migmatites, and outer zones of pegmatites.

Of the rare varieties of inclusions, we shall note only the completely crystallized inclusions with a liquid-water phase. They have been found in pyroxene and nepheline from the ijolite-melteigites of the Gula Pluton, in nepheline from the miaskites of the Urals and the nepheline syenites of the Toskul (Sangílen) and Botogol massifs.

Crystallofluidal Inclusions. Of the varieties of crystallofluidal inclusions of residual melt-brines noted in Yermakov's classifications (1972), which consist of inclusions from the essentially silicate type $(C_t > C_e) > G$ to essentially salt-composition of the type $(C_e > C_t > (G > L))$, we have the possibility of defining, from appropriate data, only the high-temperature inclusions of predominantly salt composition. Inclusions of the type $(C_t > C_e) > G$ have not been found in the items examined by us. Examples of a similar variety, $C_t \gg C_e + G$, have, in accordance with Yermakov's classification, been considered in the section devoted to crystallized inclusions. Therefore, only the essentially salt crystallofluidal inclusions of residual melt-brines are described here.

These inclusions are typical mainly of the latest magmatic phases in the formation of intrusions. In the ultramafic alkaline complexes, primary crystallofluidal inclusions are normal for the carbonatite stage. In the minerals of granitoids and in the outer zones of pegmatites, they have been found only in the form of pseudosecondary inclusions, and in the form of primary inclusions, they are apparently only found in the block and core zones of pegmatites.

In the phase composition of the crystallofluidal inclusions, studied in the Gula dolomite and the Beloziminsk (East Sayan) ankerite, from the carbonatites, salts, solution, and gas are present, the ratios of which vary from (75-85):(15-10):(10-5) respectively. The salt phases consist of either a uniform salt aggregate, which almost completely fills the vacuole space, or a multitude of small crystallites, evenly distributed in the space of the inclusions. The forms of the crystalline phases may vary from irregular to well-facetted; they are greenish, brown, black or colorless. In these crystallofluidal inclusions, the liquid phase with a gas bubble occupies a clearly segregated separate space or has been randomly distributed in the interstices between the crystalline phases. The gas bubble has usually been deformed by the crystalline phases, especially in the second case.

[47] In contrast to the crystallized inclusions, the first features of solution of the crystals (salt phases) in the crystallofluidal inclusions appear at low temperatures, in the present case beginning at 120-150°C. Their complete solution takes place at a few tens of degrees before homogenization of the inclusions.

As a second example, we shall describe the highest-temperature crystallofluidal inclusions in a quartz from the graphic zone of zoned pegmatites. Salt phases also predominate in these inclusions, occupying more than 80% of their volume. Most of the salt phases are colorless and isotropic. The presence of anisotropic salts has also been noted. The salts are well facetted. The gas phase of the inclusions usually consists of a large deformed bubble, occupying up to 10% of the volume of the entire inclusion. The quantity of liquid phase is small (about 5%). In many inclusions, the presence of a xenogenic ore phase has been recorded. On heating, the great majority of crystallofluidal inclusions are sealed (?unsealed) at 400-500°C. During the process of heating an inclusion up to homogenization, the gas bubble usually disappears below 300°C. Up to this time, the salt solution occupies 10-15% of the volume of the inclusion. On further heating to the homogenization temperature, melting of the undissolved phases takes place. The homogenization temperature of the unsealed inclusions reaches 660-700°C. At this temperature, the inclusion contains either melt-brine alone, or in addition a xenogenic ore phase, which is not dissolved on heating the inclusion to 1400°C.

B. Anomalous Melt Inclusions

The anomalous nature of the phase relationships in some groups of gas-liquid and melt inclusions was known in the previous century. In the last decades, three principal sources which caused anomalies in the inclusions have mainly been considered: partial sealing of the inclusions, separation of inclusions in the heterogeneous state, and capture of primarily inhomogeneous media ('combined' inclusions).

The first detailed classification of anomalous inclusions was presented by Yermakov (1972) for gas-liquid inclusions. He divided all the anomalous gas-liquid inclusions into three classes: syngenetic, subsyngenetic, and epigenetic, which, in their turn, were divided into seven species and nine varieties.

In spite of some specific features of the anomalous melt inclusions, it has proved possible to apply this same classification almost completely, with small changes, during their description. The specific nature of the anomalous melt inclusions is the fact that all the species of syngenetic and subsyngenetic anomalous inclusions are duplicated among the epigenetic types. This depends on the fact that the melt inclusions may not only be mineral-forming media, but they are also secondary products, giving the same anomalies that are typical of the syngenetic and subsyngenetic (primary and pseudosecondary) inclusions, but having relation to the formation of minerals (e.g., epigenetic melt inclusions in xenoliths and contact rocks). Moreover, among the epigenetic anomalous inclusions, it is possible, in addition, to recognize specific examples of anomalous inclusions of remelting, examples of which are the inclusions in impactites (Plate I, fig. 5) and some xenoliths (Plate I, fig. 6; Plate IV, figs. 1,7).

Syngenetic anomalous melt inclusions. This class includes
[48] various 'combined' (Bakumenko, 1965, 1970) inclusions, together with those containing adhesion bubbles (Yermakov, 1972), and hence we have assigned inclusions with syngenetically captured crystals ('satellites' and 'precursors,' etc.) (Plate I, fig. 7). Anomalous inclusions with adhesion bubbles are formed during the capture of primary heterogeneous 'boiling' melts (Plate I, fig. 8). For example, glassy inclusions with an anomalous phase of liquid-like carbon dioxide are known in intratelluric phenocrysts, having been captured during boiling of melts under conditions of increased (?decreased) pressure. Among such anomalous inclusions, there are transitions to almost pure carbon-dioxide inclusions of the exsolving gas phase ('bubble adhesion' proper) and to syngenetic normal melt inclusions. In the minerals of the eruptive rocks, which crystallize under conditions of melt effervescence at low pressures, an anomalous gas phase of low density (CO_2 usually predominates in it) is present in the anomalous inclusions. In this case, there are transitions to gas inclusions and to normal glassy types.

A further variety of anomalous melt inclusions is formed as a result of unmixing phenomena in water-rich silicate melts with salt fluids. The transitions from such inclusions to normal melt and water-salt inclusions were first described by Roedder (1970). Special interest here centers round the clarification of the relations between the normal silicate melt inclusions and those of silicate-salt melt-brines in the outer and inner zones of pegmatites. Both groups of inclusions occur in the outer zones of pegmatites with aplitic and graphic texture. In the inner zones (with block and quartz-rich core), inclusions of silicate melts have not so far been found (we know of no experimental evidence for such occurrences), but inclusions of salt melt-brines are quite well-developed. Evidently, somewhere on the boundary of these zones we may expect to find anomalous inclusions, formed during stratification of the residual melt, but only if such stratification did take place, that is, if the transition process was not a gradual one. At present, there are also possibilities for careful thermometric investigations of 'pseudo-anomalous' inclusions of gas bubbles in silexite pegmatites, which, according to Yermakov (1972, p. 215) '...are only the gas component of microportions of melt inclusions, a portion of them, but not a complete system of inclusions.' Resolution of this problem would be finally reached by discussion of the origin of all zones of chambered granite pegmatites.

As a second type of anomalous melt inclusion we may cite those with *crystal-satellites* (i.e., 'solid inclusions', ed.) and other crystals of extraneous matter (Yermakov, 1950), because they are very often the cause of the anomalous nature of the phase relationships (see Plate I, fig. 7). Many accessory and rock-forming minerals have appeared in melt inclusions as syngenetic phases. They are readily distinguished from daughter minerals by the fact that they are always found in the form of independent crystalline inclusions. In doubtful cases, there is always the possibility of control by observing the inclusion during the homogenization process. Melting of phases of extraneous matter prior to homogenization of the gas phase never occurs. Extremely high temperatures are necessary for this.*

We must specially emphasize that when determining normality or abnormality in inclusions, it is necessary to work only with series of inclusions, because in individual cases as a consequence of kinetic [49]factors (delay in gas release, or non-uniform crystallization), some syngenetic normal melt inclusions, in spite of uniform filling, have a different phase composition and appear to be anomalous. Such normal pseudo-anomalous inclusions, in contrast to the anomalous types, homogenize at identical temperatures.

A special variety of *relict* anomalous inclusions has been described by Gromov & Smertenko (1971) in secondary albites from the blocky zone of pegmatites. These are primary quartz-rich inclusions, probably, with feldspar and either without a gas bubble or with one that is difficult to distinguish. It has been suggested that relict melt inclusions have been preserved in albite, '...after metasomatic replacement of late microcline, and the inclusions have been somewhat altered' (the

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*However, in some cases, melting of daughter minerals also sets in at more substantial temperatures than for the disappearance of the gas phase (Reif, 1973a,b; Sobolev & Bazarova, 1973). In such inclusions, the fusion temperature for the daughter minerals is the real homogenization temperature.

daughter minerals, which consisted of K-feldspar, have been albitized, and the gas bubbles have been deformed or eliminated)' (p. 82).

Subsyngenetic anomalous melt inclusions of this type are formed along with normal pseudosecondary melt inclusions. All the cases of anomalous gas-liquid inclusions considered by Yermakov (1972) have equivalents among the melt inclusions.

Disjointed (disconnected) anomalous melt inclusions are found quite rarely. They are formed as a result of late separation of previously heterogenized pseudosecondary and still less frequently, primary inclusions, which have a markedly disequilibrium form. Most commonly, we observe cases of segregation into individual 'related' inclusions with an anomalous gas phase, and less frequently, cases of segregation of crystalline gas-captives. The process may be readily modelled.

Refilled anomalous inclusions are formed during repeated mechanical sealing in the process of continuing crystal growth. In this case, the contents of the inclusion turns out to be partially or completely identical to those of the later normal inclusions, which have been confined to the corresponding crack. Refilled inclusions may be found, if they posses some distinctive features: specific dimensions and crystal facets, different from normal inclusions, a different gas-phase volume, a lesser degree of crystallization, and a different homogenization temperature.

Incompletely-disturbed inclusions are characterized by an aureole of wedging-out cracks, which are usually confined to the 'sharp' ribs and apices of the inclusions (Plate I, fig. 3), and also to the crystal phases projecting from the inclusions.

Exploded inclusions are similar to the preceding type. They are generally characterized by aureoles of daughter gas or glassy inclusions, which have been formed around the exploded inclusion (Plate I, fig. 9). The phenomenon of 'explosion' of melt inclusions may be associated with: 1) external heating (during inflow of new portions of magma), which leads to a marked increase in internal pressure in the inclusion; 2) a drop in the high external pressure during transfer of the host from the depths to the surface (splitting effect of inclusion); 3) an unfavorable regime at the time of polymorphic transitions, accompanied by compression of the cooling mineral-host (cleaving effect of inclusion).

Epigenetic anomalous melt inclusions.

All the above-mentioned anomalous effects have been observed among melt inclusions in xenoliths and contact rocks. Thus, we have observed secondary anomalous glassy inclusions and inclusions of the main mass (?matrix) with adhesion bubbles and solid inclusions (apatite) in xenoliths of vein quartz from the basalts of the Apackhonchich flow from the Klyuchevka Volcano (Bakumenko et al., 1947b). Here, exploded [50]and refilled, originally gas-liquid inclusions have been recorded, into which melt has penetrated, and the entire range from normal secondary glassy inclusions through anomalous types to CO_2-refilled inclusions with daughter glassy and gas inclusions has been observed (Plate I, fig. 6; Plate IV, fig. 7). An interesting type of anomalous secondary inclusion of glass and gas, confined to the induction surfaces, has been found in samples of ultramafic xenoliths in the Avachi Volcano (Plate IV, figs. 1,2).

A special group of epigenetic inclusion includes the *remelted* types, formed at the site of local melting either of the mineral itself, or of the phases present in it. Such melting, as noted above, has been observed during lightning strikes, fires, impact effects of cosmic bodies, thermal metamorphism associated with the injection of melts, and as a consequence of other events.

3. THERMOMETRIC INVESTIGATIONS OF MELT INCLUSIONS.

The determination of the homogenization temperature of melt inclusions and verification in artificial inclusions. The first indications of the theoretical possibility of using melt inclusions for thermometric purposes were presented in the works of Yermakov (1950, 1972). Barrabé & Deicha (1956) carried out 'pyrognostic' investigations based on the crystallization of glassy inclusions during the process of short-term heating at a temperature not exceeding 1000°C at first, but later extending up to 1200°C. These experiments showed the possibility of using inclusions for the study of the features of crystallization of natural melts and the devitrification of glasses.

At the first conference on geological thermobarometry in May 1963, Bakumenko (1965) discussed the first attempts to homogenize glassy inclusions during heating in a Dolgov-Bazarov thermochamber and the results of visual observations of phase transformations. However, the scope of the thermochamber only permitted observations on the initial phases of melting of the glass, and the decrease in dimensions and the change in configuration of the gas phase of the inclusions. In order to achieve complete homogenization of all the inclusions, it was necessary to obtain higher temperatures and to conduct longer experiments at the limits of the thermochamber. The experiments demonstrated the fundamental possibility of homogenization of melt inclusions and the determination of the temperature of this homogenization. In fact, during the examination of the cooled samples at high magnifications it was discovered that some of the inclusions (the smallest) had been successfully homogenized.

Kalyuzhnyi (1965) using a specially constructed vacuum thermochamber, succeeded in making visual observations during the course of homogenization and for the first time, determined the homogenization temperature of glassy inclusions in the phenocrysts from the hyalodacities of Transcarpathia. In the laboratory of Mineral-Forming Solutions of the Institute of Geology and Geophysics (Novosibirsk), modernized chambers were created shortly afterwards, working in an atmospheric medium, in which T. Yu. Bazarova (in Sobolev et al., 1967b) and Bakumenko (in Bakumenko et al., 1967, 1969) carried out analogous experiments with melt inclusions in minerals from nepheline basalts, andesites, basalts, and quartz porphyries. In all these experiments, the homogenization temperature exceeded 1100°C. It is natural that such high temperatures of homogenization raised strong doubts amongst many geologists about the correct application of the results of measurements to the objectives of geological thermometry. This was especially so, since five to ten years ago, there were very strong trends towards lowering the temperature estimates for the processes of magmatism.

[51] Mineral-thermometry had already been subjected to such doubts during the first stage in its development, when the first attempts at the geological application of the results of homogenization of gas-liquid inclusions were made (Yermakov, 1950; Smith, 1953, etc.). Inadequacy in explaining the facts discovered during this stage of the study of the

inclusions concerning the inconstancy of the phase relationships of neighboring inclusions, observations on the loss of material during heating of the inclusions, and on the refilling of inclusions during the later actions of solutions and melts, produced erroneous hypotheses that processes of refilling inclusions are possible not only during mechanical sealing of the inclusions, but also through substantial volume diffusion through the undisturbed crystalline structure. In order to allay these suspicions, work by a larger group of scientists became necessary (Yermakov, 1950, 1972; Smith 1953; Chaikovsky, 1951; etc.). They set about discussing the conflicting data and showed that the unstable phase relationships recorded are, in some cases, the consequence of the mechanical sealing of the inclusions, in others, the consequence of the non-syngenetic nature of the inclusions, and in a third instance, the consequence of the initially heterogeneous state of the captured solutions or of some other factors. Special experiments were also carried out which showed that the sealed inclusions did not change their phase relationships even with lengthy heating at a temperature, somewhat exceeding that of homogenization (Kalyuzhnyi, 1960; Chaikovsky, 1951). Later on, with the aid of a study of inclusions in synthetic minerals, direct support was obtained for the agreement between the contents of the inclusions and the homogenization temperatures, and the conditions of capture of the inclusions (with correction for pressure). In recent times, the method of homogenization of gas-liquid inclusions has received widespread acceptance.

Doubts have also been cast at the thermometric investigations of melt inclusions, which were widely carried out after modernization of the Dolgov-Bazarov thermochamber, and also after the introduction in practice of a method of quenching homogenized melt inclusions with a subsequent study of the quenched inclusions under the microscope.

The most problematic question was: does the experimental homogenization temperature for the melt inclusions correspond to the true temperature, or, as a result of some residual phenomena, do the phase transformations during heating and cooling of the inclusions turn out to be reversed? In this case, it is impossible to reproduce repeatedly the conditions of homogenization, and therefore, the homogenization temperatures again obtained during heating will be extremely overestimated as compared with the true temperatures.

In order to solve this problem, diopside crystals were grown under known conditions from melts of different composition in the Laboratory of Experimental Mineralogy of the Institute of Geology & Geophysics (Novosibirsk), and the melt inclusions in the diopside were studied thermometrically in the Laboratory of Mineral-Forming Solutions (Bakumenko et al., 1967). Diopside was crystallized from systems of two compositions: melts were obtained from a diopside charge with addition of 5% CaF_2 as a mineralizer and from a charge of diopside-anorthite composition (without mineralizers). The melts were of different viscosity and were maintained at 1350°C, and were later crystallized at 1300°C. During the time of crystallization, the diopside took up melt inclusions. During subsequent cooling of the samples, the melt in the inclusions contracted, gas bubbles appeared, and then the melt vitrified. The glassy inclusions with gas bubbles were then subjected to a thermometric study. During the heating of the samples with glassy inclusions in the microthermochamber, a decrease in the gas bubbles was observed and the subsequent homogenization of the inclusions at 1300 ± 10°C. This indicates the reversibility and reproducibility of the phase transformations during the processes of heating and cooling of the inclusions. The experiments are the basis [52] for using not only gas-liquid, but also melt inclusions, for thermometric purposes.

The thermometric investigations of natural crystallized inclusions differ in no fundamental way from those of glassy inclusions. In order to obtain an equilibrium homogenization temperature for the crystallized inclusions, greater exposures are necessary as compared with those for the glassy inclusions. Longer experiments based on heating are also necessary during the study of relatively large inclusions as compared with small ones. The optimum rate of heating and the length of the experiments still depend on the composition of the inclusions: increase in the amount of silica and decrease in the amount of volatile components in the inclusions require relatively larger times for homogenization.

Observations on the behavior of inclusions during changes in temperature. During the heating of melt inclusions, in addition to the homogenization temperatures, we define the temperatures of appearance of the first portions of melt as a consequence of liquefaction of glass or the partial melting of crystalline phases. The appearance of melt may be judged from the change in shape of the gas phases, their displacement, and the appearance of new small gas bubbles. These observations enable us to judge the temperature of crystallization of the melts and of their complete crystallization. Observations on the appearance and disappearance of a gas bubble in the melt of the inclusions during cooling and heating enable us to explain the kinetics of the process of their homogenization - heterogenization, and consequently, to select the optimum regimes of thermometry of inclusions in actual cases. Kinetic graphs showing the dependence of homogenization (heterogenization) temperature of inclusions on time, after approach to the prescribed temperature, determine the rate of establishment of equilibrium in inclusions of a given composition during the course of the process of homogenization (heterogenization). Figure 20 shows the combined curves for processes of homogenization (1-6) and heterogenization (1'-6') for inclusions in minerals of different rocks (the work was carried out in association with A.I. Chepurov and V.P. Chupin). All the time recordings have been taken from the moment of establishment of equilibrium at the temperature maximally close to the state of homogenization (previously, the inclusion had been maintained at this temperature). From the time during which the combined curves flatten out on the basis of temperature, we may judge the realization of equilibrium. It is most rapidly established for ultramafic and mafic compositions (2-5 minutes). For inclusions of alkaline ultramafic composition, equilibrium is achieved after 15-20 minutes. The longest exposures are required for the establishment of equilibrium in melts of acid compositions (more than 40 minutes), which is associated with their increased viscosity.

There is undoubted interest in the appearance of an inverse (anomalous) slope on the kinetic curves of heterogenization of certain melts of acid composition (see Fig. 20, 4', 5', 6'). Normally, as the temperature falls, only a decrease in the time necessary for the appearance of a new phase (the gas bubble) is observed for the homogenized inclusions of melts of different compositions. But for the acid melts at certain temperatures, the situation occurs that, with fall in temperature, the time required for heterogenization of the melt again begins to increase. This phenomenon is apparently associated with a

[53]

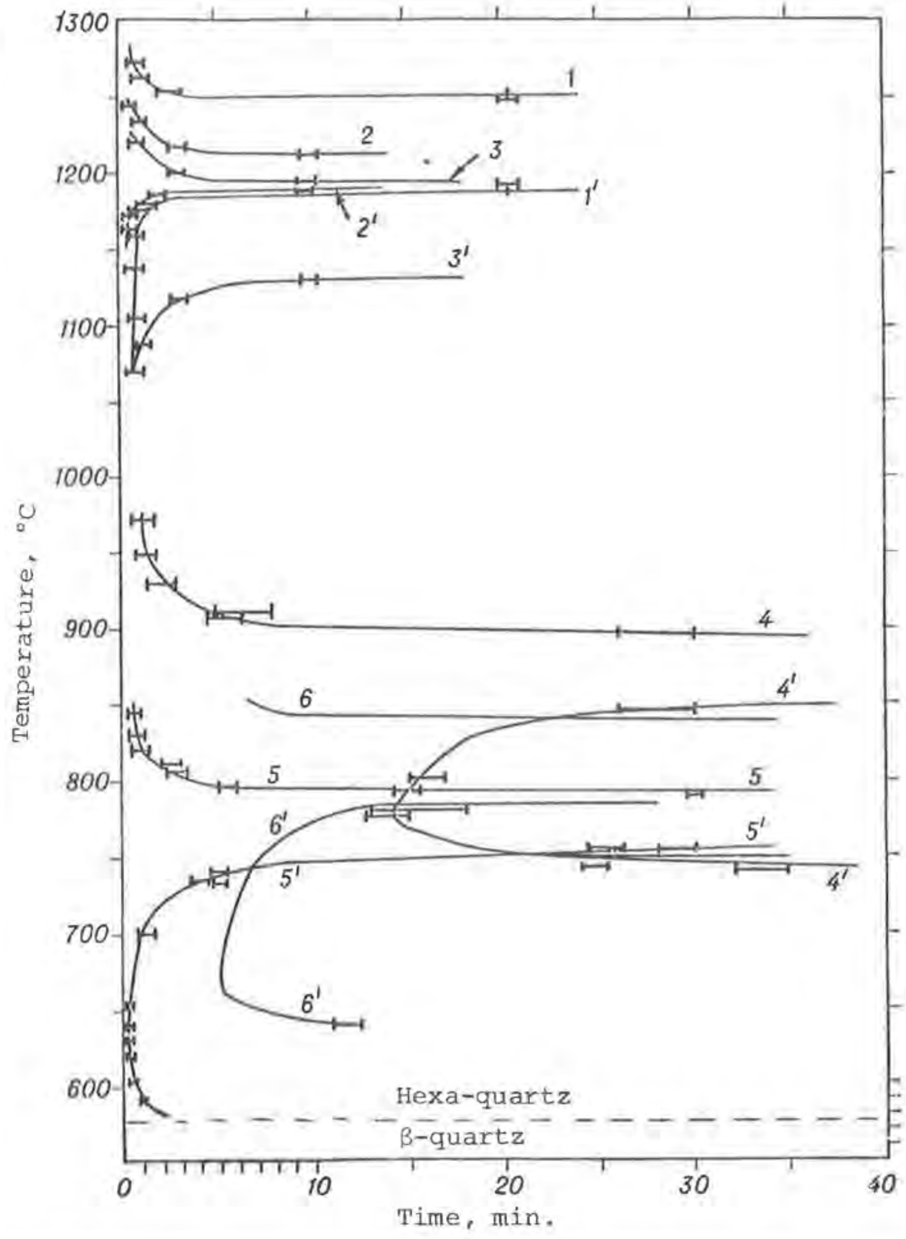

Fig. 20. Combined kinetic curves of homogenization (1-6) and heterogenization (1'-6') of melt inclusions.
Time is reckoned from the moment when the inclusions has almost been brought to equilibrium homogenization (1-6) or completely homogenized [sic] (1'-6'). 1 and 1')augite from picritic lava (Mid-Atlantic Ridge); 2 and 2') diopside from biotite peridotite-porphyrite (Central Aldan); 3 and 3') clinopyroxene from pseudoleucitite (Central Aldan); 4 and 4') quartz from rhyolites (Upper Aldan); 5 and 5') quartz from pumice (khangar volcano, Kamchatka); 6 and 6') quartz from peripheral zone of pegmatites (Upper Aldan).

significant increase in the melt viscosity in the given range of decreased temperatures. Here, the threshold of softening of glass is reached. Below the given curve, there is a region of rapid 'thickening' and vitrification of the melt inclusions, where heterogenization of the melt inclusions does not take place at any temperature during the longest exposures.

The conduct of such experiments with natural inclusions enables us to select the optimum regimes of sample heating in order to obtain thermobarometric data. For example, for the granitoids a rapid heating (10-30°/min) is permissible prior to melting of the contents of the inclusions. From the moment when melting begins, the temperature is increased more slowly (1-2°/min) and episodic temperature exposures (several hours) are made. In order to determine the homogenization temperature of previously stabilized inclusions, exposures over 40-100 minutes (near the homogenization point) are necessary. It is natural that a repeated check is necessary. The overall time of the [54] experiment occupies about 6-12 hours. Heating of mafic, and even more so ultramafic compositions may be carried out in a shorter time, respectively 3-5 and 1-2 hours (Bakumenko et al., 1973b).

Observations on the homogenization curves show that the region of the softened state of the cooled melt is quite large. It is significantly below the temperatures of the commencement of melting of the solid phases, that is, the solidus temperatures of systems of natural composition. For example, in individual cases, it falls to the temperature of polymorphic transformation of quartz (below 600°C). This enables us to explain the well-known phenomena of mobility of natural melts at anomalously low temperatures; the low-temperature injection of dikes, auto-extrusions, protrusion of 'needles' in volcanic piles, protrusion of lava extrusions, and the mobility of lava flows. This has been the basis of numerous discussions about the supposedly high saturation of natural melts in volatiles and the low-temperature nature of magmas.

An important constant, which may be obtained from observations on the change in volume of the gas phase during temperature change, is the coefficient of volume expansion β. This constant enables a quantitative understanding of shrinkage phenomena, which takes place during cooling of natural melts, and in the case of heating of magmas, the mechanisms and features of the injection of magmas.

In order to calculate the average coefficient of volume expansion of a melt in the temperature range from T_V to T_n, it is necessary to determine the value of the relative volume of melt V_{T_V} and V_{T_n} at these temperature values. This is readily done, if we calculate the volumes of the gas phase corresponding to these temperatures. The value of β is calculated according to the formula

$$\beta = \frac{V_{T_v} - V_{T_n}}{V_{T_n}(T_v - T_n)} .$$

The value of the constant increases sharply at increased temperatures (Chupin et al., 1974).

Moreover, there is still much to be done in this field. Particularly important to us is the establishment of temperature corrections for inclusions, captured by a crystal at high pressures. However, it must a priori be emphasized that these corrections may only be positive, as for the water system. At the same time, their value should differ many times (probably by 1-2 orders) from those for water and gas-liquid inclusions, since the coefficient of compression for silicate melts is close to that for silicate minerals, and these corrections may be ignored to a first approximation*.

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*During the time of going to press of this work, a report by I.M. Volokhov appeared (An estimate of the precision of thermobarometric reconstructions of conditions of formation of magmas and magmatic minerals. Geologiya Geofiz. Novosibirsk, No. 1, pp. 12-19 (1975); (ed. note: this was translated in Fluid Inclusion Research, v. 8, p. 214-219), placing in doubt the validity of the method of thermometry of melt inclusions itself, and a reply will be provided.** Here, we shall only record the following: 1. The whole sequence of Volokhov's remarks is associated with a simple misunderstanding. 2. The main theme of that author's claim that water is released from an inclusion during the process of its homogenization, may be refuted by Yu. A. Dolgov's specially and easily reproduced experiment, which emphasizes the adequate sealing of the water-bearing inclusions at a temperature and time, significantly exceeding the normal conditions of observation.

**Ed. note: For a translation of this rebuttal, see Sobolev, Bakumenko, and Kostyuk, 1976, in this volume of Fluid Inclusion Research.

Chapter VII

THE CHEMISTRY OF THE SILICATE AND GAS PHASES OF MELT INCLUSIONS [151]

1. THE DIRECT DETERMINATION OF THE COMPOSITION OF THE SILICATE PORTION OF MELT INCLUSIONS.

There is undoubted interest in the study of the composition of the silicate portion of inclusions of magmatic melts in minerals from the most varied rocks. Such investigations have begun only in recent years, owing to the improvement in the techniques of ultra-microanalysis, in particular, X-ray spectral analysis with the electron microprobe, and the development of the appropriate methods of such analysis. This was accompanied by the almost simultaneous appearance in a number of countries (USA, Japan, France, and the USSR) of publications devoted to the quantitative determination of the chemical composition of melt inclusions in minerals.

A great deal of work has been carried out by the American investigators, E. Roedder and P. Weiblen (Roedder & Weiblen, 1970a,b; 1971; 1972; 1973; etc.), on the composition of inclusions of silicate melts in minerals from lunar rocks (samples from Apollo-11, -12, -14, and -15, and stations Luna-16, and -20). Individual publications, devoted to the determination of the composition of magmatic inclusions in minerals from terrestrial, mainly eruptive rocks, have been issued in Japan (Komatsu & Yajima, 1970, etc.) and in France (Clocchiatti, 1971, 1972; etc.).

In the USSR, investigations have been made, concerned with the qualitative determination of the composition of melt inclusions in minerals (Valyashko et al., 1968; Dolgov et al., 1969; Abramov & Volynets, 1973; etc.). Most recently, work has begun on determining the quantitative composition of melt inclusions (Chepurov et al., 1974; etc.).

The value of the data obtained from studying the composition of inclusions of magmatic melts in minerals is difficult to overestimate, but the available information has not so far enabled us in adequate measure to define the chemistry of the mineral-forming media based on inclusions in minerals. The inadequacy of the factual information and sometimes unsatisfactory precision of the analyses limit the discussion of the results, so that it seems appropriate to us to note only some aspects of the problem.

The most significant aspect in the study of inclusions of magmatic melts is the question of coincidence between the composition of relicts of magmas, preserved in minerals, and that of the media from which the rock crystallized. With this in mind, and to a first approximation, we may carry out a comparison between the compositions of inclusions of glass in the olivines from basalts (Table 16, analyses 1-3) and the corresponding rocks (see Table 22, analysis 3c); these are distinguished by a somewhat increased amount of silica. With a certain degree of tolerance, the compositions of these and others turn out to be completely comparable.

[152] Table 16. Composition of Inclusions of Glass (Average) in Minerals of Certain Rocks.

Oxides	1	2	3	4a	4b	5a	5b	6
SiO_2	48,7	51,7	51,7	75,1	74,5	73,0	74,67	73,4
TiO_2	1,4	0,7	2,7	—		—		—
Al_2O_3	19,3	20,9	19,3	13,8	13,0	12,2	11,76	12.5
FeO total	7,3	7,2	7,6	1,7	2,2	1,1	1,24	1,0
MgO	4,9	1,9	6,1	0,3	0,4	—		0,2
CaO	11,4	12,8	10,6	0,4	0,2	0,7	1,34	0,6
Na_2O	2,3	2,0	1,9	3,3	0,7	3,8	3,83	3,2
K_2O	2,2	0,2	0,4	4,9	6,5	3,0	3,00	4,9
Total	97,5	97,4	100,3	99,5		93,8		97.8

— = n. det.

Notes:1) in olivine from an olivine basalt of the alkaline series of Japan (Komatsu & Yajima, 1970); 2) in olivine from olivine basalt of the tholeiite series of Japan (Komatsu & Yajima, 1970); 3) in olivine from an olivine basalt of the tholeiite series of the Hawaiian Islands (Komatsu & Yajima, 1970); 4) in quartz from rhyolites; 5) in quartz of acid lavas from Alaska; a) composition of inclusions, b) rocks (Clocchiatti, 1972); 6) in quartz of acid lavas from Japan (Komatsu & Yajima, 1970; Clocchiatti, 1971).

A clearer picture of agreement between the compositions of glass inclusions and the bulk compositions of the rocks may be traced for the acid series (see Table 16, analyses 14-16). On the basis of amounts of the principal oxides, inclusions of glass in quartz from acid lavas differ little (within the limits of analytical error) from the bulk compositions of the rocks. The greatest differences concern the amounts of alkalies, but they may, most probably, be explained by methodological errors in determining Na_2O and K_2O, rather than by an actual difference in the compositions. Together with this, to draw the conclusion that the composition of inclusions preserved in minerals reflects the composition of the mineral-forming media on the basis of one similarity alone in the compositions of inclusions and the rocks themselves, would not in general be acceptable. There are a number of reasons, on the strength of which analyses of glasses from inclusions in minerals are distinguished from the bulk composition of the rock.

Composition of preserved inclusions and the process of crystallization differentiation of a melt. Of significant importance in the difference in composition between the preserved glasses and the rock composition is the process of crystallization differentiation. Crystallization of minerals causes a change in the composition of the melt, as a result of which differences appear in the compositions of the inclusions of melt, trapped during different phases of crystallization: in different minerals or even in different growth zones of a particular crystal, portions of magma differing in composition are preserved.

In the composition of the glass of inclusions from the marginal and central zones of olivine from volcanics of the Kuril Islands, the differences are slight, but completely regular (Table 17, analyses 1 and 2). Inclusions in the center of crystals are poorer in silica and richer in femic components; in their normative composition there is less quartz (8.9% as against 22% in the composition of the peripheral inclusions) and richer in anorthite (40.9% as against 28.1%) and

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Table 17. Composition of Inclusions of Glass from Different Zones of
[153] Crystals.

Oxides	1	2	3			4			Components	1	2	3		4	
			a	b		a	b	c				a	c	a	c
SiO_2	52,5	59,7	70,2	51,04	72,4	57,1	51,4	42,32	qz.	8,9	22,6	41,5	37,1	1,5	—
TiO_2	0,9	1,2	—	0,23	0,0	N det.	0,8	0,38	cor.	—	—	1,2	—	—	—
Al_2O_3	18,3	15,8	14,7	3,12	13,5	5,0	1,2	5,12	or.	0,6	3,9	17,3	7,2	24,5	13,6
Fe_2O_3				1,80	2,7			3,59	ab.	16,3	24,6	29,4	32,0	1,0	—
FeO	8,5	6,5	1,6	21,12	1,2	8,3	6,6	0,30	an.	40,9	28,1	4,5	16,1	1,7	1,7
MnO		N. det		1,11	0,6	N.det.		0,16	ne.	—	—	—	—	—	3,7
MgO	3,1	2,3	0,1	16,35	0,6	17,7	15,3	29,07	lc.	—	—	—	—	—	2,8
CaO	11,4	6,7	0,9	1,96	3,4	5,7	23,0	5,41	en.	7,7	5,7	0,3	1,5	44,1	—
Na_2O	1,9	2,0	3,5	0,22	3,8	0,2	—	0,78	fs.	14,1	15,4	2,0	5,7	15,2	—
K_2O	0,1	0,7	2,0	0,03	1,2	3,8	—	2,89	wo.	6,5	2,2	—	0,4	11,9	10,5
H_2O^+				—				2,52	fo.	—	—	—	—	—	52,3
H_2O				0,37	0,4			0,11	fa.	—	—	—	—	—	6,3
Total	96,7	98,8	99,9	99,44	100,4	97,8	99,2	99,64	mt.	—	—	—	3,9	—	5,3
									il.	1,7	2,3	—	1,2	—	0,8

Note:- Fe_2O_3) determined as Fe_{total} by electron microprobe. 1, 2) in olivine from volcanics from the Kuril Islands: 1) from center, 2) from periphery of crystals (Komatsu & Yajima, 1970); 3) in hypersthene from Japanese dacite: a) inclusions of glass, b) mineral-host, c) rock (Komatsu & Yajima, 1970); 4) in diopside from biotite peridotite-porphyrite of Central Aldan: a) pseudosecondary inclusions of glass, b and c) the same as in 3).

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pyroxene (28.3% as against 23.3%). The composition of glass inclusions from the central zones has a higher MgO/(MgO + FeO) ratio, equal to 0.39 as compared with 0.30 for inclusions from the peripheral zones. All this indicates a change in composition of the melt as a result of crystallization differentiation towards more silicic melts, that is, trending towards a residual melt.

The process of crystallization differentiation in a crystallizing melt is also indicated by a comparison between the composition of glass inclusions, preserved in hypersthene from a Japanese dacite (see Table 17, analysis 3) and that of the main rock mass. The glass of the inclusions differs markedly in the content of the principal petrogenic

Table 18. Compositions of Glasses and Crystals in Multiphase Inclusions of Melts in Minerals.

[154-155]

Oxides	1			2			3			4		5			
	а	б	в	а	б	в	а	б	в	а	б	а	б	в	г
SiO_2	58,7	44,2	53,5	61,6	52,1	44,64	58,9	40,3	49,98	62,1	53,9	57,9	45,0	30,3	44,9
TiO_2	0,2	1,4	1,5	0,1	0,5	1,14	0,5	—	0,86	0,5	0,3	1,8	—	0,2	—
Al_2O_3	24,4	15,2	19,9	21,4	1,8	12,08	21,2	—	15,45	21,0	2,0	13,1	34,4	—	35,5
Fe_2O_3						3,09			5,08						
FeO	2,5	7,2	5,4	1,8	8,2	2,80	2,7	18,6	4,11	2,4	6,0	5,3	1,7	32,2	1,9
MnO	N. dct					0,13	N. dct		0,03	N. det.				0,51	—
MgO	0,1	9,3	3,1	0,1	12,6	5,49	0,5	41,1	5,38	0,1	15,3	1,7	—	31,5	—
CaO	7,8	23,5	14,5	0,4	23,2	12,81	1,0	N. dct.	4,91	0,3	22,0	17,1	17,0	0,20	17,3
Na_2O	2,9	—	2,7	4,5	1,2	1,05	5,0	—	2,40	4,4	—	0,58	1,3	—	1,5
K_2O	1,2	—	0,9	11,2	—	8,70	10,1	—	7,50	8,4	—	0,43	0,09	—	0,07
Total	97,8	100,8	101,5	101,1	99,6		99,9	100,0		99,2	100,0	97,91	99,49	100,97	101,17
Normative composition, wt. %															
Qz.	18,3		1,9	—		—	—		—	2,0		22,1			
Cor	4,1		—	1,1		—	0,2		—	4,2		—			
or.	7,2		5,6	66,2		13,9	59,6		44,5	49,5		2,2			
ab.	24,6		23,1	17,8		—	16,3		13,1	37,2		5,2			
an.	38,7		39,2	2,0		—	5,0		9,2	1,4		31,7			
lc.	—		—	—		29,2	—		—	—		—			
ne.	—		—	11,1		7,7	14,2		4,0	—		—			
wo.	—		13,7	—		23,3	—		4,2	—		22,2			
en.	0,3		7,7	—		—	—		—	0,3		4,2			
fs.	4,2		7,4	—		—	—		—	3,6		6,7			
fo.	—		—	0,2		9,8	0,8		9,4	—		—			
fa.	—		—	2,5		0,2	2,5		1,4	—		—			
il.	0,5		2,9	0,1		2,1	0,9		1,7	0,9		3,5			
mt.	—		—	—		5,8	—		7,4	—		—			
ap.	—		—	—		3,0	—		2,0	—		—			

Note:-1) olivine from Japanese picrite: a) glass, b) pyroxene from inclusion; c) composition of same items, analyzed by wide probe (Komatsu & Yajima, 1970); 2) pyroxene from fergusite-porphyry in Eastern Pamir: a) glass, average of 8 analyses, see Table 19; b) mineral-host; c) rocks, containing in addition Cr_2O_3-0.03, H_2O-0.45, P_2O_5-1.30; 3) olivine from olivine pseudoleucitite from Central Aldan: a) glass, average of 8 analyses, see Table 20; b) mineral-host; c) rocks in addition containing Cr_2O_3-0.18, P_2O_5-0.88, CO_2-0.14); 4) pyroxene from olivine pseudoleucitite from Central Aldan: a) glass, average of 4 analyses, b) pyroxene; see Table 20; 5) olivine, from rock at Luna-16 station: a) glass, b) plagioclase from inclusion, c) mineral-host, d) plagioclase from rock (Roedder & Weiblen, 1972).

[155]oxides from that of the hypersthene, but is similar to the rock composition, being even more acid (41.5% of normative quartz as against 37.1%).

In order to clarify the nature of the changes in composition of the entrapped inclusions in minerals during the process of crystallization of a rock, a comparison has been made between the composition of the secondary inclusions and the bulk composition of an ultramafic rock (see Table 17, analysis 4). The secondary inclusions fill the cracks in diopside from a biotite peridotite-porphyrite from Central Aldan and their preservation took place after crystallization of the olivine and pyroxene phenocrysts. The composition of the glass of the secondary inclusions bears the clear features of a residual melt and differs markedly from the bulk composition of the rock. Quartz is present in the normative composition of such a glass, whereas the rock itself is markedly undersaturated in silica (nepheline and leucite are present). The glass of the inclusions, however, remains magnesian (44 wt % enstatite), but the MgO/(MgO + FeO) ratio is 0.79 as against 0.84 for the rock. There is also much more orthoclase (saturated aluminosilicate) than in the rock. We must also note a greater agreement between the compositions of the inclusions and the rocks in the acid series (see Table 16), which probably depends on the fact that the acid rocks themselves and the glasses preserved in the minerals of such rocks are the end members of crystallization differentiation and consist essentially of silica and alumina.

The process of crystallization differentiation in preserved inclusions. The glass of inclusions may reflect the magma composition at the moment of preservation only if the subsequent cooling had not altered its composition, that is, if the relict of melt was preserved as a glass and did not precipitate material on the walls of the inclusions. Such is typical of the glassy inclusions in minerals affected by rapid cooling. However, it is more usual for the minerals to contain inclusions with three and more phases (glass + gas + crystalline phases). This leads us to another interesting aspect of the investigation, a consideration of the process of crystallization differentiation, which takes place in a magma chamber, as exemplified by the study of relicts of magmatic media, preserved in minerals. [156]Multiphase inclusions of melts in minerals (excluding combined inclusions with xenogenic phases) indicate the continuation of crystallization in already preserved vacuoles. In this case, we may discover the entire range from primary features of the formation of crystallites to complete crystallization of the melt, when glass is absent, in the inclusions from different rocks. Such crystallization of inclusions (that is, precipitation of solid phases in vacuoles) is accompanied by the deposition of material, related to the mineral-host, on the vacuole walls. The melt composition, in this case, regularly changes and acquires a residual character.

Table 19. Composition of Inclusions of Glass in Pyroxene (1-8) from a Fergusite-Porphyry in Eastern Pamir.

Oxides	1	2	3	4	5	6	7	8
SiO_2	60,4	58,4	62,4	62,5	62,5	62,8	62,9	61,4
TiO_2	0,1	0,2	0,1	0,1	0,1	0,1	0,2	0,1
Al_2O_3	22,1	21,9	20,7	21,9	21,4	21,2	21,4	20,4
$FeO_{t.t.}$	2,3	2,4	2,0	1,5	1,7	1,7	1,4	1,6
MgO	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1
CaO	0,2	0,4	0,4	0,4	0,4	0,3	0,4	0,4
Na_2O	2,9	5,3	4,7	4,9	4,2	4,3	4,6	4,9
K_2O	12,9	11,4	11,2	11,1	10,9	11,1	11,7	9,4
Total	101,0	100,1	101,6	102,5	101,3	102,7	101,6	98,3

The above is supported by a description of a three-phase inclusion in an olivine from a Japanese picrite (Table 18, analysis 1). Attention is drawn to the marked deviation in the composition of the glass towards the leucocratic side as compared with that of the picrite. Against this background, however, the overall composition of the contents of the inclusions (analysis 1c) already approaches to some degree the rock composition. The noted differences are also clarified in anslyses 2-4 (Tables 18-20), which present the compositions of glasses from three-phase inclusions in pyroxenes and an olivine from a pseudoleucitite from Central Aldan and a fergusite-porphyry from Eastern Pamir. These glasses are characterized by a much more acid composition as compared with the bulk composition of the rocks. It must be stated that in the present case, such a significant difference [157] in composition is dependent not only on the crystallization of the inclusions, but also on other factors, including the capture of already partially differentiated portions of magma with a markedly more acid composition. Evidence in favor of the residual nature of such glasses may be the appearance in them of normative quartz, and also the MgO/(MgO + FeO) ratio, which decreases in the residual portions of the melt. From this point of view, there is an interest in the coincidence in the compositions of the glasses (within limits of analytical error) in the pyroxenes from potassium alkaline basaltoids (olivine pseudoleucitite and fergusite-porphyry), which may indicate the composition of the end members of differentiation of an alkaline-basaltoid magma.

Table 20. Compositions of Glasses from Melt Inclusions in Olivine (1-8) and Pyroxene (9-12) from Olivine Pseudoleucitite from Central Aldan

Oxides	1	2	3	4	5	6	7	8	9	10	11	12
SiO_2	59,0	60,1	57,1	60,9	60,0	57,5	57,7	59,2	63,4	63,4	61,1	60,3
TiO_2	0,64	0,62	0,79	0,58	0,60	0,28	0,48	0,32	0,44	0,26	0,34	1,08
Al_2O_3	21,8	21,8	21,0	20,2	21,1	23,5	20,9	19,5	21,5	21,2	20,2	21,0
Cr_2O_3	—	—	—	—	—	—	—	—	—	—	—	0,07
FeO_{tot}	2,78	2,70	2,82	2,14	2,17	1,96	3,52	3,45	2,53	2,43	2,10	2,56
MgO	0,55	0,22	0,22	0,48	0,30	0,43	1,44	0,49	0,09	0,12	0,10	0,05
CaO	0,11	0,39	2,36	0,08	0,07	0,27	2,30	4,30	0,27	0,42	0,19	0,41
Na_2O	4,88	5,75	5,38	4,90	5,85	5,14	3,24	4,50	5,30	4,51	5,20	2,73
K_2O	9,85	9,98	10,1	10,7	10,7	10,0	10,1	9,10	9,00	8,08	9,01	7,34
Total	99,62	101.5	99,77	99,98	100,8	98,67	99,71	100,8	102,6	100,5	98,27	95,55

An analogous picture is also characteristic of inclusions in minerals from lunar rocks (see Table 18, analysis 5). In a crystallized inclusion in an olivine from the rocks at Luna-16 Station, consisting of glass (analysis 5a), plagioclase (analysis 5b), and other phases, the glass has quite an acid residual composition (about 22 wt % of normative quartz).

In order to obtain some idea of the composition of the captured melt in multiphase inclusions, it is necessary either to analyze all the inclusions with a wide probe, or, as will be shown below, prior to analysis on the microprobe, experimentally to homogenize these inclusions.

It should be specially noted that the preserved inclusions, which may be distinguished by their chemistry from that of the rock, may for certain reasons not reflect the composition of the medium from which the rock crystallized. For example, Anderson and his co-authors (in Roedder & Weiblen, 1971) have shown that inclusions of a silicate melt in an olivine from Sample 1240 (Apollo; ed. note - Sample 12040) differ significantly from the rock composition. It has been suggested that these olivines have come from a more differentiated source, and that they are xenogenic for the present rock.

It is also regarded as important to consider the gradient of concentration around the growing crystal, when because of differences in the diffusion of different elements in the silicate melt and the rapid growth of the crystal, a change develops in the composition of the various sectors of the crystallizing melt (Roedder & Weiblen, 1971). In this case, the preserved inclusions will not reflect the true composition of the magma. However, the scale of this effect is so far difficult to assess.

The composition of unusual inclusions of magmatic melts in minerals. There is special petrological interest in an investigation of unusual multiphase inclusions of magmatic melts, and in particular, inclusions with immiscible liquids. Roedder & Weiblen (1970a), during a study of [159] inclusions in minerals from lunar basalts, have established immiscibility in the lunar magma, dependent on the low chemical potential of oxygen. They have analyzed the compositions of two immiscible melts in plagioclase and pyroxene (sic), which turned out to be close to a potassium granite and a ferropyroxenite (Table 21). Analogous immiscible compositions have been identified in the main mass of the rocks from 'Apollo' and 'Luna-16'. Roedder & Weiblen (1971) have also drawn attention to the phenomenon of immiscibility of melts in samples from the Hawaiian Islands, California, and some other regions, where one of the immiscible liquid phases consists of globules with a high iron content. However, the available data are so far inadequate for a categoric confirmation of the essential role of the process of melt immiscibility in petrogenesis.

Table 21. Composition of Immiscible Melts from Inclusions in Minerals from Lunar Rocks (average of 37 analyses; Roedder & Weiblen, 1970b).

Oxides	1	2	Norm. comp.	1	2
SiO_2	76,1	47,8	qz.	42,5	5,5
TiO_2	0,5	3,7	cor.	0,5	—
Al_2O_3	11,7	3,2	or	39,0	1,7
FeO_{tot}	2,5	31,4	ab.	3,2	1,1
MgO	0,3	2,3	an.	9,5	7,2
CaO	1,9	11,2	wo.	—	20,2
Na_2O	0,4	0,1	en.	0,7	5,7
K_2O	6,6	0,3	fs.	3,8	51,6
			ol.	0,9	7,0

Note:- Compositions of inclusions, corresponding approximately to: 1) potassium granite; 2) ferropyroxenite.

Experimentally heated and quenched melt inclusions in minerals. A no less important aspect of the investigation is the study of the composition of inclusions that have been experimentally homogenized or heated to determined temperatures and then quenched. Homogenization of inclusions during heating makes it possible to restore them to the conditions of capture and to judge the composition of the preserved medium. With this in mind, it is appropriate to compare the composition of the homogenized inclusions and that of the rocks themselves. From the example of a homogenized inclusion in olivine from 'Apollo-11'

Table 22. Compositions of Experimentally Heated and Quenched Inclusions
[158-159] in Minerals.

Oxides	1			2		3			4		
	a	b	c	a	b	a	b	c	a	b	c
SiO_2	40,8	37,5	30,93	48,5	n.d.	50,5	n.d.	50,36	58,7	58,2	53,7
TiO_2	9,8	—	10,82	4,6	•	2,6	•	2,65	0,5	0,7	n d
Al_2O_3	9,8	0,1	10,11	10,0	•	13,3	•	13,35	20,4	10,0	13,4
Cr_2O_3	0,4	0,3	0,39	n.d.	•		n d			n d,	
Fe_2O_3		—									
FeO	20,7	26,5	19,25	12,0	20,4	10,4	16,8	11,17	3,6	4,1	6,5
MnO	0,24	0,28	0,25	n.d.			n.d.			n.d	
MgO	7,0	34,5	7,84	9,6	40,7	8,0	43,0	8,30	1,4	2,0	5,8
CaO	11,1	0,6	11,27	13,2	0,25	11,4	0,36	10,80	2,0	2,6	8,7
Na_2O	0,2	—	0,38	0,37	n.d.	1,9	n.d.	2,33	4,0	3,4	2,5
K_2O	0,05	—	0,05	—	•	0,44	•	0,54	8,8	7,1	6,1
Total	100,09	99,78	100,09	99,20		98,54		99,56	90,4	07,5	96,7

n d. = not determined

Normative comp., wt. %

	1a	1b	1c	2a	2b	3a	3b	3c	4a	4b	4c
qz.	1,7		0,7	5,4		1,3		—	—	—	—
cor.	—		—	—		—		—	0,6	1,6	—
or.	0,3		0,6	—		2,2		2,8	51,8	41,7	36,2
ab.	1,7		3,2	3,2		16,3		19,9	23,1	28,8	10,5
an.	26,4		25,6	28,1		20,7		24,5	10,0	12,8	7,2
ne.	—		—	—		—		—	6,0	—	2,4
wo.	12,0		12,3	15,6		12,4		12,3	—	—	16,0
en.	17,4		19,6	23,9		19,9		17,2	—	5,0	—
fs.	22,0		10,8	14,4		14,8		13,3	—	0,3	—
fo.	—		—	—		—		2,4	2,5	—	10,1
fa	—		—	—		—		2,1	4,5	—	9,2
il.	18,0		20,2	8,8		5,0		5,2	0,9	1,4	—
ap.	—		0,8	—		—		—	—	—	—

Note:- 1-3) homogenized and quenched inclusions of glass in olivines from rocks: a) composition of glass, b) mineral-host, c) rock; 1) 'Apollo-11'(Roedder & Weiblen, 1970); 2) 'Apollo-12': a) average of 3 analyses (Roedder & Weiblen, 1971); b) [host olivine (avg. of 3)]; 3) Hawaiian Islands: a) average of 5 analyses (a, b - Roedder & Weiblen, 1971; c - Wright et al., 1968); 4) heated and quenched inclusions of glass in pyroxene from olivine pseudoleucitite from Central Aldan: a) up to 1100°C, b) up to homogenization temperature, 1200°C, average of two analyses, c) up to 1300°C (see also Table 18, analyses 3c, 4).

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rock (Table 22, analysis 1), complete agreement between its composition and that of the rock is seen*. Such results have been obtained for other lunar rocks (Table 22, analysis 2 and some rocks from the Hawaiian Islands (Table 22, analysis 3). It is true that in not every case of homogenization of inclusions has a composition close to the average bulk composition of the rock been obtained. For example, the homogenized and then quenched inclusions of glass in pyroxene from an olivine pseudoleucitite from Central Aldan have a composition markedly more leucocratic than that of the rock itself (see Table 22, analyses 4a and b) and even a certain reheating of the contents of the inclusions above the homogenization temperature does not give the bulk composition
[160]of the rock, and only demonstrates the presence of a significant amount of the diopside molecule, the material of the mineral-host, which has

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*Such complete coincidence in the compositions has been obtained after substracting a certain amount of olivine (the mineral-host) from the analysis, which decreases the value of the data obtained. (Ed. note: no such subtraction was made in analysis 1.)

naturally been dependent on melting in the inclusion of the glass material in the vacuole. This fact emphasizes the capture by the pyroxene of an already partially differentiated melt. It is appropriate to recall that the pyroxene crystallized during the concluding phase of crystallization of the phenocrysts, on the boundary of crystallization of the bulk of the rock.

2. CHEMICAL COMPOSITION OF THE GAS PHASE OF INDIVIDUAL INCLUSIONS IN MINERALS OF ALKALINE ROCKS

Up until the present time, sufficient representative information has accumulated, which will enable us, on the basis of a study of melt inclusions, to determine the temperatures and the aggregate state [161]of the mineral-forming media during crystallization of alkaline rocks and the relative amount of volatile components as a whole. However, the available results of determinations on the chemical composition of the gas phase in inclusions in minerals of alkaline rocks, are so far much too restricted in number, that is is not possible to reach any far-reaching conclusions based on them. Up until now, it may be stated that the prevalent component during the early stages of magmatic crystallization of all the alkaline rocks examined has been carbon [162]dioxide (Tables 23,24). Only during the crystallization of the present-day leucite lavas of Vesuvius has the principal role been played by nitrogen and rare gases, comprising on average 76.8%.

Table 23. Results of Qualitative Analysis of Composition of Gas Phase of Individual Inclusions.

Region	Rock	Mineral	T_H, °C	Concentration, vol.%			
				H_2S; SO_2; NH_3; HCl; HF	CO_2	H_2	Nitrog.
1	2	3	4	5	6	7	8
Hungary, Bakoni massif	Nepheline basalts	Olivine (P)	1290 1290 1270	7,56 5,10 6,0	92,2 94,7 93,5	0,0 0,0 0,0	0,24 0,20 0,5
		Pyroxene (P)	1270 1270 1250	2,0 2,0 0,8	97,0 94,5 97,5	1,0 2,5 1,0	0,0 1,0 0,7
		Pyroxene* (S)	1120 1130	0,0 0,0	20,2 39,2	0,0 0,0	0,0 0,0
		Nepheline (P)	1120?	1,5 1,8 1,2 1,2 1,2 1,18	97,0 96,5 94,4 96,5 94,2 95,1	0,7 1,34 1,5 0,5 1,93 3,7	0,8 0,36 2,9 1,8 2,67 0,0
Mayo Island	Efindite	Apatite (P)	1180	14,0	86,0	0,0	0,0
		Pyroxene (P)	1160 1160 1150	4,5 2,5 6,85	95,5 97,5 93,15	0,0 0,0 0,0	0,0 0,0 0,0
		Amphibole (P)	1140 1140 1140	8,0 10,0 10,0	85,8 82,6 81,0	0,0 0,0 0,0	6,2 7,4 6,0
	Melilite ankaratrite	Olivine (P)	1170 1170	11,2 7,7	55,1 57,2	0,0 0,0	33,7 35,1
		Olivine (S)		8,4	90,9	0,0	0,7
		Pyroxene (P)	1160	7,7	58,5	0,0	33,8
	Basanite	Pyroxene** (P)	1180 1180 1160	1,60 2,02 4,1	64,5 62,3 60,5	0,0 0,0 0,0	19,54 21,98 23,6
Eastern Pamir	Fergusite-porphyry	Leucite (P)	1380 1380 1380	0,0 0,0 0,0	90,0 86,0 71,0	10,0 14,0 14,2	0,0 0,0 4,8
		Pyroxene (P)	1320 1300 1300	0,0 0,0 0,0	97,2 94,3 95,3	2,1 5,4 Not anal.	0,7 0,3
Vesuvius	Present-day lava	Leucite (P)	1340 1340 1340	0,0 0,0 0,0	26,8 19,3 23,8	0,0 0,0 0,0	73,2 80,7 76,2
		Pyroxene (P)	1320 1340	0,0 0,0	6,0 10,8	0,0 0,0	94,2 89,2

*In the secondary inclusions of pyroxene there are liquid hydrocarbons, the average amount of which comprises 70.3 vol. %.

**An average amount of 13.3 vol. % of CO has been found in the gas phase of inclusions in a pyroxene from the basanite.

Table 24. Results of Partial Chemical Analysis of Gas Phase of Individual Inclusions in Minerals of Intrusive Alkaline Rocks.

Massif	Rock	Mineral	Gas composition, vol %					
			H_2S, SO_2	Cl^-	CO_2	CO	H_2	N_2 + r.g.
Botogol	Nepheline syenite	Nepheline			97,0			3,0
					96,5			3,5
					82,0			18,0
					93,7			6,3
Lovozero	Urtite	Nepheline			73,2			26,8
					73,7			26,3
					64,7			35,3
					83,4			12,6
Ilimaussaq	Naujaite	Nepheline			62,6	4,57	4,92	27,81
Ilimaussaq	Naujaite	Chkalovite			23,5			76,5
					37,2			62,8
					40,5			59,5
Goryachegorsk	Theralite	Pyroxene	12,2		69,7			18,1
				25,8	69,5			5
				22,8	70,7			6,5

Note:- All the analyses in Tables 23 and 24, were made by N.A. Shugurova.

The group of gasses including H_2S, SO_2, NH_3, HCl, and HF is completely absent from inclusions in minerals of the leucite-bearing basaltoids, and in the remaining eruptive rocks, it is present in amounts not exceeding 14 vol. %.

Liquid hydrocarbons have been found in the pseudosecondary inclusions in pyroxene from nepheline basalts. This indicates that the hydrocarbons were captured by the magma from the country rocks or during its movement towards the surface. Gaseous hydrocarbons have also been identified in secondary inclusions in nepheline from an urtite in the Lovozero Massif (Bazarova, 1969).

Only a partial chemical analysis of the gas phase has been carried out in most cases for the primary inclusions of the intrusive rocks, because the gas residue, after absorption of CO_2, turned out to be so small, that it would have been impossible to analyze it further. A complete analysis has been made only for the minerals from the rocks of the Ilimaussaq Massif. Attention is drawn to the predominance of nitrogen and rare gases in the gas phase of primary inclusions of chkalovite, which crystallized during the closing phase of emplacement of the rock. Here again, the decreased role of CO_2 during the closing stages of crystallization is emphasized.

3. CHEMICAL COMPOSITION OF THE GAS PHASE OF INDIVIDUAL INCLUSIONS IN MINERALS OF CALC-ALKALINE ROCKS

All the chemical-analytical work has been done carried out by N.A. Shugurova using the methodology developed in the Laboratory of Mineral-Forming Solutions of the Institute of Geology and Geophysics (Novosibirsk) (Dolgov & Shugurova, 1966, 1968; Shugurova, 1968a,b). Most of the analyses have been accompanied by thermometric investigations of the same inclusions (Bakumenko, 1970; Bakumenko et al., 1969, 1970, 1973a, 1974; Lapukhov et al., 1971; Chupin et al., 1974a, b; etc.).

The information obtained on the gas regime of crystallizing calc-alkaline magmas is variable (in most cases, isolated measurements). Relatively representative data are available only for the basalts of the Klyuchevak Volcano and certain rocks of acid composition. There appears to have been no study made of rocks of intermediate composition.

The principal gas components of the calc-alkaline melts are CO_2 or nitrogen + rare gases, or both together. 'Acid' gases are usually present as additives. Carbon monoxide appears irregularly, and exceptionally, hydrogen and hydrocarbons. Water has not been analyzed. The composition of the gases captured at different temperatures, even from one and the same melt, is variable (Figs. 21-24). The data obtained are quite contradictory and create a false impression of the absence of any patterns in the changes in the composition of the gases. However, individual trends of change in the gas regime are more and more apparent in many cases and will be discussed below. All the gases discovered have been recorded earlier during a study of gas release from magmatic rocks (along joints and in drill-holes), by fine grinding in vacuum mills, and during high-temperature heating of magmatic rocks (Sokolov, 1971; etc.). However, the bulk data, obtained by these methods, are even more contradictory. The source of the gas examined is not always clear. In the first two cases, there is possibility of contamination of the gas mixture by newly-formed (mechano-chemical) hydrogen and hydrocarbons, and also by atmospheric nitrogen, and in the last case, by dissociation products. The method of direct analysis of volcanic gases from lava lakes and fumaroles also has its deficiencies (Naboko, [163] 1961; Basharina, 1949, 1953; etc.). Here, contamination of the gas mixture is often observed by atmospheric components, groundwater components, and products of the chemical interaction between gases, released to the melt from the surrounding rocks. Therefore, the original composition of the volcanic gases may be intensely distorted (enriched in less active gases, etc.). Below, we shall consider some results of analyses of the gas phase of individual inclusions, captured directly from crystallizing calc-alkaline melts.

Basalts. The basaltic melts of Klyuchevskaya Sopka at the time of the deep-seated crystallization of the pyroxene phenocrysts are characterized by a predominance of CO_2 over all the other gases (besides water). Nitrogen + rare gases are sometimes present in marked amounts, and are sometimes completely absent, and other gases are present only in the form of impurities: acid gases constantly, and CO spasmodically. The evolutionary features of the gases, dependent on the degree of cooling of the melt, will be considered on the basis of the lavas from the Apakhonchich flow and flows and extrusions of the Piip breakthrough.

Apakhonchich flow. The deep-seated gas regime has been studied on the basis of analyses of the gas phase of primary and pseudosecondary melt inclusions in clinopyroxene phenocrysts and secondary inclusions (of melt and essentially carbon-dioxide refilled types) in quartz xenocrysts. The age relationships of the various types of inclusions and the temperatures of their capture (based on homogenization temperatures or other features) have been provisionally explained. It has been established that CO_2 has predominated in the melt from the very beginning of crystallization of clinopyroxene (see Fig. 21). At increased temperatures (1240°C and above), nitrogen + rare gases have been present in substantial quantity, and 'acid' gases (most commonly, SO_2, judging by drop reactions) in markedly minor quantities. As the temperature falls during the process of crystallization of the melt, a decrease in the amount of nitrogen + rare gases is observed, and at temperatures below 1220°C, nitrogen is an additive to markedly predominant carbon dioxide. The spasmodic increase in nitrogen concentration (at 1240 and 1185°) is apparently associated with the influx of a portion of undifferentiated deep-seated lava, enriched in nitrogen, into the crystallizing center. Curiously, carbon monoxide often appears in the gas mixture in such a situation.

An analysis of the gas phase in the later, refilled carbon-dioxide and glassy inclusions in xenolithic quartz, has recorded a clear sequential change in the composition of the deep-seated gases during the uprise of melt up until the moment of eruption of lava on the surface: during the advance of the melt from below, where the early inclusions with compressed CO_2 (gas-liquid) have been refilled, to shallower depths, where secondary glassy inclusions have been captured and the late inclusions have been refilled with less dense CO_2 ('gas'), enrichment of the melt in sulfurous gases from 6-7 up to 15-19 vol.%, has been recorded (these data have been plotted on Fig. 21 at temperatures of 1175°C and below). (Fig. 21 is discussed in Chapt. V).

Under surface conditions, after the eruption of lava, the marked drop in pressure results in degassing of all and primarily the poorly soluble gases from the melt. In the advancing lava flow, only the most soluble volatiles, mainly water, are retained. But they are also gradually removed from the melt in the form of residual and fumarolic gases as the lava congeals and crystallizes. Their compositions in the Apakhonchich flow (in a mixture with atmospheric components) have been determined by Naboko (1949, 1953a, b) and Basharina (1949). Water predominates in the fumarolic gases, along with atmospheric gases (nitrogen and oxygen). The other gases consist of SO_2, HCl, H_2, and CO. Since our analyses have not identified hydrogen, it is possible that its manifestation in fumarolic gases is associated with some secondary chemical processes.

Thus, an overall trend in the alteration of the gas regime based on the degree of cooling and crystallization and the uprise of melt [164] towards the surface, is the depletion of the melt in the poorly soluble gas components and enrichment in the more soluble components in the following sequence: depletion in nitrogen and rare gases and enrichment in CO_2 on cooling to 1180°C; on further cooling up to the moment of eruption, accumulation of SO_2 takes place, as a result of which, some fall in the volume proportion of CO_2 is observed; at the moment of eruption and after the outburst of lava from the magma conduit, there is enrichment in residual water and the appearance of H_2 and CO (as a consequence of chemical reactions?), which are released in the form of residual and fumarolic surface gases.

The Piip breakthrough. In order to study the gas regime during the crystallization of basalts at the Piip breakthrough, it was necessary to examine a larger number of samples in connection with the complicated geological situation. We carried out a thermometric study and the determination of the compositions of the gas phase of inclusions in clinopyroxenes from seven sequentially erupted portions of lava: from flow (1) and extrusions (2 and 3) of the first phase of activity of the lateral outbreak of the volcano; from flows (4 and 5) and extrusions (6 and 7) of the second phase of activity. The analyses have shown (Bakumenko et al., 1973a) that CO_2 markedly predominates in the gas phase, the content of nitrogen varies from 0 up to 20-22 vol. %, and the acid gases are present in small amounts in all the samples (3.7 - 11.5 vol. %). The repeated eruptions have led to the oscillatory nature in the compositional change in the volatiles in each portion of the cooling melt (see Fig. 22a, b). The fluctuations in composition depend on an alternation in the processes of removal of nitrogen during lowering of temperature of the melt and its accumulation in connection with the influx of new portions of melt. For the melt, erupted in the form of a flow (portion 1), analyses have defined the presence in variable amount of all three groups of gases (see Fig. 22a). The subsequent portions of melt from extrusions (2 and 3) under deep-seated conditions are characterized either by the absence of nitrogen (2), or its decreased amount (3) as compared with the first portion of melt. In sample (2), nitrogen appears anew only in the inclusions captured in underground conditions (at a temperature of 1110°C).

In samples (4) and (5) from the flows of the second phase of activity, nitrogen is present in the melt only at increased temperatures (1260-1240°C), but as the temperature falls to 1200°C and below, it completely disappears (see Fig. 22b). In the next portion of melt from extrusion (6), nitrogen was absent under deep-seated conditions and appeared only in the inclusions, captured under surface conditions (at temperatures of 1060 and 1110°C), that is, the situation, typical of the samples from flow (1) and extrusion (2) of the first phase of activity, was repeated here.

In the melt of extrusion (7), in contrast to the almost simultaneously formed extrusion (6), nitrogen is present. Its quantity is not diminished, as in the other extrusions, but is the same as in the portion of lava from flow (5), which was erupted before it. This extrusion is also distinguished from the others by the increased temperatures of the commencement of crystallization of the clinopyroxene (up to 1290°C) and the erupted lavas. It is very likely that the source of its lavas was in the magma conduit somewhat separately and deeper than that of the lavas of the other extrusions and flows, and therefore the effect of the previous eruptions was not reflected in the composition of the gases of the portion of melt (7).

Summarizing the data based on two phases of activation, we may speak of a trend towards depletion of the crystallizing melt in nitrogen as the temperature fell [portions (3) and (5)] and towards a decrease [portion (3) as compared with (1)] or complete removal of nitrogen from the later portions of melt [comparison of (2) with (1) and (6) with (5)]. In the magma column, these later portions of differentiating melt apparently occurred immediately below those earlier erupted. In this respect, the mechanisms of differentiation and the transfer of the gases are not so far obvious.

Andesites. In connection with the hypotheses concerning the increased water saturation of andesitic magmas, we have conducted an experiment to [165]discover the appropriate proofs through a study of inclusions. With this in mind, it is possible to study not only the inclusions in phenocrysts (see Table 2), but also the secondary inclusions in the minerals from xenoliths. As a result of a study of the inclusions in clinopyroxene and olivine from ultramafic xenoliths in the Avachi Volcano, it has been revealed that, in contrast to the deep-seated lherzolitic nodules, in which Roedder (1965) discovered inclusions of highly-compressed liquid CO_2, the minerals of the Avachi lherzolites have in their place inclusions with water, and the xenoliths themselves appear to have been captured at shallow depths (Bakumenko & Sobolev, 1974). The temperature of the andesitic melt, which transported the xenoliths, is indicated by secondary glassy inclusions in orthopyroxene, which have been homogenized at 1210°C and above. In the low-density gas phase of these inclusions, carbon dioxide is present (97.8 wt %) with a trace of acid gases (2.2 wt %). In contrast to the phenocrysts of the surrounding andesites, in which many primary and pseudosecondary melt inclusions have been found (see Table 2), only secondary melt inclusions have been found in the minerals of the ultramafic segregations. Consequently, the segregations are not the products of segregation of normal phenocrysts, but represent xenoliths of holocrystalline rocks. Along with the normal secondary melt inclusions, combined glass-gas and gas inclusions are encountered (Plate IV, Figs. 1, 2), and also complex inclusions of spinel, which have been formed from the breakdown of olivine (Plate IV, Figs. 5, 6). Such inclusions have also been known earlier. But there is a special interest concerning the problem of gas-saturation of andesitic magmas relating to the gas-liquid inclusions in which the liquid phase has turned out to be an aqueous (!) solution, and not CO_2 (Plate IV, Figs. 3, 4). During heating of xenoliths by the lava that captured them, a high water pressure was developed (up to 7-8 kb) that is difficult to explain (Bakumenko, 1972). The presence of problematical gas-liquid inclusions in the xenocrysts creates a false picture of boiling of the surrounding andesitic melt with the release of a liquid-like solution under conditions of high water pressure. However, in the phenocrysts, there are neither gas-liquid nor combined glass-fluid inclusions, which would indicate boiling of the melt. Against the hypothesis on the capture of water during boiling are the high homogenization temperatures of the melt inclusions. An analysis of geologic-mineralogic information and data based on inclusions suggests that the source of the water in these inclusions was not the surrounding melt, but the xenoliths themselves (Bakumenko & Sobolev, 1974). During the capture of fragments of serpentinized ultramafic rocks, which form intrusions in the basement below the volcano, deserpentinization of the xenoliths took place as a consequence of the heat activity of the transporting melt, and this was accompanied by the release of water. A substantial portion of it has been retained in the form of inclusions in the minerals of the xenoliths, and an insignificant portion passed into the melt, and this is indicated by the formation of narrow rims of hornblende phenocrysts around the xenoliths. These data unequivocally indicate the almost complete dryness of the Avachi melt and the crustal nature of the ultramafic xenoliths.

Rocks of acid composition. Pyroclastic, eruptive, and subvolcanic rocks. In contrast to the basaltoids, the compositions of the gas phase of the crystallizing melts of acid composition alter more smoothly, without marked oscillations, but they may vary within very wide limits (Bakumenko, 1971; Bakumenko et al., 1969, 1970; Lapukhov et al., 1971). In those cases, were genetic associations between acid differentiates and basaltic volcanism have been recorded, this is apparently explained by a tectonic regime, quieter and more favorable to differentiation of the original melt. Under some conditions, the predominant gas is nitrogen + rare gases, and in others, CO_2, or their mixture, with acid gases usually forming an additive. Nitrogen often predominates during the initial high-temperature phases [166] of crystallization of phenocrysts, and is later replaced by carbon dioxide. This case has ultimately been clearly manifested during the process of crystallization of quartz from pumice in the Khangar Volcano (Bakumenko et al., 1970). Here, in parallel with the accumulation of CO_2 and the removal of N_2, which was sharply intensified at 1050°C, some enrichment of the cooling melt in 'acid' gases took place (see Fig. 23), and prior to the eruption, enrichment undoubtedly in water.

The predominance of nitrogen (up to 100%) has also been identified in the high-temperature (1260°C) primary glassy inclusions in quartz from the quartz porphyries of Armenia and certain inclusions in quartz from the intrusive quartz porphyries of the Salair Ridge (see Table 4, Chapter 5). It must be stressed that a decrease in the amount of nitrogen with depth clearly identified for the intrusion of the Salair ore field (see Fig. 24). This same trend has been recorded for the near-surface zone of Kamenusha intrusion. Such a trend has also been established for the basaltic melt that fed the 'Piip breakthrough' (Klyuchevskaya Sopka). Allowing for this trend, it may be suggested that the portion of melt which served as the source of pumice in the Khangar Volcano, has also been associated with differentiation in the apical portion of the magma chamber of the volcano.

Granites and pegmatites. The first ideas about the composition of the volatiles in granites and especially in pegmatites were provided in the bulk analyses of the gas phase of various types of inclusions (Elinson & Polykovsky, 1961; Kalyuzhnyi & Kovalishin, 1967; Mineraloutvoryuyuchi flyuidi [Ukr.], 1971; Lazarenko et al., 1973). According to Kalyuzhnyi & Kovalishin, nitrogen markedly predominates over CO_2 and other components in unaltered granites (Ukrainian Shield). Closer to the pegmatites, the amount of CO_2 increases and that of nitrogen decreases. This same trend is preserved in the pegmatites (in their internal parts, CO_2 predominates over nitrogen). In the outer zones, nitrogen sometimes predominates or both nitrogen and CO_2 are present in large amount.

Direct investigations of the gas phase of individual melt inclusions in other granitoids provide a different picture. According to Bazarov et al. (1969), in a quartz from the granites of the Bitu-Dzhida Complex, only CO_2 (83-81.5 vol. %) and 'acid' gases (17-18.5 vol. %) are present.

In the anatectic granites of the Aldan Shield, according to A.A. Tomilenko and V.P. Chupin, nitrogen is either absent from the inclusions (the granulitic facies of metamorphism), or is present in insignificant amount (amphibolite facies). In the leucosomes of migmatites of the granulite facies, nitrogen is absent from the gas phase of the inclusions, or its amount is negligible (up to 2 vol. %) (Chupin, 1973b; Chupin et al., 1974; and Chap. VI,3). An association has been recorded between the composition of the gases and that of the fluids in the metamorphosed sequences, which have been subjected to anatexis.

Quite unique is the composition of the gas phase in the muscovite-quartz melt inclusions, which occur in quartz from the granites of the Kurba Pluton (Eastern Baikalia), studied by F.G. Reif. CO_2 and 'acid' gases are completely absent from them. The principal components are H_2 and nitrogen + rare gases, and hydrocarbons are present in small amount.

Thus, it has so far been difficult in the case of the granitoids to compile an integrated hypothesis on the most important trends that define the gas regime in crystallizing granitic magmas. Analyses of the gas phase on the basis of pegmatites are so far lacking.

CHAPTER VIII

A COMPARISON OF THE RESULTS OF A THERMOMETRIC STUDY OF ROCK-FORMING MINERALS WITH DATA FROM INDIRECT GEOTHERMOMETERS AND FROM AN EXPERIMENTAL INVESTIGATION OF CORRESPONDING MINERAL ASSOCIATIONS

[167]

All that has been stated in Chapters 5 and 6 may be used to make certain inferences about the temperature conditions of crystallization of the rock-forming minerals in the most important types of igneous rocks. As noted earlier, the temperatures of basaltic lavas, erupted on the surface, are on average 1100-1200°C, but occasionally reach 1250°C. Lower temperature values (near 1000°C or even somewhat below) have been established for the acid, alkaline-earth, and sodic alkaline lavas. Extremely high initial temperatures are also characteristic of the leucite-basalt lavas. Nevertheless, the whole mass of information on the temperatures of lavas does not reflect the true picture, firstly, because almost always, the temperature of the surface layer of lava, intensely oxidized by the oxygen of the atmosphere, has been measured, and secondly, because the temperature measured is by no means that of the initial, but rather the last state of the melt, that is, a melt already partially differentiated and deprived of a significant proportion of its volatile components.

The information about the initial PT regime in a magmatic melt may naturally represent only the products of the early stages of crystallization. These very records are the melt inclusions, captured by the central portions of phenocrysts. In the basaltic rocks, such minerals include magnesian olivine and pyroxene, and basic plagioclase. Tables 6 to 8 show that in the calc-alkaline and alkaline basalts, the temperatures of crystallization of the olivine phenocrysts, judging from the homogenization temperature of the inclusions, are close to 1300°C; for the olivine phenocrysts in the hypabyssal meimechites, peridotite-porphyrites, and certain gabbros, this figure rises to 1400-1450°C. The homogenization temperature in inclusions in olivine and anorthite from gabbros is sometimes raised to such values, although in general it is somewhat below 1350°C. It is characteristic that clinopyroxene is usually precipitated after plagioclase: the homogenization temperatures of inclusions in pyroxene only in rare cases exceed 1300°C (most commonly in the high-potassium rocks), but they almost never fall below 1200°C. Only in the alkaline basaltoids of the Cape Verde Islands did the values for pyroxene and olivine fall within 1150-1180°C (see Table 6).

It is noteworthy that not only basic, but also intermediate plagioclase in the acid pumices from Khangar Volcano on Kamchatka and the hyalodacites of Transcarpathia, contains very high-temperature primary glassy melt inclusions, homogenized respectively at 1080-1350 (Bakumenko et al., 1970) and 1340°C (Kalyuzhnyi, 1965). The upper value for the homogenization temperatures of inclusions in alkali-feldspar and quartz from the dacites of Mendeleev Volcano reaches 1150°C, and in quartz from the Khangar pumices, even 1260°C. Unusually high homogenization temperature values for inclusions in nepheline from African nephelinites, exceeding 1200°C, and in isolated cases, rising to 1300° and above, have [168]been presented by Naumov et al., (1972). Very high homogenization temperatures, ranging from 1250 to 1290°C*, have also been obtained for a nepheline from Hungarian basalts. Isolated experiments on the homogenization of inclusions in biotite from leucite rocks have emphasized the possibility of its precipitation from melts, apparently characterized by significantly increased PT parameters; the conditions for the formation of leucite are referred to in Chapter IX.

An analysis of the available data on the homogenization temperatures of inclusions indicates that there are almost no marked differences in the thermal regime of crystallization of the leading rock-forming minerals of the intratelluric phase in the eruptive and subvolcanic rocks, on the one hand, and the plutonic (undoubtedly similar in chemistry), on the other. Thus, the temperature limits of the formation of the alkaline-earth and alkaline basalts of the most varied regions, in oceanic and continental areas, almost never fall below 1200°C. Approximately the same values are preserved in the intrusive alkaline gabbroids. It needs to be recorded that in the non-olivine types of basalts and gabbroids, the crystallization temperatures of plagioclase are always markedly higher than in clinopyroxene. This completely conforms with the studies of Yoder & Tilley (1965) and Tilley et al. (1969, 1971) on the melting of 'dry' basalts of different composition. Much lower temperatures of formation are characteristic of the plutonic rocks of granitoid composition and the nepheline syenites of the orogenic belts. In general, the upper limits of crystallization of the framework aluminosilicates and quartz rarely exceed 1000°C here (see Table 15). Against this background, the homogenization temperatures for minerals in the acid eruptive rocks appear quite high, when even for quartz, upper values reaching 1150-1200°C, are indicated (see Table 8), but sometimes they turn out to be extremely high for intermediate plagioclase, alkali feldspar, and pyroxene (in the range of 1200-1300°C).

It may be noted that when the chemical composition is similar, the melts of acid eruptive and intrusive rocks are characterized by a marked difference in the content of water, which is undoubtedly associated with features of their origin.

Thus, all the above, illustrated by the numerical data in Tables 1, 3, and 5-15, indicates the extremely high initial temperatures of melts of the most varied composition. In the lavas, erupted on the surface, these temperatures are significantly lowered. There is no doubt that such a lowering takes place in part even in the magma center, this being established primarily, from the homogenization temperatures of the glassy melt inclusions in the central and marginal parts of the same crystals of early generation, and secondly, on the basis of a sometimes significant acidification of the basalt melt after precipitation of the most refractory phases (the most basic framework aluminosilicates and the most magnesian femic minerals). Partial loss of heat also takes place from the magma in the conduits. As a result, the drop between the temperature of the melt, captured by the mineral during the earliest phase of crystallization, and that (the lava) erupted on the surface,

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*The anomalous nature of the inclusions by no means reflects the true temperatures of crystallization, since above 1250°C, nepheline passes into carnegieite.

may be 200-300°C.

[169] 1. COMPARISON OF RESULTS FROM DIRECT DETERMINATIONS OF TEMPERATURES OF MINERAL-FORMATION WITH DATA OBTAINED FROM OTHER GEOTHERMOMETERS.

In the second chapter, we considered a whole series of indirect geologic thermometers of the type, material composition of mineral - conditions of its formation, and also certain criteria, introduced in order to establish the validity of the observed results. It is extremely important to recall that the data obtained with the aid of each such thermometer for the rock-forming silicate, by no means reflect the temperature of its crystallization, but the temperature of the established stability of its composition either during the late-magmatic stage of formation of the rock, or even during the phase of possible post-magmatic reworking of the latter.

The widely-known two-feldspar thermometers of Barth (1951, 1956, 1962), later interpreted (refined) by Ryabchikov (1965a,b), are not devoid of the deficiency noted. A detailed analysis of the merits and deficiencies of the Barth-Ryabchikov thermometers, accompanied by a comparison of the results obtained from them with homogenization-temperature data on gas-liquid inclusions (but not melt inclusions, which more closely reflect the true temperatures) in the same samples, has been carried out by Vartanova *et al*. (1972). These investigators studied 11 granitoid massifs in Transbaikalia of different scale and depth of formation. The overall assessment of such geothermometers made by them is as follows: higher figures (by 50 and sometimes, 70-80°C) have been obtained from Barth's diagram of 1956, as compared with the thermometer which he developed in 1962. In the great majority of cases, the temperatures, based on Ryabchikov's geothermometer (1965b), are significantly lower than those obtained by Barth's method, especially if they are compared with the results from Barth's (1956) diagram, where the difference sometimes reaches 260°C. In general, the homogenization data for gas-liquid inclusions in quartz and feldspar from these same analyzed samples, obtained by Z.V. Shcherbakova (*in* Vartanova *et al*., 1972), reflect markedly higher (by 100 and even 200°C) crystallization temperatures for the granitic melt, than for any of the indirect geothermometers. The reasons for such discrepancies have been considered above.

An analogous situation has been observed in the application of Perchuk's indirect geothermometers (1965, 1970). The difference in temperatures, recorded from diagrams of the nepheline - alkali feldspar phase relationship (Perchuk, 1965) and those obtained by T. Yu. Bazarova during the homogenization of gas-liquid inclusions in nepheline from these same samples, is 350-450°C, with the indirect geothermometers almost always giving values that are too low.

The condition of strict equilibrium between the associated minerals in a defined interval of *PT* parameters is one of the unconditional premises in the regional-metamorphic processes. However, a comparison between the temperatures, taken from Perchuk's diagrams (1970) for completely real multi-mineralic associations, frequently gives unsatisfactory results. Thus, on the basis of chemical analyses of minerals for the triple parageneses, hornblende - clinopyroxene - orthopyroxene, and hornblende - clinopyroxene - garnet from rocks of different metamorphic facies, Kostyuk (1970) has made an estimate of the temperatures of equilibrium coexistence for each of the listed pairs

of minerals in the triple and even quaternary parageneses. Firstly, it has been recorded that there is a significant spread of data, obtained for identical associated pairs, belonging to a particular metamorphic facies, and secondly, there is a significant disagreement in the results obtained for different associated pairs of minerals from a single
[170] polymineralic rock. The difference in temperatures in the best case is 50-100°C, but it frequently reaches 200-300 and even 500-600°C.

The geothermometers developed by Hamilton & Mackenzie in 1960, and Hamilton (1961) for nepheline-bearing rocks have been widely accepted by investigators. The basis of these thermometers is the principle which associates certain features of the chemical composition of nepheline and K-feldspar with the temperatures of formation. The authors used the ratio of the Na-K minals in nepheline, on the one hand, and the relationship between the latter and 'excess' silica, on the other, in the system $NaAlSiO_4 - KAlSiO_4 - SiO_2 - H_2O$, which vary according to temperature. The isotherms of Hamilton's diagram (1961) (500, 700, 775, and 1068°C) have been plotted on the basis of points of stoichiometrically ascribed compositions. And since the compositions of such synthetic nephelines have been defined by the quenching method, the chemistry of the mineral, in each case, has naturally reflected the 'magmatic' stage of its crystallization. Thus, the isotherms on the diagrams under consideration, constructed for nephelines synthesized under strictly controlled conditions (stoichiometric ratios of components, and water temperatures and pressures), which initate the crystallization of nepheline and alkali feldspar from a melt, undoubtedly correctly reflect the interrelationship between the mineral composition and the *PT* parameters of its formation.

In addition, it has been revealed that the use of such isotherms for establishing the temperatures of formation of natural nephelines is faced with a series of difficulties. 1. The composition of the natural melt is much more complex than that set in the experiment. In this case, the parameter of pressure, created by the volatile components, remains completely unknown. The pressure may either be similar to that set in the experiments*, or may differ significantly from it on either side. 2. During post-magmatic evolution, there is a process of adaptation of the natural framework aluminosilicates to the new physicochemical and *PT* conditions with corresponding redistribution of the isomorphous elements among the associated minerals. These compositions, already new in most cases, do not reflect the true temperature of their crystallization, but that of the established equilibrium (phase relationship). Hamilton's (1961) diagram associates, as has been noted, the mineral composition with the actual *PT* conditions of its formation. Hence the particular discrepancies which also result during the removal from it of temperatures for such already transformed natural aluminosilicates. 3. Both the quality of the chemical analysis of the mineral, and also the method of calculating its composition, have a marked influence on the results obtained, since according to the accepted formula for calculation from the isotherms, far from identical results may be obtained (Kostyuk, 1971).

A comparison of the data based on temperatures obtained by the method of homogenization of inclusions in nepheline, with those taken from Hamilton's (1961) diagram, for the same samples, frequently displays a complete coincidence in the results or a discrepancy of 20-30°C.

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*The experiments have been conducted at a stable water-vapor pressure, approximately equal to 1 kb, or more precisely 1063 bars.

However, in most cases, this difference is 100-150°C and more (Kostyuk & Chepurov, 1975). The reason for this is in part imprecision in determining alkalies in the analyses of nephelines, but mainly, apparently, a significant redistribution of elements during the post-magmatic phase, whereas the inclusions preserved in the mineral-host reflect the temperatures inherent in the melt at the time of its crystallization.

In summarizing what has been said about the means and methods of establishing the crystallization temperatures of the rock-forming minerals in igneous rocks, once again we shall adopt the position that [171] all the numerous indirect geothermometers are based on one and the same principle, the mutual conditionality of the chemical properties of the mineral (including its content of particular trace elements) and the PT conditions of its crystallization. Since, however, the overwhelming majority of the rock-forming silicates belong to solid solutions with complete or limited isomorphism of the principal elements (K-Na, Na-Ca, Fe^{2+}-Mg, Fe^{2+}-Mn^{2+}, Fe^{3+}-Al, Fe^{3+}-Ti^{3+}, Al^{3+}-Si^{4+}, Ti^{4+}-Si, etc.), then as the PT parameters in the crystallizing system change, there is an inevitable alteration in the ratios of the isomorphous mixtures, that is, redistribution of the defined pairs of elements takes place, which is common for two or more associated minerals. And because the temperature range of existence of the melt may be extremely drawn out, judging from the melt inclusions in odinite from 1100-1200 to 600°C, transformation in minerals with isomorphous mixtures are also achieved down to the lowest-temperature stages of the magmatic, and sometimes the post-magmatic history of the mineral. Only in the case of quenching of the mineral (volcanic eruptions, diatremes, and thin volcanic bodies) may we estimate the possibility of determining with the aid of indirect thermometers, temperatures close to their true value. Hamilton's (1971) geothermometer occupies a special place in this respect, and it has been discussed in greater detail above.

The most objective method is that of direct thermometric investigations, enabling us on the basis of melt inclusions to reconstruct not only the temperatures of the earliest stages of magma crystallization, but sometimes also the thermal evolution of these stages in time, down to the relatively lowest-temperature phases.

2. COMPARISON OF RESULTS FROM DIRECT DETERMINATIONS OF PT CONDITIONS OF MINERAL-FORMATION WITH DATA FROM AN EXPERIMENTAL INVESTIGATION OF THE CORRESPONDING MINERAL ASSOCIATIONS

An extensive list of published works has been devoted to clarification of the results of an experimental study of the processes of mineral-formation under the most varied prescribed original conditions. Of course, we have the possibility of commenting only extremely briefly on some of them, which reflect a more or less close similarity to natural systems, and which have been studied thermometrically.

The most reliable and close to actual results may be provided by experiments either on relatively dry melts of the basaltic type, or those carried out during the synthesis of anhydrous minerals in 'dry' systems, because the presence of water substantially displaces (lowers) the points of eutectic crystallization of the phases. And because the amount of water contained in actual melts remains almost unkown to us, the extrapolation of experimental data from aqueous systems into natural processes is frequently highly provisional.

For the basaltic compositions, beginning with the extremely basic picritic varieties and extending to the olivine nephelinites and leucite basalts, there is a series of experimental works, carried out by Yoder & Tilley (1963, 1965), Tilley, Yoder & Schairer (1969, 1971), Schairer & Yoder (1971), T.H. Green & Ringwood (1968, 1970), D.H. Green & Ringwood (1970), Cohen et al., (1970), etc. In essence, almost all the experiments have been carried out on the melting of natural basalts or chemically identical synthetic glasses either at atmospheric pressure, or on 'dry' systems at increased and high pressures, or finally, at the appropriate pressures created by water vapor.

[172] In the earliest series of experiments, carried out in 1956 by Yoder & Tilley (1963), by melting tholeiitic basalt from Kilauea at atmospheric pressure, the following sequence of crystallization was established: olivine (1235°C) → clinopyroxene (1190°C) → plagioclase (1170°C); the process terminated completely at 1090°C. A study of the three most important types of basalts (tholeiitic, alkaline, and high-alumina) led the authors to the following conclusions: 1) under experimental conditions, all three basic phases are crystallized within a small temperature range; 2) all three main phases appear together at an approximately identical temperature (from 1160 to 1170°C), independent of the bulk composition of the basalt; 3) the complete range of crystallization is small, of the order of 150°C; 4) for the basalts under consideration, olivine or plagioclase appear on the line of liquidus as far as pyroxene. In principle, such experiments based on the melting of 'dry' basalts were carried out by these authors in 1962 (Yoder & Tilley, 1965), with only one difference -- the investigation was extended to 10 samples of basalts mainly from the volcanoes of the Hawaiian Islands.

The authors concluded that the order of crystallization of the minerals in the melt remained essentially the same, although in a number of cases (commonly in the non-olivine basalts), it was achieved according to a somewhat different scheme: olivine → plagioclase → pyroxene.

A series of experiments, similar in their operation, but with a greatly expanded assortment of basalts from picritic varieties to alkali basalts and olivine nephelinites, was carried out by Tilley, Yoder & Schairer from 1962 to 1965 (Tilley et al., 1969, 1971). In this instance, an extraordinarily high initial crystallization temperature for olivine was established (up to 1245°C) in the picritic basalts, whereas in the normal tholeiitic basalts, it lay in the range from 1245-1175°C. However, the precipitation temperatures for clinopyroxene (1160°C) and plagioclase (1155°C) remained in these and other rocks perceptibly constant and almost identical. A different order of crystallization was recognized by these authors in the alkali-basalt series. Usually, the olivine and plagioclase here have been interchanged in places, that is, the process proceeds according to the scheme: plagioclase (1187-1140°C) → clinopyroxene (1160-1100°C) → olivine (1065-1130°C). Only in the olivine nephelinites, where nepheline and melilite appear instead of plagioclase, is the normal scheme retained: olivine (1300-1260°C) → pyroxene (1190-1160°C) → melilite (1130-1100°C) → nepheline (1080°C). In regard to the order of precipitation of the minerals, Tilley et al. (1969) have noted that in the more basic melt compositions, the crystallization series opens with olivine, whereas in the more ferruginous compositions, it gives place to plagioclase and very rarely, pyroxene.

By melting picrites (meimechites), containing (?) 3% of water in the glass, at a pressure of 8 kb, it was revealed that the lower temperature limit of crystallization of forsterite (Fo_{85-88}) lies at 1450°C (the upper limit is raised to approximately 1750°C); lowering the temperature of the differentiate, similar in composition to basalt ($\underline{n}_{glass} = 1.575$), is accompanied by the precipitation of anorthite (1200-1170°C), and at temperatures around 1150°C, crystallization of clinopyroxene begins (Genshaft et al., 1968). Homogenization of melt inclusions in the meimechites has established analogous limits for the formation of the minerals (see Table 9): forsterite, 1450 ± 30°C; clinopyroxene, 1230-1170°C (plagioclase is absent). The break between the lower limit of cyrstallization of forsterite and the commencement of precipitation of clinopyroxene (± plagioclase) in the picritic basalts and meimechites has turned out to be perceptibly constant, and is 220-250°C. It remains almost as high (160-190°C) for Mg-olivine and diopside in the biotite peridotite-porphyrites from Central Alaan (Chepurov, 1973b) and the gabbroids from Malyi Semyachik volcano in Kamchatka (Selyangin, 1973).

[173] Assuming a value for adiabatic cooling at ca 4-5°/kb, we obtain a pressure drop between the crystallization of olivine and pyroxene of about 40 kb. The unusually deep-seated nature of the olivine in the meimechites is suggested by its high content of chromium in the form of Cr^{2+} (up to 0.11%; N.V. Sobolev, 1971), which is associated with the low oxygen potential. For the Earth's mantle, this primarily characterizes the deep-seated nature of the process. These figures are comparable with the amount of chromium in the olivines of diamond-bearing kimberlites, particularly from the inclusions in diamonds, formed at depths of 150-200 km.

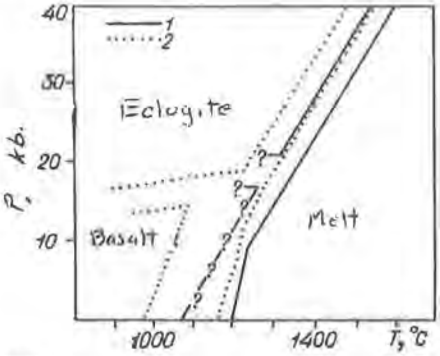
The temperature break is significantly reduced to 60-80°C in the basalts. It is normal for the temperatures of precipitation of pyroxene and plagioclase (or nepheline) to be very similar, with the differences not exceeding 10-20°C, and this pattern is maintained not only in the synthetic, but also in the natural basaltoids, including the alkaline types also (the basaltoids of Iceland, the nepheline basalts of Hungary, the leucite phonolites of Vesuvius, the dolerites of Yessei, etc.; see Tables 6-8).

The highly potassic mafic and ultramafic rocks of the Bufumbira Province in the East African rift zone, with their normal assemblage of minerals (forsterite, diopside, åkermanite, and leucite), have been experimentally studied by Gupta (1972) at atmospheric pressure. By the method of dry fusion, he established the temperatures of crystallization of the triple points for such associations as $di_{39}ak_{29}lc_{32}$ (melilite leucitite rock), 1281°C; $fo_{3}di_{60}lc_{37}$ (ugandite), 1296°C; and $fo_{17}ak_{78}lc_{5}$ (katungite), 1428°C. As in the case of the subalkaline picrites of sodic affinities, the temperatures of formation of the potassic basaltoids and ultramafites have turned out to extremely high, which also conforms with the information on the homogenization temperatures of inclusions in the minerals from analogous rocks (olivine 1300°C, then leucite 1250°C and pyroxene from the same sample at 1200°C in the leucitites of Visoke Volcano in the Bufumbira Province; see Tables 7 and 8).

During the fusion of an anhydrous basalt of the olivine tholeiite type from New Mexico, at an overall pressure of up to 40 kb, Cohen et al. (1970) have ascertained that at $\underline{P} = 1$ atm, olivine ($\underline{f} = 55$ mol %) and plagioclase (An_{60}) appear on the liquidus line almost simultaneously at a temperature of about 1200°C, and clinopyroxene begins to separate at somewhat lower temperature values. However, at a pressure exceeding

9 kb, olivine has not yet formed, and the paragenesis pyroxene + plagioclase remains stable up to 17 kb. The liquidus temperature in the field of basalts at low pressures (upper limit 8.25-10 kb, defined by the disappearance of olivine) does not exceed 1265°C. The field of basalts at high pressures (ca 9-17 kb) is limited at the top by the appearance of an essentially almandine garnet (about 50 mol. % alm). The liquidus temperature within the 20 kb limit rises to 1380°C. It is extremely noteworthy that with increase in pressure, the plagioclase becomes more sodic and at P = ca 17 kb, its basicity may fall to An_{25}. The melting curves are shown in Figures 29 and 30.

Experiments on the fusion of four samples of basalts (olivine tholeiite, high-alumina, alkaline, and oxidized) in the temperature range of 600-1250°C and water pressures of 1, 2, 5, and 10 kb, led Yoder & Tilley (1965) to such general conclusions as: a) with increase [174] in water pressure, the liquidus temperatures are lowered significantly (at P_{H_2O} = 5 kb, the difference is more than 100°C as compared with the crystallization temperature of the melt in a dry system); b) the change in water pressure may be accompanied by a change in the sequence of crystallization phases; c) the interval of crystallization pressures and temperatures for basaltic compositions expands significantly with increase in water pressure; d) amphibole may exist in restricted limits in equilibrium with olivine and clinopyroxene.



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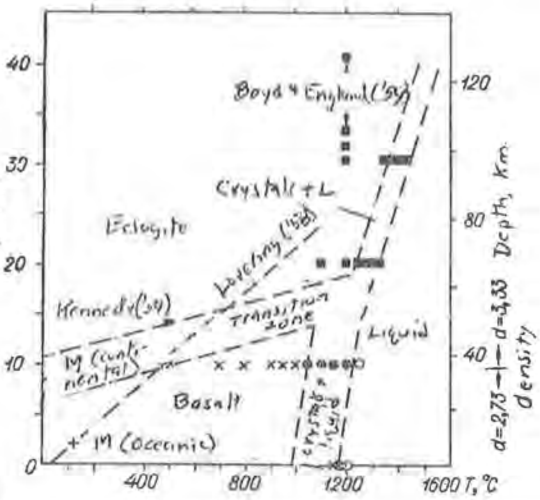

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Fig. 29. Melting curves for basalt:
1) from Buffalo region, New Mexico, after Cohen et al. (1970); 2) after Yoder & Tilley (1965).

Fig. 30. Stability fields for basalt and eclogite (after Yoder & Tilley, 1965).

According to T.H. Green & Ringwood (1970), who fused the glasses from natural basalts, identical to the high-alumina quartz tholeiites, at 1100°C and P_{H_2O} = 9-10 kb, the presence of water lowered the crystallization temperature on the liquidus curve by approximately 200°C. The sequence of precipitation of minerals was as follows: clinopyroxene → orthopyroxene → amphibole (ca 960°C and below) → plagioclase (ca 920°C).

Thus, we have been concerned with two cases of experiments, extreme in methodological respects, with basalts ('dry' melt and fusion at pressures created by water). In the great majority of experiments of Yoder & Tilley (1965), from 15-16 to 22-24 wt. % of water was added to the ampoule. T.H. Green & Ringwood maintained the condition that $\underline{P}_{H_2O} < \underline{P}_{load}$.

According to the latest investigations of Kadik, Lebedev & Khitarov (1971), at a temperature of 1200°C and 2000 atm, 4.6 wt. % of water is dissolved in the basaltic melt, and at 5000 atm, not more than 8.5 wt. % of water. Consequently, the above-noted amounts of water were clearly in excess above saturation by the melt in the experiments.

The most significant conclusions from the experiments with basaltoid compositions amount to the fact that if the natural samples, assumed to be alkaline basalts, contained olivine, clinopyroxene, and intermediate plagioclase in the phenocrysts, then their fusion in a water-saturated system will lead to the appearance of amphibole and mica in different combinations with the above-indicated minerals. So far, data are available on the crystallization of such amphibole-bearing rocks from Mayo Island, where the temperature of homogenization is in fact somewhat lowered (it lies near 1150°C). However, it is much higher than the crystallization temperatures of the water-saturated melts and corresponds to a water content of not more than 2-3%. The amphibole andesites of Kamchatka are extremely high-temperature and consequently dry magmas (for the plagioclase, the homogenization temperature exceeds 1360°C; see Table 2).

The extremely extensive information on the homogenization temperatures of melt inclusions in minerals from rocks of the basaltoid family in general (see Tables 6-8), normally exceeding 1100and even 1200°C, most probably reflect an analogy with experiments on dry basalt fusions. It is evident that these data emphasize the prevalent hypothesis in petrology concerning the relative paucity of water in natural ultramafic and basaltoid melts.

[175] Experimental work, involved with a study of the conditions of mineral-formation in ultramafic and mafic rocks of the intrusive facies, has in most cases been a continuation of experiments based on the fusion of natural basalts or synthetic glasses corresponding to them in composition at increased temperatures, but mainly at increased and high pressures (Green & Ringwood, 1968; Cohen et al., 1970), or by fusion of dry systems of basic composition at atmospheric pressure (Yoder & Tilley, 1965; Schairer & Yoder, 1971; Tilley, Yoder & Schairer, 1971; etc.).

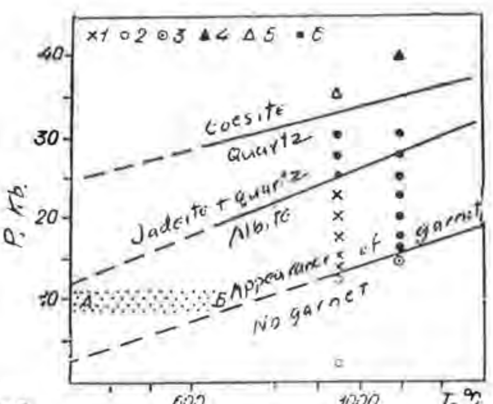
According to T.H. Green and Ringwood (1968), at moderate total pressures of the order of 10 kb in melts of the calc-alkaline series, the temperature of fusion of a quartz-tholeiite composition is 1280°C, and of an extremely acid rhyodacite, 1200°C (as noted above, the pressure of water vapor in this same system lowers the liquidus temperature by approximately 200°C). Complete crystallization of a quartz-tholeiite melt at pressures of the order of 17 kb and $\underline{T} = 1250°C$ (boundary of the 'transition zone' into eclogites, according to Cohen et al., 1970) ends with the appearance of the association clinopyroxene + plagioclase + garnet + ore mineral. The rhyodacite composition at 13 kb and 1100°C forms a quartz - K-feldspar - pyroxene association. According to Cohen et al. (1970), with $\underline{P}_{total} < 9$ kb and $\underline{T} < 1200°C$, a rock of the olivine-gabbro type will crystallize on the solidus curve: olivine (hyalosiderite) + plagioclase (labradorite) + clinopyroxene, and in the zone bounded by pressures of 9-17 kb and $\underline{T} = 1200-1270°C$, the olivine in this association becomes unstable and disappears. These parameters thus characterize the field of stability of the two-mineral gabbro.

Experiments with synthetic compositions, corresponding to an anhydrous adamellite, were carried out at high pressures and temperatures by D.H. Green & Lambert (1970). At 950°C and P_{total} = 2.5-12.5 kb, the principal minerals forming are quartz, alkali feldspar ($san_{50}ab_{50}$), and plagioclase. The presence of pyroxene at P = 2.5 kb has been suggested, but at 12 kb it is already clearly diagnosed. At P = *ca* 14 kb, garnet appears, associated with the above-listed minerals. The position of the curve for the formation of garnet on the *PT* diagram for acid melts, according to the authors, is reflected in Figure 31. This system readily explains the possible means of origin of the charnockitic rocks, which form, apparently, at extremely large pressures of the order of 12-13 kb. However, it is difficult to extrapolate it onto the normal granitic melts, since the latter are significantly saturated in water and, moreover, the granites, which crystallize under crustal conditions, scarcely could have undergone the indicated or even higher pressures, reproduced by the authors. Thus, the experiments have established that, complete melting is achieved in the water-saturated systems of acid (granitoid) composition in the range of 730°C at P_{H_2O} = 1 kb and 640°C at P_{H_2O} = 5 kb (Tuttle & Bowen, 1958). These figures certainly only define the possible lower temperature limits of the existence of the melt, that is, its state close to the solidus curve, because the available information on the homogenization temperatures of melt inclusions in the minerals of granites and of some granitic pegmatites indicates much greater *T*-parameters for their crystallization, sometimes exceeding 1000°C. The solubility of water in a granitic melt, according to Kadik *et al.* (1971), is 8.5 wt. % at 3500 atm and 800°C, or 11.3 wt. % at 5000 atm and 640°C on the solidus curve. In other words, in granitic compositions, sufficiently saturated in water, melting should be achieved at extremely moderate temperatures and pressures.

The system $K_2O - Al_2O_3 - SiO_2 - H_2O$ has been studied by Zharikov *et al.* (1968), Ivanov *et al.* (1969), and Ivanov & Zharikov (1972). And
[176] although these same investigators consider that this system is of interest in identifying the conditions of formation of the pegmatites, greisens, and various metasomatites, allowing for the fact that the upper *PT* limits (up to 700°C and P_{H_2O} = 1000 kg/cm^2) correspond to those in the experiments of Tuttle & Bowen (1958), it may be partially extrapolated into the processes of granite-formation, since here also, at 600°C a stable quartz - K-feldspar (sanidine)-muscovite association appears. The results of the most important experiments are reflected in Figures 32 and 33.

Briefly summarizing the available information on the conditions of deep-seated mineral-formation, obtained by completely different methodological means, we may note that the data on the homogenization temperatures of melt inclusions in rock-forming minerals, illustrated in generalized form in Tables 2, 3, 5-15, reflect their extremely complete agreement with the data from experimental investigations on corresponding compositions. It may be emphasized that, with moderate water-saturation under isoboric conditions, the temperature curve for the solidus of ultramafic and mafic calc-alkaline compositions is located above that
[177] for acid compositions, that is, the lower temperature limits of their crystallization are directly related to the chemical composition of the melts. This range turns out to be extremely extensive, from 1350 to 1300°C in the leucite ultra-mafic rocks and tephritic compositions down to 700-680°C in some acid rocks, and also the sodic alkaline melts. It

has been established experimentally that the temperature break between the solidus and liquidus curves for basaltic compositions (the complete



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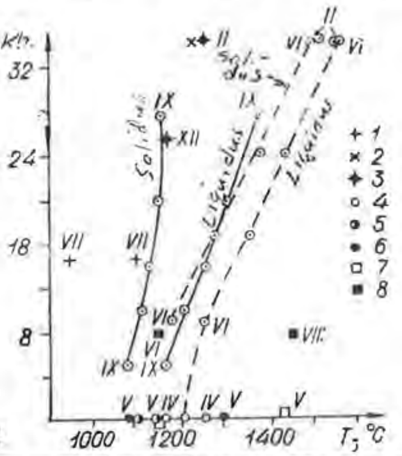

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Fig. 31. Stability of minerals in a rock, corresponding in composition to an average adamellite, under conditions of high temperatures and pressures. Associations: 1) qz + pfs + kfs + px + gar; 2) qz + pfs + kfs + px; 3) qz + kfs + px; 4) coesite + kfs + px + gar; 5) qz + coesite + kfs + px + gar; 6) qz + kfs + px + gar; A-B) range of probable variations in temperature at base of continental crust (after Green & Lambert, 1970).

Fig. 32. Melting curves for rocks of varying basicity at high temperatures and total pressures in the range of 1 - 35,000 bars in dry systems. 1) granites; 2) dacites; 3) andesites; 4) tholeiitic basalts; 5) trachybasalts; 6) nephelinites; 7) picritic basalts; 8) ultramafics. Sources: I) Kadik et al. (1971); II) V.A. Zharikov and Yu. A. Litvin (pers. comm.); III) Tuttle & Bowen (1958), synthetic melt of system ab - or - SiO_2 - H_2O; IV) Yoder & Tilley (1965); V) Tilley et al. (1971); VI) Cohen et al. (1970; VII) D.H. Green & Lambert (1970); VIII) Genshaft et al. (1968); IX) Khitarov et al. (1972).

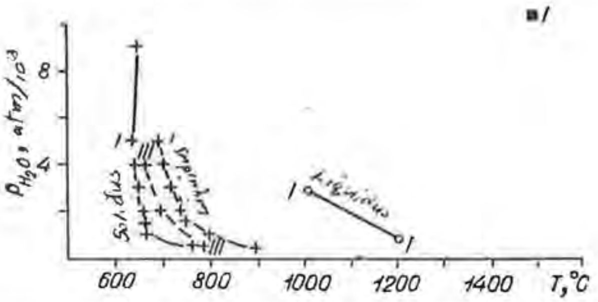

Fig. 33. Melting curves for rocks varying basicity at high temperatures and pressures, created by water vapor. For symbols, see Fig. 32.

interval of crystallization) is from 100-120 to 150°C. Judging from the data of T.H. Green & Ringwood (1968), it remains approximately the same in the dacites and the rhyodacites. Homogenization of inclusions in the central and marginal zones of the same phenocrysts of eruptive rocks, reflecting the stages of crystallization, close to the initial and terminal phases, supports approximately this same interval of crystallization for natural melts, corresponding to 100-130°C. It is evident, however, that the complete break between the liquidus and solidus curves here is even somewhat greater, since the arrangement of the inclusions may not strictly define either the very initial or the terminal moments of the crystallization process.

An experimental study of the anhydrous system $Na_2O - Al_2O_3 - Fe_2O_3 - SiO_2$ at atmospheric pressure, set up to represent the process of formation of certain types of alkaline rocks, was made in 1966 by Bailey & Schairer (1970). They obtained temperatures for a whole series of ternary points of the type ne-aeg-hem (908 and 893 ± 5°C), ne-aeg-di (727 ± 5°C), and ne-ab-aeg (858 ± 5°C), which in the nature of the associations approach to a certain degree the composition of the ijolites or (sometimes) the urtites. Commenting on the results of their experiments against the overall background of existing hypotheses proposed to explain the means of formation of the alkaline rocks, these authors have concluded that '...whatever the source of the melts, there can be no doubt as to the existence of an ijolitic magma'. In this respect, we may only note that the temperatures of eutectic crystallization obtained by Bailey & Schairer for a dry system have turned out to be relatively low, and it is, perhaps, difficult to extrapolate them into natural processes, since the lowest minimum homogenization temperatures for inclusions in minerals from melteigites of complicated platform assemblages rarely fall below 1100°C, and in general, exceed 1200°C (see Table 9).

Sokolov (1973), without indicating the minerals in which homogenization of melt inclusions was carried out, provided the overall temperature limits of formation of alkaline rocks of the carbonatite complex of the Kovdor Massif (Kola region): for a porphyritic ijolite, 1160-1100°C, and for a nepheline-pyroxene rock, 1000-880°C, that is, they are much higher than in the synthetic systems recorded. An apparent explanation may be that the typical melteigite-ijolites of the complex assemblages contain not acmite, but pyroxene close to diopside. In essence, it would be convenient to consider such a system here, but with MgO participating instead of Fe_2O_3. So far as we know, no such system has been examined.

There is a brief observation in Chapter IX on the experiments, associated with explaining the possibility of the existence of carbonatite melts in nature.

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The effect of coloration of certain salts under the influence of X-rays is suggested for rapid and valid identification of minerals (salts) present in inclusions of solutions and melts. Experiments have been made with the most common daughter minerals (NaCl, KCl), confirming the method. The recognition of daughter minerals in multi-phase inclusions of mineral-forming solutions and melts has been up to now an extremely difficult operation, because of their very small size. Existing methods for the identification of ultra-microscopic phases have been rather completely expounded in papers by Ermakov (1) and Roedder (2), where the authors with exhaustive depth reveal the problems of the new fields of mineralogy and thermobarometry -- ultramicromineralogy -- and discuss the prospects of its development. The main tasks of the identification of daughter minerals are the explanation of the features of chemical composition of the inclusions within minerals for the solution of important genetic problems of the mineral world. Regrettably, up to the present the most practical method of determination of the composition of inclusions is the analysis of aqueous extracts, permitting one to show only the soluble components. This method has many inadequacies, the principal one being that it gives information on the total composition of (a mixture of) inclusions of different genesis. The possibility of microchemical methods of analysis of the composition of individual inclusions is very limited, because sufficiently large inclusions are very rare in nature.

An ideal method for the study of the geochemistry of mineral-forming solutions is the determination of the salt content of individual inclusions without opening and with minimum expenditure of time. Here the most promising point is the identification of solid salt phases (daughter minerals), present in the inclusions at ordinary temperatures or precipitated by artificial cooling. For this purpose the authors propose the application of the long known and physically studied effect -- the coloring of certain salts (minerals) under the influence of X-rays. Especially detailed studies have been made of the effect of coloring by X-ray treatment of alkali halides, and especially of NaCl and KCl. It is precisely these salts (halite and sylvite) that are the most abundant daughter minerals in fluid inclusions.

Experimental tests of the possibility of identification of alkali halide salts by the coloring by X-ray treatment of inclusions of fluid phases were carried out both on synthetic as well as natural inclusions. The former consisted of hermetically sealed (fused) flasks of volume 1.5-2.0 mm^3, in which in equilibrium with saturated solutions were individual crystallites of NaCl, KCl, and mixtures of them. Irradiation of the flasks for 15 minutes by X-rays (tube with tungsten anode, voltage 40 kV, current 40mA) caused intense coloration of the crystallites of NaCl in a yellow color, of KCl in deep lilac, which permitted one without difficulty to distinguish these phases visually in the mixtures. The intensity of the color is dependent on the radiation dose and fades gradually under the influence of daylight. Under natural conditions studies were made of the coloring of NaCl (halite) in gas-liquid inclusions in calcite and quartz. The results were analogous. The crystals of halite acquired a noticeable yellow color, even at high magnifications. It is characteristic that the minerals containing the inclusions (quartz and calcite) are not changed and their transparency after irradiation is not decreased. Of importance is the possibility of coloration of hydrohalite ($NaCl \cdot 2H_2O$). This permits one rather accurately to determine the presence of small amounts of NaCl in the solution and to determine its concentration in a relatively simple way.

Besides the minerals mentioned, coloration is acquired by NaF (villiaumite) and LiF, the former rose, the latter brown. One might expect coloration of elpasolite (K_2NaAlF_6), cryolite (Na_3AlF_6), and other minerals, already known or not yet identified in multi-phase inclusions of solutions and melts. Experimental studies are necessary on the effects of different impurities in the minerals on the speed and intensity of their coloration in order to obtain more information on the usefulness of the proposed method.

In conclusion, it must be emphasized that the use of the effect of coloration of certain minerals for the accurate and rapid identification of daughter minerals without opening the inclusions is very promising and should be introduced into the practice of ultramicromineralogy.

Literature

1. Ermakov, N.P., Geochemical systems of inclusions in minerals, Moscow, "Nedra", 1972.
2. Roedder, E., in the volume, Geochemistry of hydrothermal ore deposits, Moscow, "Mir", 1970.

(Abstract translated by Michael Fleischer).

Indices

The user should keep in mind the following features of these indices. The indexing procedures and entries are evolving (particularly with this volume) and hence are not uniform from one volume of COFFI to the next, and even within a given volume consistency cannot be claimed, so caveat emptor. Where several different items in the given category occur on the same page, the number of such items is put in parentheses after the page reference. Some items may continue on to following pages. Transliteration of Cyrillic has not been uniform in the various sources used, and hence the user must look under both possible spellings, e.g., Ye and E, ...iy and ...ii, etc. As all entries in the Translation section are also entered in the Abstracts action in alphabetical order, no Author index is needed.

SUBJECT INDEX

See general notes above. I have tried to make this a user-oriented index rather than a documentalist's type index. Only data in the title and abstract are indexed, and then only if they appear to be of more than incidental mention. Misleading or erroneous translations may have resulted in occasional incorrect or omitted entries. Some entries are included under a given subject heading even though the index word does not occur in the abstract. The deposit type is indexed only where it is evident without research. The aim has been to err on the side of completeness and convenience to the user. Thus I have attempted to index some related or possibly pertinent items, and even ones involving negative data or evidence, under each category. The ore type terms such as porphyry copper and Mississippi Valley are used loosely. Analyses for specific elements are indexed only when they are particularly unusual or significant; thus semiquantitative spectrographic analyses are generally ignored. The mineral host for the inclusions studied is indexed except for decrepitation studies. Entries that would include too many page references are listed without page numbers. Some entries with broad and diffuse applicability (e.g., "Geobarometry, methods and comparisons") have only a few of the most pertinent page references.

DEPOSIT INDEX

Notes: See page 255. Individual deposit place names are indexed only when significant data are presented. Inexact place names (e.g., "Soviet Far East") are not entered, nor are individual mines in districts known by a district name. Soviet place names may be listed under various transliterations and in particular, with different endings; thus Began and Began'skii, Blyava and Blyavinsk, Kochkar and Kochkarskoje.

Errata

Note: This listing includes corrections to all published volumes. The editors would appreciate notice of any other errors or omissions.

	Volume	Page	Item†	Line*	
Text:	3	113	1	center	Change: cp = content; ah = anorthite? to cp = average; ah - analyses metasomatites to metasomatism
	4	51	3	5	Add: See Nash and Theodore, same page.
	5	118	1	2	Change: statistical to static
	5	118	1	25	Same change
	7	39	2	4	Change: (in Italian) to (in French)
	7	39	2	10	Delete word vitreous
	7	39	3	1	Change: Clocciatti to Clocchiatti
	7	62	6	4-5	Delete editorial note
	7	123	3	-12	Change: alkanes to alkenes
	7	154	1	3	Add: v.9
	7	167	2	--	Abstract for Petrichenko and Slivko, 1973a has wrong page numbers; it is the correct abstract for next item Petrichenko and Slivko, 1973b.
	8	28	3	bottom	Change: Zatsika to Zatsikha
	8	47	1	13	Add (5) after leachates
	8	47	1	13	Insert mass spec anals (2) show before G phase
	8	81	5	2	Add: In Carbon and its compounds in endogenetic processes of mineral formation - Abstracts of Regional Meeting, L'vov, Sept. 1975: L'vov, Acad. Sci. Ukrainian SSR.
	8	82	1	11	Change to read heterogeneous
	8	82	2	11	Change: in solution to into ores
	8	96	2	3	Change metasomatites to metasomatism
	8	98	2	bottom	Add: T_H 390-250° in greisens
	8	104	1	2	Add pp. 139-152
	8	104	1	9	Change to decarbonation
	8	120	2	8	Add: Silite is SiC in rod form
	8	141	3	1	Change: hypergene to supergene
	8	145	3	9	Insert (sic.) after 360°C
	8	159	1	4	Add: 120-820°C (sic.),...
	8	160	5	3	Change: metasomatites to metasomatism
	8	160	6	2	Change: metasomatites to metasomatism
	8	166	4	6	Change: H_2O to H_2O_2
	8	213	2	-10	Change: Basarova to Bazarova

† Partial items are also counted

* Minus sign refers to lines up from bottom of item

Index:	2	162	Samoylovich - change to 70(2)
	2	163	Add Yermakov - see Ermakov
	3	138	Halite deposits - add II-69,70
	5	142	Halite deposits - add pp. 39 and 97
	7	49	DOMINIQUE, Joseph, et al. - change to JOSEPH, Dominique, et al. and insert on p. 89
	8	223	Mass spectrometry - Add p. 47

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