IMA MEETING '74

INTERNATIONAL MINERALOGICAL ASSOCIATION

NINTH GENERAL MEETING

COLLECTED ABSTRACTS

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Main Session: PEGMATITES AND PEGMATITE MINERALS
Introductory lecture
GRANITIC PEGMATITES AND THEIR MINERALS:
SELECTED EXAMPLES OF RECENT PROGRESS

P.Cerný, Winnipeg, Canada

The pace of systematic investigation of granitic pegmatites
has slowed in the few past decades but considerable progress
has been made in the crystal chemistry of some minerals and
in petrological interpretation based on experimental work.
Recent developments in the mineralogy of pegmatites will be
shown on examples of the Fe, Mn, Ta, Nb oxides, phosphates,
lithium micas, and pollucite.

Advances in pegmatite petrology will be demonstrated on the
Jahns-Burnham and Stewart models, primary vs metasomatic as-
semblages, lithium aluminosilicates, feldspar chemistry, and
the graphic granite problem. A review of the petrography and
mineralogy of the giant Tanco pegmatite in southeastern Mani-
toba will be presented. The pegmatite, the world's largest
deposit of tantalum, cesium, and refractory-grade spodumene,
displays many characteristics supporting recent petrological
theories, but it also shows some puzzling phenomena which are
yet to be explained.

MINERALOGY AND STRUCTURE OF LITHIUM PEGMATITES

E.W.Heinrich, Ann Arbor, Michigan, USA

In homogeneous (unzoned), granitic, lithium pegmatites (Type I) high-iron spodumene is the sole representative of lithium. Increasing structural complexity of pegmatites is accompanied by increasing diversity of lithium mineralogy. Zoned pegmatites (Type II) rich in lithium contain zonal assemblages that include low-iron spodumene, petalite, triphylite-lithiophilite, and amblygonite-montebrasite, singly or in various combinations. Zoned pegmatites with superimposed replacement (secondary) units (Type III) can contain the additional lithium species: lepidolite, zinnwaldite and lithium tourmalines. In addition, this third complex class of pegmatites commonly is characterized by the presence of a variety of hydrothermal "decay" products that contain lithium:

From petalite: spodumene + 2 quartz intergrowth
("petamene", "spodulite", "squi")

From spodumene: eucryptite + albite — Li mica + albite
("cymatolite")

                cookeite
                bikitaite
                Li-clay minerals

From triphylite: tavorite

From amblygonite: palermoite, bertossaite, lithiophosphate

Lithium minerals formed exogenically in the metasomatic wallrock haloes of pegmatites that contain primary spodumene are lithium biotite and the lithium amphibole, holmquistite.

In contrast, in alkalic-granitic and nepheline-syenitic pegmatites, lithium is represented by the lithium micas, taeniolite, polylithionite and protolithionite, by lithium amphiboles (including Li-riebeckite), and by the fluoride, cryolithionite. In these petrologic categories of pegmatites discrete lithium species are restricted to structurally complex (Type III or "fully differentiated") pegmatites.

MINERALOGY OF THE PERALKALIC PEGMATITES

I.V.Bussen, E.M.Eskova, A.P.Khomyakov, Yu.P.Menshikov, A.N.Merkov, E.I.Semenov, Moscow, USSR

Pegmatites of agpaitic nepheline-sodalite syenites, rich in sodium, were earlier known in Greenland (Ilimaussaq) and Kola peninsula (Lovozero, Khibina). But these pegmatites on the surface were intensively changed. During last years new bodies of pegmatites have been found and investigated by the authors in deep part of Lovozero massif, much lower of water penetration zone. These pegmatites appeared to contain a lot of minerals, which are unusually rich in sodium and readily change and dissolve in water. Extra-ordinarity of these peralkalic pegmatites is emphasized by the finding of 11 new sodium and rare-metals silicates by the authors:

Mineral	Formula
Ilmajokite	$Na_2Ti[Si_3O_9]\cdot 4H_2O$
zorite	$Na_2Ti[Si_3O_9]\cdot 3H_2O$
penkvilksite	$Na_4Ti_2[Si_8O_{22}]\cdot 5H_2O$
kazakovite	$Na_6H_2Ti[Si_6O_{18}]$
vuonnemite	$Na_{11}TiNb_2[P_2Si_4O_{25}F]$
bornemanite	$Na_{12}Ba_2Ti_5Nb_2[Si_8P_2O_{44}]$
laplandite	$Na_4CeTi[PSi_7O_{22}]\cdot 5H_2O$
saghinite	$Na_3Ce[Si_6O_{15}]\cdot 6H_2O$
umbozerite	$Na_3Sr_4Th[Si_8O_{23}(OH)]$
lovdarite	$Na_3KBe_2Si_6O_{12}(OH)_8$
raite	$Na_4Mn_3[Si_8O_{21}]\cdot 10H_2O$

Peralkalic pegmatites and hydrothermalites (ussingite, natrolite) concentrate near foyaite and malignite horizon which is also extremely rich in sodium, rare and volatile components. Nearly horizontal pegmatite layer has thickness up to 1,6 m and length more than 26 m. Outer pegmatite zone (~0,5 m) consists of big crystals of microcline, sodalite, arfvedsonite, aegirite, eudialyte. Central zone (and apophyse) is mainly natrolitic. Natrolite (and analcite, ussingite) also form small hydrothermal veins with similar mineralization. In addition to our new minerals mentioned above nearly 50 other rare minerals were found here.

PETROGENESIS OF THE GRANITE-PEGMATITE-SYSTEM
IN THE NORTHERN END OF THE PIKES PEAK BATHOLITH, COLORADO

W.B.Simmons, New Orleans, and E.W.Heinrich, Ann Arbor, USA

A distinctive cluster of well-zoned pegmatites occurring near
the northern margin of the Pikes Peak batholith in Jefferson
County, makes up the South Platte pegmatite district. The whole
assemblage constitutes a well-defined granite-pegmatite system.
The major petrologic units are: 1) granite; 2) quartz monzonite;
3) pegmatite; 4) aplite dikes; 5) xenoliths of biotite gneiss,
granitic gneiss, and associated aplite; 6) quartzite dikes;
7) Idaho Springs Formation; and 8) high-level Tertiary gravel.
The granite occurs as an outer zone of the batholith and sur-
rounds the interior-zone quartz monzonite.

Normative analysis indicates that the granite and Q-monzonite
formed from liquids of essentially similar composition, their
differences being principally modal. Ab-Or-Q and Ab-Or-An-(SiO_2)
plots fall close to the minimum-temperature-melt compositions
in both systems. Plots of Ab/An and Ab/Q ratios versus P-T data
for experimental water-saturated melts indicate that the granite
crystallized under lower P_{H_2O} conditions than the Q-monzonite.

The district is characterized by over 50 large concentrically
zoned, nearly vertical pegmatites, which all occur within the
pluton rather than marginal or exterior to it. In shape and
external structure, two end-member types are distinguishable:
(1) vertical pipe-like bodies with essentially circular plans;
(2) vertical to steeply dipping, thick ellipsoidal lenses.
Pegmatites of the central group are restricted to elevations be-
tween 6800 and 7800 feet within the granite, forming a clearly
defined level of pegmatites. The concentric internal zonation
consists of the idealized sequence: 1) very poorly developed
border zone (usually absent), 2) wall zone of biotite graphic
granite, 3) outer-intermediate zone of giant biotite crystals
(rarely present), 4) intermediate zone of microcline-perthite,
5) core-margin zone of green fluorite, 6) large core of massive
quartz or quartz-microcline, 7) secondary replacement units,
containing albite, fluorite, rare-earth minerals and hematite.

Fractional crystallization of the Pikes Peak magma resulted in
water-enriched liquid segregates of residual fluids which be-
came the parent fluid from which the pegmatites crystallized.
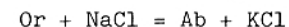
NEPHELINE PEGMATITES IN THE BANCROFT AREA, ONTARIO CANADA

G.M.Anderson, G.Sylvester and E.J.Reeve, Toronto, Canada

A narrow, discontinuous belt of syenite and nepheline syenite
gneisses extends for over 160 km in northern Ontario, trough
the town of Bancroft. Within the nepheline-bearing gneisses
there occur several large (50-100 m) pegmatite bodies consist-
ing almost entirely of albite-oligoclase, nepheline and bio-
tite. Two pegmatites and their adjacent gneisses in the York
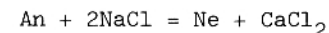River area have been diamond-drilled and studied in detail.

The gneisses and unzoned pegmatites have rather simple miner-
alogy with no unusual trace element concentrations and no rare
mineral occurrences. Plagioclase is generally unzoned, shows
two generations, and ranges from about An_1 to An_{30}. Nepheline
compositions cluster around $Ne_{77}Ks_{21}Qz_2$. Microcline is minor
and ranges from about Or_{70} to Or_{95}.

The bulk compositions of the pegmatites are $Ne_{67}Ks_{11}Qz_{22}$ and
$Ne_{50}Ks_{10}Qz_{40}$ (CIPW norms) and gneiss compositions are similar
but highly variable. These compositions cannot be derived by
differentiation of known igneous rock compositions, nor can
they represent partial melting of the host gneisses unless un-
realistically large degrees of melting are postulated.

Many of the compositional and textural features of these rocks
can be explained by the hypothesis that post-metamorphic ion-
exchange reactions between quartz-poor feldspathic gneisses
and NaCl-rich brines have taken place. The reaction:
$$Or + NaCl = Ab + KCl$$
depleted the rocks in Or content (thus the strange pegmatite
compositions) and the reaction:
$$An + 2NaCl = Ne + CaCl_2$$
produced nepheline. These reactions result in a second gener-
ation of plagioclase higher in Ab. In the presence of quartz
the reaction:
$$An + 2NaCl + 4SiO_2 = 2Ab + CaCl_2$$
enriches the rock in Ab and depletes it of quartz. The occur-
rence of sodalite sporadically throughout the belt shows that
NaCl was present.
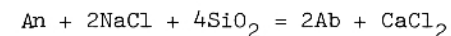
A NEW CALCIUM ZIRCONIUM SILICATE - ARMSTRONGITE,
ARMSTRONGITE - ELPIDITE ISOMORPHIC SERIES AND MINERAL
PARAGENESIS OF ZIRCON MINERALS IN ALKALINE GRANITE
PEGMATITES

N.V.Vladykin, V.I.Kovalenko, I.L.Lapides, Irkutsk, USSR

A new mineral - armstrongite, $CaZr[Si_6O_{15}]\cdot 2,5H_2O$, was
found in agpaitic alkaline granites and pegmatites of Han-
Bogdo massif in Mongolia and named in honour of N.Armstrong
- the first man who had set foot on the Moonland.
Han-Bogdo massif is a part of South-Gobi alkaline rock belt
and is composed of arfvedsonite granites. Numerous ekerite
and pegmatite dikes contain elpidite as rockforming mineral
(up to 20 %). Practically all known elpidites were of sodium
composition and it seemed to be no isomorphism in this group
of minerals. As CaO content in Han-Bogdo elpidites was 1-3,5 %
armstrongite appeared to be the pure calcium analogue of elpi-
dite. We assume the occurrence of elpidite-armstrongite iso-
morphic range with their limited miscibility. Decreasing of
density, increasing of refractivity and lowering of symmetry
from orthorhombic system to monoclinic system was found in
the elpidite-armstrongite range. Polysynthetic twinning was
found in armstrongite. Asymmetric isomorphism ($2Na \leftarrow Ca + vacancy$)
seems to occur in this case. The presence of alkali controls
the structural positions of water and dehydratation. Three
energetically different water positions and zeolite-like char-
acter appear to be revealed in this mineral group during ther-
mographical and IR investigation. Zirconium of Han-Bogdo mas-
sif is concentrated mainly in armstrongite-elpidite minerals
which are typomorphic minerals of alkaline granites in gene-
ral. They are associated with accessory synchisite, monazite,
rare-earth sphene, neptunite, spherulite of zircon, native
gold, and yellow titanosilicate.

TRIPHYLITES AND LITHIOPHILITES FROM THE GRANITE PEGMATITES
OF KITEE AND TOHMAJÄRVI PARISH, E-FINLAND

Pekka Kallio and Reijo Alviola, Haukilahti, Finland

A pegmatite bearing rare element minerals was discovered in
the Kitee-Tohmajärvi area in 1971. In 1972 and 1973 about 500
pegmatites were studied. Beryl was found in about 80 pegma-
tites and Li-minerals in 14 pegmatites. None of the pegmatites
proved to be economically important. The pegmatites are as-
sociated with the tourmaline-bearing Kitee granite; they occur
in Karelian micaschists, quartzites, black schists and amphi-
bolites. According to radiometric determination (U-Pb-age from
zircon) the age of the pegmatites is 1810 m.y. Microcline,
albite (including cleavelandite), quartz, muscovite and black
tourmaline are the main minerals. Beryl, garnet, apatite (of-
ten hydroxylapatite) and Fe,Mn-phosphates are common. Arseno-
pyrite, löllingite, pyrite, pyrrhotite, sphalerite, uraninite
and columbite are also met with, but in minor amounts. Green
and red tourmaline, montebrasite, spodumene, cassiterite and
lepidolite occur in only a few pegmatites.

Fe,Mn-phosphate crystals or nodules were found in 14 pegma-
tites. The biggest nodules are 30-50 cm in diameter; usually
the nodules measure 1-3 cm. The most common Fe,Mn-phosphates
are triphylite-lithiophilite, sicklerite, heterosite and
alluaudite. In some pegmatites triphylite is the primary min-
eral of the big nodules, in other lithiophilite.

In the big nodules triphylite is covered by concentric shells
of alteration products. Greenish grey triphylite is surrounded
by brown ferrisicklerite, while the outermost shell consists
of green vivianite and yellow ludlamite or purple heterosite.
The border between ludlamite and vivianite is gradational;
other borders are sharp.

The lithiophilite nodules consists of Ca-poor lithiophilite
interlaminated with a Ca-Mn-Fe-phosphate (electron microprobe
analysis). The X-ray diffraction powder photographs indicate
that also the interlaminating mineral is lithiophilite. Both
minerals have been partly altered into alluaudite and tri-
ploidite.

A NOTE ON SCORZALITE FROM ZENAGA PLAIN PEGMATITES, ANTI-ATLAS, MOROCCO

A.M.Fransolet, Liège, Belgium

In the phosphates from the precambrian pegmatites outcroping in Zenaga Plain (Anti-Atlas, Morocco), scorzalite frequently occur.

On account of the very fine grained shape and the mixture of muscovite, apatite, hematite, quartz and also mitridatite, the accurate determination of scorzalite is not easy. It is characterized by a unit-cell dimensions measurement and by a DTA curve. A qualitative test by microprobe shows a higher content in Fe with regard to Mg.

In the Angarf-Sud pegmatite, the phosphates have a zonal structure. A core of gray triphylite, widely replaced by green alluaudite, is fringed by reddish fine-grained apatite. The more important secondary phosphates are: barbosalite, tavorite, melonjosephite, hureaulite and whitlockite. Quartz and mainly pyrite are also associated. If muscovite occurs in this assemblage, it is systematically accompanied by scorzalite and fringed by apatite.

Investigations of this blue phosphate under microscope show an interesting paragenesis. Scorzalite replaces muscovite and is inserted in its cleavage. Hematite and fine grained apatite are also present in the cleavage. Some quartz also crystallizes following this direction. Sometimes, the structure is cutted by mitridatite veinlets.

In the Tazzarine-Est pegmatite, scorzalite is embedded in heterosite. It replaces patches of muscovite completely; the structure is still remaining.

From these observations it seems that scorzalite forms under a low oxygen fugacity, probably immediately after magnesian triphylite and before alluaudite and apatite. The solution, rich in phosphorus, ferrous iron, with a little magnesium, reacts with mica that gives aluminium; SiO_2 and K are released. So it is not necessary to evoke a metasomatic process to explain presence of aluminium and, a recurrence phenomenon to explain ferreous iron and magnesium.

PHOSPHATE MINERALS FROM PEGMATITES OF THE NORTHEASTERN BRAZIL

R.Rodrigues da Silva, Recife, Brazil

Typical zoned granite pegmatites of the heterogeneous type, of the Northeastern Brazil have been investigated for their phosphate and associated mineral content.

The pegmatites under consideration occur in the States of Paraiba and Rio Grande do Norte, near the cities of Equador, Parelhas, Pedra Lavrada, Picos, etc. Besides those of the normal beryl-tantalite pegmatites the following minerals appear:
arrojadite, barbosalite, beraunite, chavesite, huréaulite, leucophosphite, metastrengite, mitridatite, scorzalite, tavorite, vivianite and others.

Detailed description of the occurrences, chemical analysis, physical properties, X-ray data (diffractometry and spectrography), thermal analysis (DTA and TGA) are given for these minerals.

PHOSPHATE MINERALOGY OF THE TIP TOP PEGMATITE, BLACK HILLS,
SOUTH DAKOTA, USA

W.L.Roberts, South Dakota, and George Rapp, Minnesota, USA

The Tip Top pegmatite contains thirty-seven mineral species,
twenty-two of which are phosphates. Of these only two, tri-
phylite and montebrasite, crystallized as primary minerals
in the late magmatic stage of crystallization. The other
twenty phosphate species are secondary minerals formed as
alteration products from the disintegration of large tri-
phylite masses in the presence of residual pegmatitic hydro-
thermal fluids.

The mechanisms contributing to the formation of this large
secondary suite are solution, alkali leaching, oxidation,
hydration, hydroxylation and Ca/Mg metasomatism. The secon-
dary phosphates formed by one or more of these mechanisms
are: ferrisicklerite, heterosite, mitridatite, laueite,
ludlamite, bermanite, rockbridgeite, hureaulite, fairfieldite,
collinsite, jahnsite, robertsite, segelerite, whitlockite,
leucophosphite, vivianite, hydroxyapatite, fluorapatite,
carbonate-apatite, and tavorite. New chemical and trace
chemical data on these secondary phosphates are included.

PEGMATITE PHOSPHATES: A MONOGRAPH

Paul Brian Moore, Chicago, USA

A monograph is nearing completion which exhaustively
treats the primary and secondary phosphates found in
pegmatites, excluding the complex uranyl phosphates
whose chemistry is as yet unresolved. Ninety-eight
species are included. The study involves a complete
collection of references, crystal drawings, crystal-
chemical characters, optical properties, paragenetic
settings and occurrences. Some salient features in-
clude:

1. Nine species new to science (jahnsite, segelerite,
   robertsite, foggite, whitmoreite, goedkenite, and
   three awaiting approval by IMA).

2. Revisions of the crystal chemistry of xanthoxen-
   ite, azovskite, souzalite.

3. Crystal drawings of the nine new species, dufren-
   ite, mitridatite and xanthoxenite.

4. Crystal structures of mitridatite, jahnsite, mont-
   gomeryite, whitmoreite, xanthoxenite, palermoite
   and stewartite.

5. A general paragenetic-crystal chemical outline
   stressing the crystal-chemical basis of the asso-
   ciations.

ACCESSORY MINERALIZATION AND GEOCHEMICAL SPECIALIZATION OF
MUSCOVITE PEGMATITES OF DIFFERENT REGIONS

B.M.Shmakin, Irkutsk, USSR

The most characteristic (typomorphic) accessory minerals of
muscovite pegmatites are the tourmaline of dravite-buergerite
series, the garnet with the predominance of almandite and the
fluorine apatite. But such accessory minerals as beryl, urani-
nite, zircon, allanite, monazite are only in some regions or
in some veins. Accessory columbite and cassiterite can be in
pegmatites of transition raremetal-muscovite specialization,
and when the latest albitization takes place in muscovite peg-
matites.

Among the element-impurities Ba, Sr, Rb and Cs show the most
regular behaviour. The very high content of the first two ele-
ments and the low content of Rb and Cs are characteristic for
early generations of potassium minerals in typical muscovite
pegmatites. Along with the transition to raremetal-muscovite
pegmatites one can see the decreasing of Ba and Sr but the in-
creasing of Rb and Cs. As a result the ratios Ba:Rb, Sr:Cs,
etc. in early generations of potassium minerals are good indi-
cators of pegmatite specialization. The content of Ti in micas
of typical muscovite pegmatites is maximal, but contents of Nb,
Ta, Sn, F are minimal and then the figure of Ti:Nb ratio in
biotite and muscovite can be the geochemical indicator of peg-
matite specialization too.

Be-content in rockforming minerals is in good correlation with
the quantity of accessory beryl in pegmatites. It is not accu-
rately connected with the geochemical specialization. The same
can be said on Li and Rare Earths contents. But all these ele-
ments and their correlations especially show regular behaviour
in processes of postmagmatic replacement of pegmatites.

The presence ot typomorphic accessory minerals and the concen-
tration level of element-impurities depend on conditions of
formations, first of all - on pressure and composition of vola-
tile components. But contents of other elements and minerals
depend on some additional factors. The composition of wall rocks
is among these factors.

MUSCOVITE OF THE PEGMATITES OF NORTHERN PORTUGAL AND ITS
GEOCHEMISTRY

Ana M.R.Neiva, Coimbra, Portugal

The muscovite from pegmatites has tabular habit, with greater
basal spacing than the muscovite from parental granites. There
is a muscovite like feathers which is later and has greater
basal spacing than the muscovite of tabular habit. Quantita-
tive determinations of major and trace elements of nineteen
muscovites from pegmatites and eleven muscovites from parental
granites are given.

The trend of fractionation granite muscovite $\longrightarrow$ pegmatite
muscovite is clearly defined based on trace elements and
trace element/major element ratios.

Correlation between some elements were found.

Considering the importance of tin-tungsten mineralization in
Northern Portugal, the study of muscovite shows the affinity
of Sn for F. Lithium and rubidium also accompany the increase
in Sn in the muscovites from pegmatites, while Sn and Ti vary
inversely. W and Mn increase together and they are more con-
centrated in the muscovites from pegmatites.

The muscovites from pegmatites which cut schists are poorer
in Cl, F, Sn, Li, Ni, Cu, Bi, Ba than the muscovites from peg-
matites related to the same parental granite, which they cut.

DISTRIBUTION OF Sr-ISOTOPES, K/Rb, AND Rb/Sr RATIOS IN
FELDSPARS AND MICAS FROM PEGMATITES AND ADJACENT ROCKS

J.Rimsaite, Ottawa, Canada

Distributions of K, Rb, Sr, and Sr-isotopes Sr^{86} and Sr^{87} were
studied in minerals from three Canadian Li-pegmatites and
syenite- and granite-pegmatites. The Li-pegmatites contain
variable quantities of beryl, pollucite, spodumene, or tour-
maline. One pegmatite is associated with commercial Nb-Ta
deposit, and the others, molybdenum and uranium occurrences.
The syenite-pegmatite is in a Ni-Cu mine. All pegmatites are
of Precambrian age and exhibit prominent replacement textures.
The highest concentrations of Rb and F are in lepidolites
that replace beryl and spodumene during the late pegmatitic
hydrothermal phase. These lepidolites contain very little
(less than 1 ppm) or no common Sr, in contrast to the pegma-
titic albite which contains very little Rb (3.6 ppm). The
relationships found between K, Rb, Sr common (Sr_c) and Sr radio-
genic (Sr_{Ra}) in minerals from the pegmatite and from adjacent
rocks are summarized in the following table:

Origin	Mineral	K/Rb	Rb/Sr_c	Rb^{87} ppm	Sr^{86} ppm	$\%Sr^{87}_{Ra}$	Sr^{87}_{Ra}/Sr^{87}_c
Li-pegmatite hydrothermal phase	Lepidolite	2.5-6	7000-15000	4000-9300	0.0-0.1	99	2250
Li-pegmatite main phase	Al,Li-micas	10-15	4000-6000	1400-2200	0.3-0.8	95-98	500-1000
" "	Biotite & Microcline	20	100-730	1100-1500	0.5-2.2	40-70	10-25
Li-pegmatite initial phase	Na-feldspar antiperthite	40	9	38	1.5	10	1.6
Gneiss & Skarn	Biotite	110-160	30-150	26-62	0.4-0.5	25-35	1.1-2.5
Metavolcanics Metagreywacke	Biotite	300-350	8-20	120-160	1.1-1.3	7-15	7
Micas assoc. w.serpentine	Muscovite Phlogopite	500	3	50-150	2-5	2.5-9	0.5-1.5
Syenite-pegmatite	Microcline perthite	400	0.5	60	46	0.17	0.024
"	Albite	2250	0.005	0.98	65	0.00	0.0
"	Biotite	160	97	120	0.44	25	1.8

LITHIUM - ALUMINUM MICAS FROM SOUTH WEST AFRICAN PEGMATITES

C.T.Logan, Johannesburg, South Africa

Chemical and X-ray data are presented for a series of
lithium-aluminium micas collected from various points
within lithia-rich South West African pegmatites.
The relation of structural type to compositional variation
and the environment of crystallisation is considered.
Temperature and pressure appear to have played a minimal
part in determining which polymorph crystallised, and
the structural type of mica occuring in these pegmatites
provides a reliable estimate of lithium-mica composition
between wide limits.

A PRELIMINARY STUDY OF TIN MINERALISATION IN BIHAR PEGMATITES, INDIA

N.K.Mukerjee, Varanasi, India

Several occurrences of tin deposits are known from different States of India, namely Bihar, Rajasthan, Gujarat and Karnatak. But none of them has so far been proved to be of commercial importance. On the face of acute shortage and steadily increasing demand of the metal in India, it has become imperative to undertake an intensive study of their geological and economic aspects.

The present paper, mainly dealing with the occurrences in Bihar, comprises of two parts. The first one records the different cassiterite deposits in the districts of Hazaribagh, Gaya, Ranchi and Singhbhum, and supplies short descriptions. In the second part, detailed investigations of the deposit in the neighbourhood of Chhakkarbandah have been incorporated.

The Chhakkarbandah occurrence is situated about 8 km south of Deo in Gaya District of Bihar. The prospective region consists of Archaean granite-gneisses, various types of schists occasional amphibolites as country rocks which have been intruded by later pegmatites and aplites. The mineralization is restricted to the schistose rocks represented by garnetiferous quartz-sericite-biotite-muscovite-schist and quartz-sericite-sillimanite-schist, which occur dominantly in two bands running more or less north-south along the eastern flank of the local hill range. The following rocks, namely (1) Quartz-tourmaline rock, (2) Garnet-cassiterite rock, and (3) Magnetite-cassiterite rock - are richly stanniferous and these are usually found enclosed along the foliation planes of the above-mentioned rocks.

The occurrence of tin is believed to be present in two phases, firstly as a separate phase of cassiterite occurring as very tiny or micro-granular disseminations, and secondly as a dispersed phase replacing divalent iron in biotite, almandite, etc. The cassiterite content of the rocks varies widely, but it is about 1,5 % in richly mineralized zones. In the light of the detailed petrography of the various lithological units, it is believed that the formation of cassiterite in the Chhakkarbandah region is genetically connected with pegmatitic activity which had been so widespread in the Bihar-Mica-Belt.

COMPOSITE ALBITITE-APLITE AND PEGMATITE FROM MANSEHRA AND BATGRAM AREA OF HAZARA DISTRICT, PAKISTAN

Muhammad Ashraf, Lahore, Pakistan

Composite albite-aplite and pegmatite bodies have been discovered from the granitic complex of Hazara district for the first time. On the basis of field and laboratory investigations the following types of composite bodies have been discovered:

I) Pegmatitic-albitite, albite-aplite, albite-microcline-aplite/pegmatite

II) Fine to medium-grained albitite, layered-albitite and layered-aplite, and albite-pegmatite

III) Pegmatitic-albitite, medium-grained-albitite

IV) Pegmatitic-albitite, medium-grained-albitite, albite-aplite

V) Pegmatitic-albitite, medium-grained-albitite, albite-aplite, albite-(microcline)**aplite**

VI) Pegmatitic-albitite, medium-grained-albitite, albite-(microcline)aplite

VII) Albite-(microcline)-aplite/pegmatite, fine-grained and pegmatitic albitites (xenoliths)

These bodies occur in the interior zone of the granitic complex and are very simple in composition. Genetically the albitites are thought to be products of high water vapour pressure of more than 10 Kilobars, but as the vapour pressure decreased gradually the trapped liquids in fissures started crystallizing albite-aplite, albite-(microcline)-aplite/pegmatite, and albite-microcline-aplite/pegmatite depending on the favourable conditions.

PRECIOUS STONES PEGMATITES IN SOUTH AFRICA AND SOUTH AMERICA, AND THE CONTINENTAL DRIFT THEORY
H.Strunz, West-Berlin

Main Session: FLUID INCLUSIONS IN CRYSTALS
Introductory lecture

G.Deicha, Saint-Germain-en-Laye, France

The study of gas and liquids trapped in syngenetic as well
as epigenetic cavities of minerals has been widely developed
in recent years. The sessions of the Commission on ore-forming
fluids in inclusions (1) held during I.M.A. Meetings in Japan
(1970) and Canada (1972) gave proof of the importance of this
subject.

Essentially new trends in the investigation of various kinds
of microscopical and submicroscopical fluids or solid inclu-
sions are reflected in recent publications (2, 3 and 4).
Practically every regional meeting of mineralogists deals
with this matter, for instance in Europe in autumn 1973 the
Joint Session (Paris) of the English and French Mineralogical
Societies, the Symposium on Inclusions (Milano), sponsored
by the Italian Mineralogical Society with an active French
and Swiss participation, the annual meeting (Frankfurt/Main)
of the German Mineralogical Society, the 4th Russian Sympo-
sium on Thermobarogeochemistry (Rostov/Don).

Mass spectrometry, electron and ion probe as well as neutron
activation analyses of the trapped matter are now combined
with heating-, freezing-, and crushing-stage experiments, de-
crepitometry and investigation of the host cavities by replica
electronmicroscopy or direct scanning electron fractography.

Thanks to the expansion of such researches nearly all parts of
the Mineral Realm are concerned and more light is thrown on the
crystallogenesis in rocks, ore deposits and gem occurrences.

(1) For the activites of this Commission (C.O.F.F.I./I.A.G.O.D.
     see: Fluid Inclusions Research-Proceedings of C.O.F.F.I.,
     U.S. Geological Survey, Washington, annual issues since
     1968.
(2) Gas und Flüssigkeitseinschlüsse in Mineralien (1970).
     Schweiz.Miner.Petr.Mitt.Bd. 50, 208 p.
(3) ROEDDER E.: Composition of Fluid Inclusions (1972) - U.S.
     Geolog.Survey.Prof.Paper 440 JJ, 164 p.
(4) ERMAKOV N.P.- Geochemical Systems of inclusions in minerals
     (1972) Ed."Nedra", 176 p., Moscow.

THE APPLICATION OF MACRO- AND MICRO-CINEMATOGRAPHY IN THE
STUDIES OF THE CRYSTALS' AND GEMS' INCLUSIONS, PARTICULARLY
THE FLUID INCLUSIONS - Colour-Sound-Film

E.Bettetini, Nice, France

The mutual crystallographic orientation of host and guest,
that is endotaxy, makes it possible to ascertain the authen-
tity of gems and precious stones by their solid inclusions.

The fluid inclusions are the distinctive mark of the liquid
and gaseous phases which were present during the genesis
and the evolution period of the minerals and the rocks.

Under the effect of heat one can observe in certain internal
cavities of the minerals an ebullition; such as an "operation
of the open heart" which gives the impression of a beating
heart. An inward world animates itself agitating sometimes
other solid inclusions floating within the fluid or gaseous
realm.

Thus, many most peculiar and highly interesting features can
be observed, such as:

- Passage from the liquid to the gaseous state and vice-versa

- Disappearance and reappearance of retreating bubbles

- Separation of the CO_2 into two phases

- Movements of a minute solid particle to a bubble which accu-
  rately changes position according to the variations of the
  intensity of luminosity.

FLUID INCLUSIONS IN QUARTZ-CRYSTALS FROM ORPIERRE
(HAUTES ALPES, FRANCE) AND RÉMUZAT (DRÔME, FRANCE)
Coloured film

Roger Martin, Nyon, Switzerland

The Oxford marls with their characteristic levels of calcar-
eous concretions have suffered low metamorphism of anchimeta-
morphic grade, accompanied by structural deformations due to
the regional tectonic events.

During these deformations the concretions have been flattened,
and their opening cracks of perhaps even diagenetic origin
gave way to growth of quartz-crystals of a very peculiar mor-
phology which is probably due to the presence of hydrocarbons
during their growth (MARTIN 1973). The quartz-crystals are
very rich in vacuoles of growth and fluid inclusions, which
all contain besides water different hydrocarbons of gaseous,
liquid or solid consistence. Sometimes, clear yellow or red-
brown coloured oil contains small drops of denser oils or even
organic particles. In the quartz-crystals of Orpierre water
may be completely absent, and inclusions are composed essen-
tially by "oily" and gaseous substances.

The meaning of the film technics is to show how complicated
the behaviour of fluid inclusions is during heating, cooling
or rotation of the samples.

During the changing conditions between $18^{o}-50^{o}C$ the following
events are observed: formation of eddies, change of viscosity,
convection-currents, homogenization of phases, unmixing of
phases with retro-boiling, attraction or repulsion of particles.

DEICHA, G. (1970): Le degré de liberté des solutions géochi-
miques. SMPM 50, 25-35.

MARTIN, R. (1973): Morphologie des quartz de la zone d'Orpierre
(Hautes-Alpes, France). Schweizer Strahler 3,
101-118.

TOURAY, J.C. & JAUZEIN, A. (1967): Inclusions à méthane dans
les quartz des "terres noires" de la Drôme
C.R.Acad.Sc.Paris, 264, 1957-1960.

LIQUID AND GASEOUS HYDROCARBON INCLUSIONS IN QUARTZ MONO-
CRYSTALS FROM "TERRES NOIRES" AND "FLYSCH À HELMINTHOIDES"
(FRENCH ALPS): A MINERALOGICAL INVESTIGATION

Jean-Claude Touray and Jacques Barlier, Orléans, France

Gaseous and liquid hydrocarbons trapped by quartz monocrys-
tals from septaria (Terres noires) or fissure veins (flysch
à helminthoides) exhibit various appearances under the micro-
scope. The present paper is concerned by an optical study of
organic inclusion fluids upon heating and freezing stages
and relates to about a thousand of inclusions. In the range
$-150^{o}C$ to $+200^{o}C$ were determined

- melting temperatures of paraffins
- partial homogenization temperatures,
  should the occasion arise
- total homogenization temperatures.

  When possible in those water-poor samples, thermometric
  and cryoscopic investigations have been made.

The quartz crystals were collected in two domains that one may
distinguish by a microreflectometric study of the disseminated
organic material in rocks. Their frontier-line orientated gross-
ly NW-SE passes near Barles. As indicated by the temperature-
reflectance curves, this limit is an imprint of a $180^{o}C$ - $200^{o}C$
paleo-isotherm; westward temperatures are lower ($155^{o}C$ to
$175^{o}C$) and eastward they are higher (210 to higher than $230^{o}C$).

Amongst the differences between organic inclusions trapped by
the quartz from the two domains one may notice.

- An eastward decrease of the homogenization temperatures
  of the one phase gaseous inclusions probably explained by
  an increase of their density and perhaps by an increase of
  the CH_4 amount, compared with other light alcanes.

- An eastward decrease of the homogenization temperatures
  of the "petroleum" bearing inclusions possibly depending
  on a pressure increase.

Such oppositions reinforced by data from aqueous inclusions
may be explained by diagenetic against anchimetamorphic growth
of the quartz monocrystals.

CAVITIES AND INCLUSIONS IN QUARTZ FROM KING SALOMON MINES
(MENE'IYEH). SOME ASPECTS OF THEIR STUDIES UNDER THE SCANNING
ELECTRON MICROSCOPE

J.Rasumny, Orsay, France

Observations under the scanning electron microscope done in
the geological laboratory of the "Museum d'Histoire Naturelle
de Paris" have enabled to study the quartz of this copper
occurrence. The obtained electron fractographies have shown,
besides the intragranular inclusions in quartz crystals, al-
ready described from other localities by various authors
(J.VERDIER et al.: The distribution of epigenetic fluid in-
clusions as evidence of rock microfissuration. - Symposium
Soc. International Mecanique des Roches, Nancy, 1-10, fig.7-8)
also intergranular cavities, as well as contacts between quartz
and other minerals (under magnifications going over 20.000).
Some conclusions are drawn as to the possibilities of capil-
lary circulations of ore forming fluids.

AN INDEPENDENT CHECK ON THE VALIDITY OF THE PRESSURE CORRECTION IN INCLUSION GEOTHERMOMETRY, USING HYDROTHERMALLY GROWN QUARTZ

Otto C.Kopp, Oak Ridge, Edwin Roedder, Washington, USA

Primary fluid inclusions were studied in synthetic quartz crystals (~1 cm) grown in static thermal gradients from 0.5N CsOH or RbOH (partial fill 62-75 %) at 0.8-1.8 kb and 377-470°C. Inclusion homogenization temperatures (T_H) were determined blind, corrected for known pressure to yield trapping temperatures (T_T), and compared with laboratory growth temperatures (T_G) in order to evaluate the validity of inclusion thermometry when pressure corrections (P_C) are large:

T_G (est.)(°C)	411	411	394	452	462	400	447	380	399
T_H (°C)-	327	319	281	320	329	315	297	314	306
P_C (est.)(°C)	90	111	122	140	127	87	168	77	115
T_T (est.)(°C)	417	430	403	465	456	402	465	391	421
ΔT ($T_T - T_G$)(°C)	+6	+19	+9	+13	-6	+2	+18	+11	+22

In spite of relatively large values for P_C, ΔT is relatively small. ΔT is the sum of the following errors, only part of which can be evaluated with any precision: 1) Errors in measurement and interpolation of T_G in the bomb at the crystal face; 2) Errors in measurement of T_H (here probably $\pm$ 2°C); 3) Errors in calculating P_C (here probably $\pm$ 5°); 4) Errors known to be intrinsic to the T_H method, such as bubble surface tension and host mineral expansion on external pressure release and on internal pressure increase (here probably <1°C); 5) Errors suggested by others to be intrinsic to the method, such as trapping nonrepresentative fluid (unknown magnitude). We believe that (1) is probably the major source of discrepancy here, and that these data prove that if the solution composition is known adequately, pressure corrections can be large and still permit relatively accurate thermometry by means of inclusions.

ENDOSCOPICAL STUDY ON SOME CARBONIFEROUS DETRITAL SEDIMENTS FROM WEST-CENTRAL SINAI, EGYPT

Mahmoud M.Kholief, Cairo, Egypt

Inclusions were investigated microscopically in about 60 preparations of quartz grains from the Carboniferous detrital sediments of west-central Sinai. The inclusions are either solid or fluid-gaseous of primary and secondary origins. Many of the inclusions, especially the solid ones, have their impressions on the surface morphology of quartz grains. The nature and the mode of distribution of the inclusions indicate that the source rock was mainly effusive acidic and microgranitic. Subsequent tectonic effects resulted in a fissuring system and the penetration of secondary inclusions.

GASES RELEASED FROM NATURAL AND SYNTHETIC DIAMONDS BY CRUSHING UNDER HIGH VACUUM AT $200^{\circ}C$, AND THEIR SIGNIFICANCE TO DIAMOND GENESIS

A.A.Giardini and C.E.Melton, Athens, Georgia, USA

Thirty-eight natural diamond samples (21: 0.1 to 2.1 ct. each, Arkansas, U.S.A.; 16: 0.1 to 4.5 ct. each, Africa; one 2.5 ct., Brazil) were crushed in the inlet of a research mass spectrometer at 10^{-9} torr and $200^{\circ}C$. Six 36-mesh Gen. Electric synthetic diamond samples (2 from regular production, 4 from a new high pressure and temperature process) also were crushed. Most diamonds contained totally enclosed solid inclusions. All samples released gas. The average (and range) of gas composition (vol.%) from natural diamonds and from commercial synthetics shows the table.

	Arkansas	Africa	Brazil	Average	Comm. synth.	New proc.
H_2O	32.9(2.9-75.7)	34.5(0-85.1)	85.1	34.43	----	25.8
H_2	24.1(1.5-40.4)	21.6(1-59)	1.6	22.49	33.2	26.2
CO_2	22.6(5.3-37.7)	15.2(2-28.1)	5.4	18.91	12.1	17.4
CO	3.6(0.4- 9.4)	7.6(0-45.8)		5.78	----	----
N_2	7.4(0-87.2)	14.0(0-80)	1.7	9.96	----	5.1
CH_4	8.4(0.9-25.1)	6.1(0.5-18.3)	4.0	7.32	54.7	24.8
C_2H_4	-----	0.1(0 - 0.7)	0.2	0.08	----	----
C_3H_6	-----	0.2(0-2)	---	0.09	----	----
CH_3OH	0.3(0- 5.2)	-----	---	0.17	----	----
CH_3CH_2OH	0.4(0- 3.2)	0.5(0-3)	0.1	0.33	----	----
O_2	-----	0.2(0-1.9)	1.9	0.14	----	----
Ar	0.3(0- 1.3)	0.2(0-1.2)	0.05	0.3	0.05	0.6

The ratios of average (and range) of gas volume (STP) to diamond sample volume = 4.2×10^{-3} ($1.8 - 18.5, \times 10^{-3}$) Arkansas; 3.5×10^{-3} ($0.02 - 15.7, \times 10^{-3}$) Africa; 0.3×10^{-3} Brazil.

Except for N_2 (once, Arkansas), and for H_2O and N_2 (once each, Africa), H_2O, H_2, CO_2, CH_4 and N_2 always were present. O_2 was found only in a few diamonds of cube form. The gas difference in natural diamonds and commercial synthetics indicates a different formation environment. A thermodynamic interpretation of diamond genesis with various models of the C-H-O system has been carried out. Results can be interpreted qualitatively on the basis of a gas-solid reaction mechanism.

IN SITU MEASUREMENTS OF THE REFRACTIVE INDICES OF LIQUID AND GASEOUS INCLUSIONS IN MINERALS

Harry Micheelsen, Copenhagen, Denmark

The refractive indices of the gas, liquid and mineral contents of inclusions in minerals can often be measured in sity by a conoscopic method on the ordinary polarizing microscope using a slightly modified condensor. The principle of the method is that a narrow beam of light can be totally reflected on the surface of an inclusion. This can be observed by means of the Bertrand lens. The incident beam is tilted away from the microscope axis until the limiting angle of total reflection is reached; if the angle of tilt becomes too large the reflection will disappear. The tilt is obtained by manual movement of a pinhole plate placed just on top of the fully opened aperture iris-diaphragm of the condensor. Some degree of training is needed to get reproducible determinations of the limiting angle. The angles of tilt of the incident beam and of the reflected beam are measured by means of a grated ocular.

The ratio between the refractive index of the inclusion and that of the host mineral is calculated from the two angles of tilt. Large single inclusions with approximately plane surface give better results (± .002 to .012 depending on n) than groups of small inclusions (± .01 to .05). Solid-solid grain boundaries can also be measured in petrographic thin sections, but care is needed to distinguish between refraction and reflection.

Inclusions in rock crystal from a quartz vein in alkali granite from the Ilimaussaq intrusion, South Greenland, show in this way the presence of several phases, here given as n_D- values and a tentative identification:

n = 0.99	- air	n = 1.432 - fluorite
n = 1.19	- liquid CO_2	n = 1.452 - ?
n = 1.24	- light hydrocarbon liquid	n = 1.478 - 1.500 natrolite
n = 1.34	- cryolite	n = 1.517 - immersion oil
n = 1.367	- NaCl solution	n = 1.534 - albite
n = 1.398	- mirabilite	n = 1.543 - halite

THE CARBON ISOTOPIC COMPOSITION OF CO_2 IN FLUID INCLUSIONS

Jochen Hoefs, Göttingen, Germany (FRG)

CO_2 from fluid inclusions is extracted through decrepitation
in vacuum. Two sets of samples have been analyzed:

1. Quartzes from the granulite facies of Norway
2. Olivines from xenoliths in basic and ultrabasic
   rocks from various localities.

The δ^{13}C-values of the quartzes showed a variation range
of -5 to -22 ‰ relative PDB. The majority of the analyzed
samples varied between -5 and -8 ‰, favouring a deep-seated
(juvenile) origin. The CO_2 from the olivines showed a very
strange isotopic composition, δ^{13}C-values, in general, varied
between -20 and -28 ‰. Some speculations will be given about
the controversial meaning of this isotopically light carbon.

FLUID INCLUSIONS IN CHARLEVOIX CRYPTOEXPLOSION STRUCTURE
ROCKS (QUÉBEC - CANADA)

Maurice Pagel and Bernard Poty, Vandoeuvre-les-Nancy, France

Two main kinds of fluid inclusions related to the genesis of
the cryptoexplosion structure have been recognized in Charle-
voix area:

Numerous minute fluid inclusions which are located in planar
deformation structures. The fluid phase of these inclusions
is essentielly aqueous and the ratio H_2O liquid/H_2O vapor is
quite variable. However, a large number of these inclusions
contain only vapor. There are evidences of necking down for
many inclusions. Salinity, estimated from microthermometry
measurements, varies from 1 weight percent equivalent NaCl
to saturation at room temperature.

Inclusions of the other kind occur as clusters, mainly in
quartz of breccias, in quartz relicts from rocks which are
almost entirely recrystallized and also in milky quartz from
"Mont des Eboulements". These inclusions contain H_2O vapor,
though a few show also low salinity aqueous solution.

Besides these features, older aqueous or CO_2 rich inclusions
(CO_2 rich from high grade metamorphic rocks and anorthosites)
have undergone morphological, physical and chemical changes
related to the cryptoexplosion. The modifications are due
mainly to microfracturing of quartz but also to decrepitation,
followed by healing, at high temperatures.

The great extent of low density water bearing inclusions in-
dicates high temperatures and low pressures during their
formation. In addition, lack of CO_2 associated to the crypto-
explosion as confirmed by microthermometry, crushing and gas
chromatography, is rather contradictory with a volcanic pro-
cess. Necking down in planar decorated features indicates
that temperature decreased during healing after the shock. He-
terogeneous chemical composition of the aqueous solutions show
a complex history of mixing. Finally the decreasing abundance
of transformed and gas inclusions towards the margin of the
structure gives us new and supplementary criteria to the me-
teoritic hypothesis retained for this structure (RONDOT, 1968).

TEMPERATURE GRADIENTS AND ORE DEPOSITION IN THE
NORTH PENNINE OREFIELD

F.W.Smith & R.Phillips, Durham, U.K.

Measurements on fluid inclusions in fluorite have been
used to establish transverse, longitudinal and vertical
temperature gradients in the PbS - ZnS - CaF_2 - $BaSO_4$
bearing veins of these Hercynian age deposits.

Vertical gradients varying from $0.1^{\circ}C/m$ at 500 m depth
to $0.5^{\circ}C/m$ near surface are found, with formation tem-
peratures ranging from 195 to $130^{\circ}C$.

The significance of these results in understanding the
mode of formation of the ores is discussed.

FLUID INCLUSIONS IN SOME GANGUE MINERALS FROM DEPOSITS IN
SOUTHERN FRANCE

C.Gritti-Baudracco, Toulouse, France

The laboratory of mineralogy and crystallography of Toulouse
develops since several years determination methods for fluid
inclusions in gangue minerals from regional deposits. The
techniques used are decrepitometry, decrepitoscopy and the
hot plate of DEICHA.

Because of its abundance in deposits in southern France
(deposit of Pessens, Colombies (Aveyron), Clermont l'Hérault
(Hérault) etc.) baryte was selected as example.

Recently the scanning electron microscope allows to show in
these samples cavities which are not noticable by the usual
methods.

The different methods described are complementary. Their joint
use serves for the determination of the temperature of forma-
tion of gangue minerals.

THE REAL NATURE AND CHARACTER OF PEGMATITE-FORMING MELTS-
FLUIDS REVEALED BY THEIR INCLUSIONS IN MINERALS

A.I.Zakharchenko, Leningrad, USSR

Very problematic features of nature and character of pegma-
tite-forming melts-solutions and of pegmatite genesis are
understood to a extent by studies of original inclusions
of these melts-solutions relicts in pegmatite minerals,
especially in the fully-differentiated-chamber, partly in
quartz, and largerly in topaz, beryl, etc.

1) In the wall-rock parent granites these are gaseous-
solidified inclusions, composed to 90-95 % of crystallized
aggregates of minerals, and gases - to 5-10 %. The liquid
aqueous phase is lacking, but many hydrides are present.
Under heating they are fusing in the range of 800-1000°C.

2) In the marginal zones of pegmatites the original inclu-
sions are also gaseous-solidified, but with the increase
of volatile content up to 20-35 % of alkali, with appearance
of minerals of free growth. Under heating the fusion takes
place in the range of 650-850°C with complete solution of
volatiles.

3) In the inner zones (block, monomineral) a regular de-
crease of melting aggregate of minerals down to 40-20 %,
and increase of liquid-gaseous phases highly saturated in
minerals of free growth are observed. Under heating (450-
530°C) at first the solutions of minerals of free growth
in fluid takes place, and then above 530°C-fusion occurs.

4) In the inclusions of the cavity-chamber minerals we ob-
serve a complete disappearance of melting aggregate of
minerals and transition into very concentrated fluids (min-
erals of free growth up to 70-60 %).

Thus, the easily fusible melts with accumulation of fluxing
fluids and their gradial transition into highly concentrated
fluids are the pegmatite-forming agents.

METHOD OF DETERMINATION THE ORIGIN OF SOLUTIONS BY MEANS OF
ARGON ISOTOPES IN FLUID INCLUSIONS OF MINERALS

V.G.Bogolepov, Alma Ata, USSR

Based on data of argon isotopes Ar_{40}/Ar_{36} from lunar rocks,
delivered by "Apollo 2" and "Luna 16", the ratio for solar
wind equals one, but for present-day atmosphere this ratio
is 296. It is also a constant in the potassium containing
rocks, where all of Ar is represented by the heavy isotope
which is formed from K_{40}. This is borne out by a similar
ratio of argon-nitrogen in underground waters and in the
air, on agreement of observed and calculated data of con-
centration and argon pressure in different depth, and data
of isotopes of argon.

According to data of argon isotopes in gas-fluid inclusions
of minerals and rocks, determined in the laboratory of Kasak
Institute of Mineral Resourses, two types of solutions are
established. Solutions of the first type containing Ar_{40} are
juvenile and produce metamorphism up to granitization, forma-
tions in the metamorphic belts of micaceous pegmatites, and
quartz veins of the Alpine type. The second type of solutions
is characterized by the dominant role of argon from the air
(50-100 %). Argon is transported from air into hydrotherms
indirectly by way of underground waters. From hydrotherms of
this type, in weak metamorphic effusive sedimental rocks of
upper structural steps of fold areas, greisen, skarns, and
pegmatites as well as waters of some volcanic zones are
formed.

PRIMARY LIQUID INCLUSIONS AND EVOLUTION OF FELDSPARS IN
MAGMATIC GRANITES

V.V.Zalutskii, Irkutsk, USSR

In 1940 D.S.Korzhinskii pointed out that feldspars contain
abundantly finest inclusions usually taken for pellites.
This false pellitization has infrequently been mentioned
in literature up to now. The author has investigated plagio-
clases, potassium-sodium feldspars and anorthoclases con-
taining abundantly pellite like inclusions of the middle
paleozic volcano-plutonic series of the western Trans-Baikal
area. Gaseous-liquid inclusions can be detected under micro-
scope magnification of 500-800 x. They are stable while samp-
les are annealed up to 900°C and therefore are regarded as
primary inclusions. The analysis of the location of the in-
clusions and the nature of twinning and disintegration of
feldspars enables us to trace their evolution. During twin-
ning and disintegration into phases inclusions open and move
out. In the process of the microclinization of the orthoclases
the primary inclusions disappear partially or completely.

Main Session: SECONDARY MINERALS IN ORE DEPOSITS
Introductory lecture

F.V.Chukhrov, Moscow, USSR

In the Soviet geological literature that zone where secondary
minerals are deposited is designated as hypergene zone or zone
of hypergenesis. The term "hypergene" corresponds in sense to
the term "supergene" adopted in the American literature.

On the early and late stages of the Earth's geological evolu-
tion conditions for chemical weathering were distinctly dif-
ferent. Prior to the significant amounts of oxygen making its
appearance in the atmosphere, the main weathering agents were
water and carbon dioxide; in consequence a highly active decay
of silicates was going on while sulphides hardly suffered any
alteration.

With progress of photosyntheses, the atmosphere was gradually
enriched in oxygen, and, as a result, chemical weathering of
sulphides started and preceeded along with the silicates
alteration. - Although a possibility for oxidation reactions
existed as long as 3 billion years ago, still their importance
increased drastically no sooner than the vegetation emerged
into the land, which time is dated Silurian.

Besides abiogenic processes (electrochemical reactions inclu-
sive) affecting the alteration of primary ores, the organic
life activity played an important role, as well. Owing to both
- oxidation and reduction reactions resulted with these latter
leading to the secondary sulphides deposition.

Diversity of mineral association formed within the hypergene
ore zone is significantly dependent on those elements which
are carried in out from the enclosing rocks - silicium, phos-
phorus, vanadium, molybdenum, chromium, chlorine etc. Some
specific properties of secondary mineral deposition reflect
the effect of climate, while the succession in their deposi-
tion may fail through changing geological environment in the
given ore field.

The ore hypergene zone emplacement is intimately connected
with the rock alteration and the eluvial material accumula-
tion, this latter being termed crust of weathering.

OXIDATION OF SULFIDE ORES AT GRANITE GAP, NEW MEXICO

Sidney A.Williams, Douglas, Arizona, USA

Sulfide ores at Granite Gap occur in Paleozoic limestones
adjacent to the Granite Gap "granite", a coarse grained
biotite quartz monzonite. Mineralization is directly re-
lated to quartz latite granophyre dikes contemporaneous
with the "granite". Thermal zoning of ores and wallrock
alteration relates both to the dikes and to the thermal
aureole surrounding the granite. Sulfides occur in crushed
zones and favorable beds in limestones with phlogopite and
epidote. Primary sulfides are pyrite, pyrrhotite, galena,
sphalerite, chalcopyrite and arsenopyrite. Traces of matil-
dite occur in the galena.

Oxidation has been severe for a depth of up to 75 meters.
Most ores were arsenic-free and oxidation has first pro-
duced linarite-chlorargyrite-anglesite-cerussite, then
rosasite-chrysocolla-hemimorphite-malachite. With ground-
waters alkaline and at higher Eh, minerals such as murdo-
chite and tenorite formed. Only Zn and Cu migrated, re-
sulting in fractures and caves lined with malachite or
rosasite and hemimorphite.

Sulfide ores identical to those described above but carry-
ing arsenopyrite as well have oxidized in situ. Paragenetic
study indicates that only minerals in the system Fe_2O_3-PbO-
As_2O_5 formed, and in order of increasing $PbO:Fe_2O_3$ ratios.
Only when all Fe_2O_3 was precipitated did CuO enter the sys-
tem and, lastly, ZnO is involved and replaces CuO progres-
sively. A constant excess of PbO with respect to As_2O_5 held
the system within the area bounded by hematite-beudantite-
mimetite-anglesite. The transition of anglesite to cerussite
coincided with the entry of CuO into the system.

THE FERRIC SULFATES DEPOSITS IN CENTRAL DESERT OF IRAN

J.P.Berthelon and F.Cesbron, Paris, France,
and M.Sadrzadeh, Tehran, Iran

The systematic study of several sulfate rich areas, under-
taken recently in Iran, permitted to discover some paragen-
esis very rich in ferric sulfates and very similar to those
encountered at Chuquicamata (Chile) and San Rafael Swell
(Utah). These deposits were formerly worked for "alums",
employed as mordant in wool-dyeing.

The most interesting of them, near Saghand (province of Yazd),
constituting a 12 meters thick oxidation zone, results from
alteration of pyrite abundantly disseminated in more or less
pelitic schists in contact with a intrusive body.

The following paragenesis is observed:

a) in the lower level: pyrite, szomolnokite, roemerite,
coquimbite, metavoltine and voltaite,

b) in the upper level: amarantite, hohmannite, magnesio-
copiapite, butlerite and parabutlerite, jarosite,
fibroferrite.

Aluminium sulfates are quite abundant: tamarugite and halo-
trichite in the lower part, alunogen and the new mineral
khademite, $Al(SO_4)(OH) \cdot 5H_2O$, in the upper level.

Thermal analysis curves and unit cell of these minerals,
particularly alunogen, szomolnokite and khademite, were
determined. According Posnjak and Merwin's synthesis, most
of these minerals can be formed only in very concentrated
sulfuric solutions, corresponding to the desertic climate
in this part of Iran.

ON THE PROBLEM OF GLOCKERITE AS A SECONDARY MINERAL
OF ORE DEPOSITS

Bohuslav Fojt, Brno, CSSR

E.F.Glocker in 1853, has described basic and hydrous ferric
sulphate, which was later named by F.Naumann (in F.Zirkel,
1901) as Glockerite. As early as in 1909 F.Cornu drew atten-
tion to the fact that it is not a new mineral, but only
limonite with adsorbed sulphuric acid. This opinion is sup-
ported by most of the contemporary authors, although some
take it still for ferric sulphate.

A number of samples of the mentioned secondary products was
taken from the original Glocker's locality - Alt-Hackelsberg
mine - on the occasion of new researches in the region of
Zlaté Hory (previously Cukmantl), Czechoslovakia. Stalactite
and stalagmite formations of "glockerite" were slowly dried
at room temperature. Then they were subjected to chemical,
X-ray and thermal analysis and studied by infrared spectro-
scopy. It was established by these methods that the studied
material is roentgenometrically amorphous at 20°C and a sig-
nificant recrystallisation takes place at about 560°C. It
was not possible to find out unambigously whether the studied
matter contains hydroxyl group or not. The sulphate anion is
firmly bound and it is not mostly connected with sorption of
H_2SO_4. The "glockerite" formations arise there where the
pH-value is about 4,5 and locally to 1.5, in small stagnant
basins of deserted pyrite dumps.

Other secondary compounds of iron, e.g. matter corresponding
to "hydrohematite", limonite, siderogel, rarely also hisinge-
rite and karphosiderite, and of aluminium, namely allophane,
kliachite and gibbsite, occur together with "glockerite".

HYDROTHERMAL POTASSIUM FELDSPAR AT BODIE, MONO COUNTY,
CALIFORNIA, AND ITS USE IN DETERMINING THE AGE AND CONDITIONS
OF ORE DEPOSITION

Ch.W.Chesterman, San Francisco, M.L.Silberman, R.A.Koski and
B.P.Fabbi, Menlo Park, California, USA

Hydrothermal potassium-feldspar (or "adularia") occurs in
gold and silver-bearing quartz veins and in hydrothermally
altered dacite wall rocks of Pliocene age in the mines at
the Bodie mining district, Mono County, California. Chemical
and X-ray analyses of vein adularia indicate a composition
of 95 to 98 percent orthoclase. Optical, physical, and X-ray
crystallographic properties of the feldspar are consistent
with those of high temperature sanidine.

The potassium feldspar is of hydrothermal origin and developed
late in the volcanic history of the Bodie Hills volcanic field
during a period of intense potassium-silicate hydrothermal
alteration and gold and silver deposition between 8.6 and 7.1
m.y. ago. Chemical analyses of the feldspars, $0^{18/16}$ isotope
analyses of the feldspars and associated vein minerals, quartz
and calcite, and $0^{18/16}$ and D/H analyses of fluid inclusions
in these minerals indicate that ore formation occurred within
a temperature range of 215°-245°C from a very dilute solution
of meteoric origin, of constant K/Rb, $0^{18/16}$, and D/H. K and
Rb metasomatism of the wall rocks occurred principally by re-
placement of the pre-existing minerals by hydrothermal potas-
sium-feldspar.

SECONDARY MINERALS IN SCHEELITE DEPOSITS IN NORTHERN BRAZIL

A.Bhaskara Rao, Brasilia, Brazil

During the last fifteen years, the author and his associates emphasized the effective participation of hydrothermal solutions in the mineralisation of scheelite deposits in the Borborema Metallogenetic Province of NE Brazil. The mineralogical studies have revealed several minerals, and their origin is attributed either to hydrothermal solutions at low temperatures (final phases) or to meteoric waters. The secondary minerals, thus far recorded, are listed below:

Apophyllite, aragonite, bismutite, chrysocolla, chalcedony, chabasite, calcite (sugary), chlorites, covellite after chalcocite, cuprite, Fe-hydroxides and goethite, gypsum (selenite), heulandite, huntite, jasper, malachite, Mn-hydroxides, montmorillonite, mordenite, pinguite (chloropal), stilbite, tungstite, turquois and uraniferous opal.

The scheelite deposition is mainly in calc-silicate rocks (skarns). Minerals such as garnets (grossularite and andradite mixtures), epidote, hornblende, diopside and scapolite show incipient alteration, resulting in corrosion and occasional partial pseudomorphism. Huntite, found only in mine dumps, is considered as derived from Mg-rich calcites through leaching and subsequent deposition. Gypsum is characteristic in occurrence, found as large plates in solution cavities in the host rocks.

THE DEVELOPMENT OF MAGNETITE AND ITS ALTERATION PRODUCTS IN SOME PRECAMBRIAN IRON FORMATIONS

T.M.Han, Ishpeming, Michigan, USA

Magnetite is or was present as one of the principal iron-containing minerals in most of the Precambrian iron formations. Its stability varied with the postdepositional history of the iron formations. This is indicated by its textural relationships with other coexisting minerals, and the differences in composition and magnetite distribution along the same iron formation band. The objective of this paper is to describe such textural and structural features which lead to the conclusion that magnetite in the iron formations may replace or be replaced by other minerals through various geological processes under different conditions.

During the diagenesis and the incipient stage of metamorphism, the magnetite in the oxide and carbonate iron formations is stable and trends to replace other minerals, while that in some of the silicate iron formations may be altered to ironrich carbonates. Under moderate metamorphic conditions, it may be replaced by specular hematite in the oxide iron formations and by amphiboles in the silicate iron formations. In the more highly metamorphosed iron formations, it appears to have been formed at the expense of specular hematite.

Diabasic dikes in some iron formations were not only responsible for the pseudomorphic reduction of some hematite to magnetite, but also for the alterations of the pre-existing magnetite to pyrite, siderite, and chlorite along or near the dike-iron formation contacts. The most interesting and significant feature is the progressive decrease in quantity, grain size, and degree of crystallinity of the magnetite toward these dikes.

Under supergene conditions, the magnetite, almost as a rule, alters to martite and rarely to goethite and siderite. At the advanced stages of oxidation the martite grains may either be replaced by goethite or modified by the overgrowth of hematite crystals on their peripheries.

MINERALOGICAL AND GENETIC SIGNIFICANCES OF NSUTITE IN
SUPERGENE MANGANESE OXIDE ORES

Soo Jin Kim, Seoul, Korea

Nsutite is the naturally occurring equivalent of a specific
form of synthetic gamma-MnO_2. Its occurrence is confined to
the supergene manganese oxide deposits. It is most abundant-
ly found in the oxidation products of manganese carbonate
protores. It occurs in close association with birnessite,
todorokite and pyrolusite.

Nsutite is formed by various modes of formation; crystalli-
zation from true solution, colloidal precipitation and re-
placement. Ores formed by replacement are most abundant.
Replacement of other hydrous manganese oxides by nsutite
results in the shrinkage phenomena. Shrinkage cracks are
not the evidence of colloidal origin of the mineral, but
of dehydration and volume change in the replacement.

All the textural relations of nsutite with associated oxides
indicate that it is formed diagenetically at the last stage
or high oxidation stage of oxide ore formation in the super-
gene environment. The textural importance of nsutite in the
supergene manganese oxide deposits is that all the previous
textures of the ores are destructed by and newly formed by
nsutite. The presence of nsutite indicates the deydration
environment of formation under the high Eh and pH.

X-ray, thermochemical and infrared absorption spectroscopic
characters as well as the phase relations of nsutite to other
MnO_2 phases are also discussed.

CRYSTAL CHEMISTRY OF HYPERGENE MINERALFORMING PROCESS

A.S.Povarennykh, Kiev, USSR

1. Hypergene mineralforming process being characterized
by low values of T and P of surroundings is notabled for
minerals with little strength of interatomic bonds; these
minerals are stable only in the present conditions.

2. The little strength of bonds in minerals is reached by
two main modes: by increase of size and coordination num-
ber of cations, and for small and high-valent atoms by
including to the sphere of their coordination of anions
OH^- and water molecules.

3. This is the specific feature of composition and struc-
ture of hypergene minerals, which by the number of species
in some classes predominate over hypogene minerals, being
often unique by own crystal chemical peculiarities.

4. Hypergene minerals are formed at the expense of hypogene
ones by means of their change, distortion and transforma-
tion and arise either direct in situ (pseudomorphoses and
relicts) or are deposited in other place with transfer of
substance.

5. The main elements building hypergene minerals are the
following: cations - Na, K, Mg, Ca, Ba, Cu, Zn, Pb, As,
Sb, Bi, Al, Fe, Mn, V, U; radicals and anions - BO_4, SiO_4,
PO_4, BO_3, SO_4, WO_4, CO_3; AsO_4, VO_4, SeO_4, CrO_4, MoO_4, SeO_3,
TeO_3, NO_3, IO_3; O, F, Cl, OH; H_2O.

6. Into the composition of the minerals of hypergene proc-
ess enter both radicals typical for hypogene conditions
(formers seven in the previously row) and forming them-
selves solely at the hypergene surroundings with high oxy-
gen potential (nine last radicals). Combination of them
with different cations is unequal and is submitted to def-
inite regularities.

Main Session: GEM MINERALS AND GEMOLOGY
Introductory lecture
WHERE GEMSTONE RESEARCH STANDS TODAY

E.J.Gübelin, Lucerne, Switzerland

The present situation in the science of gemstones and of gem-
stone research is determined by four principle factors:

a) The discovery of new gems or gem varieties
During the last 30 years gemmologists have discovered several
new gems: taaffeite, sinhalite, painite, ekanite, as well as
the longknown minerals amblygonite, zoisite (tanzanite), jere-
mejewite etc. as new gemstone varieties.

b) New methods of testing and research
Of the traditional testing methods refractometry, spectroscopy
and microscopy the latter two have developed to high importance.
The absorption spectroscopy may serve as a criterion to deter-
mine, e.g. whether or not a green beryl is an emerald. Infrared
absorption spectra of polarized radiation seems to become impor-
tant for the distinction between certain imitations (emerald)
or treated stones (turquoise) and their natural counterparts.
The study of inclusions in gemstones, possible by means of X-ray
fluorescence and the electron microprobe, enables gemmologists
to distinguish between natural gems and their imitations and
to recognize diagnostic features typical of certain sources.

c) The manufacture of simulating products, artificial coloura-
    tion and their distinction from natural gems
Since 1945 there has been a spate of synthetic stones and arti-
ficial products the gemmologists have to deal with. Many of
these materials originally have been produced as a result of
experiments in the field of electronics and space-age pro-
grammes or in laser techniques.
Particle irradiation to improve or change the colour of gem
materials is wellknown and is mainly applied to diamonds. The
majority of "bombarded" diamonds display conclusive spectra in
the visible and the short wave end of the infrared region.

d) The application of gemmological knowledge to commercial use
    and benefit
The accumulation of knowledge gained from gemmological studies
and trade practice lead to commercial application of gemmology
for more accurate grading methods judging the qualities of gems.

FLUID INCLUSIONS AND GEMOLOGY

Jean-Paul Poirot, Paris, France

The inclusions we find in a crystal give a good idea of
the paragenesis of this crystal. Therefore the study of
inclusions is of very high importance for the jeweller.
He has so the proof that a crystal is artificial or
natural, and in this last case, from what type of ore
it comes. Of particular interest are the observations
of fluid inclusions in gems and their imitations.

SURFACE MICROTOPOGRAPHY AS A TOOL OF DISTINGUISHING NATURAL AND SYNTHETIC CRYSTALS

I.Sunagawa, Sendai, Japan

Since natural and synthetic crystals of the same mineral
species grow under different environmental conditions
and with markedly different growth speeds, some of their
physical properties are different to such extent as to
serve to discriminate between the two by conventional
methods. This is the basic idea for the identification
of natural and synthetic gemstones. Specific gravity, re-
fractive indices, inclusions, etc. have been used for
this purpose.

Differences in growth history may appear as differences
of macro-morphology (external forms of crystals) and
micromorphology (surface microtopography of crystal faces)
as well, or even more clearly than in physical properties
such as refractive indices, inclusions, etc. In this paper,
several examples will be presented how surface microtopo-
graphs are different between natural and synthetic crys-
tals, as well as among natural crystals of different ori-
gins, or among synthetic crystals grown by different meth-
ods. Examples to be demonstrated are diamond, emerald,
corundum, and others.

QUALITATIVE STUDY OF FLUORESCENCE AND PHOSPHORESCENCE OF
CUT DIAMONDS

L.Monés Roberdeau and J.M.Bosch-Figueroa, Barcelona, Spain

Study of the luminescence of "Commercial White" and "Top
Silver" diamonds. The samples studied were selected from
several lots of cutted stones. Their weight lies within
the range from 0.35 to 0.75 carats, and they belong to
the pure or V.V.S. qualities.

A mercury lamp HBO 200 W/4 with the excitation filter VG1,
Carl Zeiss, was used as source of illumination.

For the realisation of this investigation an original Monés-
Bosch chamber was constructed.

The description of the apparatus precedes the examination
of first results. For the quantitative determination a
photomultiplier EMI-9592, A-S, was assembled with an S-10
cathode. The G G 17 uranium glass, Carl Zeiss, was used as
standard.

The relative intensity of fluorescence was measured each
15 nm from 405 to 750 nm with the interference filter
Veril-S-200, Schott. With these measurements the disper-
sion curves were established.

THE "ALEXANDRITE EFFECT" IN CHROMIUM AND IRON-BEARING CORUNDUM

Hermann Harder, Göttingen, Germany (FRG)

Some very rare fancy sapphires from Ceylon, Burma and
Australia show an "alexandrite"-effect of changing colour
from blue-greenish to red-violet in response to a change
of observation from daylight (more bluish) to incandescent
light (more yellowish). X-ray fluorescence investigations
of these fancy sapphires have shown that chromium together
with iron in some ratios are responsible for this colour
changing. These sapphires contain a high content of iron
(0.03-0.3 % Fe) and a medium content of chromium (0.003-
0.1 % Cr). - Only chromium or only iron substituting for
aluminium in the corundum lattice lead to the red colour
of ruby or to blue, green or yellow colours of sapphires.
Natural blue, green or yellow corundums do not contain
transition metals other than iron in amounts sufficient
for colouration and the variation in colour is thought to
be due to the ratio between di- and trivalent iron decreas-
ing from blue to yellow. Chromium along with iron and vana-
dium are responsible for all the colours of the rubies.
The Cr:Fe ratio in the ruby may be varying from 1 : 0.1-2.
- Only those corundums which contain chromium and iron in
the ratio 1 : 5-30 show this "alexandrite" effect.
A combination of the adsorption part of chromium and that
of the iron leads to a resulting adsorption similar to the
"alexandrite" adsorption conditions.

MICROMORPHOLOGY COMMENTS ON THE IRIDESCENT CLOUDY BEHAVIOUR
OF ROSE QUARTZ (TSAOBISMUND, SW-AFRICA)

Heinrich Newesely, West-Berlin, Germany

South West African pegmatites hold within their zonar veins
rose quartz occurrences, with peculiar striations and some
parallel line work on fracture faces, and with an iridescent
cloudy behaviour. Electron micrographs from the surfaces de-
monstrate the visible striation texture to be resolvable in a
finely lamellated microtexture with preferential orientation
in the $[0001]$ zone as proved by X-ray swivel recording.

Light scattering interferences on these textural inhomogene-
ities lead to the iridescent and cloudy effects analogously
to a well known behaviour of similar microlamellated materi-
als.

Rutile inclusions - even scarcely detectable with the electron
microscope from the hydrofluoric acid residue - here don't seem
to implicate opalescent luster, but represent casual segrega-
tion of the color inducing lattice substitution centers of ti-
tanium. X-ray fluorescence analyses from the residue material
ensure the presence of iron and copper, zinc, manganese and
titanium but these latterones in the micromeasure scale, and
corroborate further the assessment of a dispersed scattering
of minor components.

PHYSICAL AND OPTICAL PROPERTIES OF GEMOLOGICAL VARIETIES
OF GARNET

M.Arbunies Andreu & J.M.Bosch-Figueroa, Barcelona, Spain

The physical properties of the following garnets were
studied: almandine, green transparent grossular, and
hessonite. The samples of gem quality were selected
coming from three different localities.

The refractive index, the density and the microhardness
of all samples were measured. The colour was established
according to the C.I.E. system by measuring the trans-
parency and the reflectance each 20 nm from 410 nm to
680 nm.

William G.Rolim de Camargo and J.B.de Madureira,
Sao Paulo, Brazil

This paper has the main purpose of identifying isomorphous
terms of garnets, by the use of triangle diagrams, which
give an approximate idea of the chemical composition of a
garnet sample, without the data of chemical quantitative
analysis. Three physical properties ($\Delta 2\theta$, n and D) are
associated to the chemical composition, being necessary
only to know the values of such three physical parameters,
in order to classify the garnet type.

In the proposed diagrams only the physical constants of
those garnet types are given the occurrence of which in
nature is relatively abundant (almandine, andradite, gros-
sular, pyrope, spessartine) and such constants are related
to the molar chemical composition. The use of $\Delta 2\theta$, instead
of a_o, is a tremendous advantage of the method, since the
usual determination of the unit cell dimensions is both
tedious and time-consuming.

Drawing of triangle charts has been possible through proof
of linearity of $\Delta 2\theta$ in function of chemical composition. The
two-dimensional triangle diagrams make much easier the mani-
pulation and the view of the plotted garnet, which is not the
case for the tridimensional tetrahedron representation (Win-
chell, 1951). The diagrams could be used for the large majo-
rity of garnets (83 %).

G.Amthauer and F.Rost, Saarbrücken, Germany (FRG)

Grossulars with gemstone quality from Tanzania have green or
brown colours, ranging from greenish to emerald-green in the
green series and from yellow to red-brown in the brown series.
Within these two series several fractions could be separated
by visual inspection. These fractions were analysed by X-ray
fluorescence and spectrographic methods and their cell edge
was determined by Guinier X-ray method with pure Si as stand-
ard. Absorption-spectra were measured on thin polished plates
and compared with the chemical analyses, so that absorption
bands could be assigned to the transition elements Cr, Mn, Fe.

The green grossulars have two absorption bands in the red and
the blue part of the visible spectrum at about 16350 and
23400 cm^{-1}, whose intensity is related to the chromium content.
Within the green series the chromium varies between 0.02 and
1.45 wt. % Cr_2O_3. The cell edge increases with the chromium
content from 11.851 Å (0.02 wt.% Cr_2O_3) to 11.886 Å (1.45 wt.%
Cr_2O_3). The two bands could be assigned to Cr^{3+} in an octa-
hedral ligand field and correspond to the transitions $^4A_{2g} \longrightarrow$
$^4T_{2g}$ (band at 16350 cm^{-1}) and $^4A_{2g} \longrightarrow {}^4T_{1g}$ (band at 23400 cm^{-1}).
The transition elements Ti, Fe, Mn, and V, which were also
analysed in these specimens, have no influence on the absorp-
tion spectra of the green grossulars.

The colour of chromium-free brown grossulars is mainly due to
strong absorption bands of Fe^{3+} in octahedral position at ca.
23000 cm^{-1} (transition $^6A_{1g} \longrightarrow {}^4A_{1g} {}^4E_g$) and Mn^{2+} in cubic
position at ca. 24500 cm^{-1} (transition $^6A_{1g} \longrightarrow {}^4A_{1g} {}^4E_g$). There
are also some weaker bands of ferric iron in the visible part
of the spectrum. The Fe^{3+} absorption band corresponding to the
transition $^6A_{1g} \longrightarrow {}^4E_g$ could be measured in the UV at 27000 cm^{-1}.
There are only small amounts of ferrous iron in the cubic posi-
tion of these brown grossulars, because the corresponding bands
at ca. 4350, 5750 and 8050 cm^{-1} are very weak. Within the brown
colour series the total Fe content (determined as Fe_2O_3) varies
between 1.4 and 3.6 wt. %, the manganese content between 0.37
and 0.87 wt. % MnO, without influence on the cell edge of
11.850 Å.

ZONAL AQUAMARINES: THEIR MINERALOGY, GEOCHEMISTRY AND GENESIS

V.F.Barabanov, Leningrad, USSR

Numerous crystals of beryl from greisen veins and tin-bismuth-tungsten deposits in USSR have been studied. It is established that crystals from veins formed in deep, relatively calm tectonical conditions have a yellow colour and a uniform structure. Crystals from veins formed in superficial, tectonically strained conditions have zonal or rhythmic-zonal composition and properties: colour, refraction of light, double refraction, specific gravity, infrared spectrum, lattice dimensions and varying content of Fe_2O_3, MgO, CaO, Li_2O, Na_2O, K_2O, Cs_2O, H_2O, Sc.

Influence of these admixtures of beryl has been observed and it is clear that Fe_2O_3 raises the refraction of light of beryl and creates a blue colour in it, CaO and MgO raises specific gravity of beryl, H_2O, on the contrary, reduces it.

Isomorphism has been established in all structural groups of beryl. A view is been expressed that in Si_6O_{18} rings a replacement of a part of Si atoms by Be and Al atoms can take place and at the same time an equivalent number of atoms of alkaline elements and Ca enters into these rings.

It is supposed that variation in properties and peculiarities in composition of these microadmixtures in zonal beryl crystals is caused by the change in crystallizing conditions which is accompanied by periodical boiling up of mineral-forming solution, seperation of gas phase, increase in alkalinity of solution and change in its oxidizing properties.

In accordance with this, zonal form of beryls can be considered as an objective criterion of geochemical conditions in formation of raremetal veins.

A NEW BLUE AXINITE FROM EAST AFRICA

E.A.Jobbins, A.Tresham, B.R.Young, London, United Kingdom

A faceted gemstone from East Africa, probably Tanzania, gives X-ray diffraction patterns for axinite, but shows low optical and physical properties. Electron microprobe analysis shows that in this stone magnesium substitutes for the iron and manganese content of the well-known material from Bourg d'Oisans, France.

PRECIOUS STONES PEGMATITES IN SOUTH AFRICA AND SOUTH AMERICA,
AND THE CONTINENTAL DRIFT THEORY

H.Strunz, West-Berlin, Germany

A preliminary comparative investigation of the precious stones
pegmatites in Minas Gerais and South West Africa reveals great
similarities in the sequence of crystallisation, in the zoning
of the pegmatites, in the concentration of common and rare ele-
ments and in the final hydrothermal recrystallisation of aqua-
marines, rubellites, verdelites, indigolites, topaz etc. These
pegmatites lie in a very straight north south girdle zone of
the early South Continent before the beginning of the continen-
tal drift. The pegmatites may be slightly older than the drift
beginning.

These observations allow a hypothesis of a great mineralogical
and geological process: The material of the upper mantle is par-
tial solid, liquid and fluid. Fluid exhalations out of the up-
per mantle into the crust material must have happened along this
girdle zone or hot line. These hydrous infiltrations were accom-
panied by the immigration or exsolution of hydrophil elements,
of K, Li, Be, B, F, etc. These infiltrations and migrations, es-
pecially a frontal metasomatic potassium transport, were followed
by migmatisation resp. granitisation of crust material. In the
late stage of the granite crystallisation, high liquid and fluid
masses, rich in rare elements, were concentrated in the roof of
the granite bodies and in fractures of the country rocks. Here
the pegmatitic minerals crystallised, and in a final hydrother-
mal recrystallisation the precious stones were produced. This
may have been a normal crystallisation sequence, but in the South
Continent it possibly was the initial stage for the breaking and
drifting of the continents. Later climate was dry in South Africa
and wet in South America. Therefore different secondary minerals
and different geomorphology were produced. - In combination with
tectonics in the front side of both drifting continents and near
the rift valleys, also precious stones pegmatites were produced;
sometimes chromium was leached out of biotites in the metamorphic
rocks, and beryls were modified to very precious emeralds.

Our further work, on pegmatites in both South Continents will try
to proof this hypothetic combination and generally the genesis of
pegmatites in the light of global tectonics.

Symposia:

Commission on Ore Microscopy
    Thursday, September 12, 1974
        Chairman: S.H.U. Bowie
        Vice-Chairman: F.M. Vokes
        Secretary: M. Font-Altaba

Commission on History and Teaching
    Thursday, September 12, 1974
        Acting Chairman: H.E.Wenden
        Acting Secretary: P.Paulitsch

Commission on Mineral Data and Classification
    Saturday, September 14, 1974
        Acting Chairman: A.Kato
        Secretary: G.T. Faust

EXPERIMENTAL STUDY ON THE PRECISION OBTAINED IN THE DETERMINATION OF REFRACTIVE INDICES BY MICROREFLECTOMETRY

B.Cervelle, C.Lévy & M.Pinet, Paris, France

An investigation on sphalerite consisted in determining their refractive indices by different methods:

    1. by classical refractometry, prism method
    2. by microreflectometry on a fresh cleavage surface
    3. by microreflectometry on two polished sections.

In the cases 2. and 3. the refractive indices $\underline{n}$ were calculated from:

a) the reflectance R_A in air, $n = (1+ \sqrt{R_A})/(1- \sqrt{R_A})$

b) the reflectance R_0 in immersion oil with index N,
$$n = (1+ \sqrt{R_0})/(1- \sqrt{R_0})$$

c) R_A and R_0 by the relation of Koenigsberger:
$$n = \frac{1/2 \; (N^2-1)}{N\left(\frac{1+R_0}{1-R_0}\right)- \frac{1+R_A}{1-R_A}}$$

The comparison of the values for $\underline{n}$ from different methods, considering as best values those obtained by classical re-fractometry, has shown that the relation of Koenigsberger furnished the best results even for a low absorbing mineral as sphalerite. Indeed this method, like every method of double determination, allows to eliminate a part of the disturbing polishing effects which appear therefore less important for they do not influence the determination of the optical constants of opaque minerals by microreflecto-metry.

OPTICAL STUDY OF MINERALS BY DIRECT METHOD

J.Nogues Carulla, A.Lopez Soler, J.M.Bosch-Figueroa,
M.Font-Altaba, Barcelona, Spain

The apparatus constructed to take measurements of re-
flectance by means of a narrow direct beam of light on
surfaces is described. The result obtained on polished
and cleavage surfaces are given and are compared with
those obtained by the microphotometer with normal in-
cidence.

OPTICAL STUDY OF GRATONITE ($Pb_9As_4S_{15}$)

J.Besteiro, A.Lopez Soler, J.M.Bosch-Figueroa, and
M.Font-Altaba, Barcelona, Spain

The refractive index and the coefficient of absorption
in the two principal directions of vibration, that
correspond to the ordinary ray and to the extraordinary
ray, in a section (11$\bar{2}$0) of a sample of gratonite
($Pb_9As_4S_{15}$) from Rio Tinto, has been calculated from
the value of reflectance in two mediums of known re-
fractive indexes.

OPTICAL STUDY OF CUPROSTIBITE (Cu_2Sb)

A.Lopez Soler, J.M.Bosch-Figueroa, Barcelona, Spain,
S.Karup-Moller, Copenhagen, Denmark,
J.Besteiro, M.Font-Altaba, Barcelona, Spain

By means of a microphotometer the principal reflectances
at normal incidence have been measured, in air and in oil,
on section ($10\overline{1}0$) of cuprostibite. Measurements were made
at intervals of 10 nm from ultraviolet to near infrared.
From 700 nm a Nicol prism was used as the polarizer; as
monochromators, glass prism and quartz prism were used.

Dispersion curves are given for the reflectances (in air,
in oil) and also for the values of the refractive index
and the absorption coefficient.

REFLECTANCE MEASUREMENTS IN MONOCHROMATIC LIGHT ON THE
BOWIE-TAYLOR COLLECTION OF 103 ORE MINERALS

S.H.U.Bowie, P.R.Simpson and D.Atkin, London, U.K.

The reflectance of 103 ore minerals from the Bowie-Taylor
collection, previously measured in white light with a se-
lenium cell photometer against an Elba pyrite standard,
has been measured in monochromatic light at four standard
wavelengths with a silicon carbide standard and a semi-
automated photomultiplier light-measuring system attached
to a Zeiss microscope. The identity of all specimens meas-
ured in this work has been confirmed by various combina-
tions of X-ray powder diffraction, semi-quantitative X-
ray fluorescence, optical emission spectrographic analysis
and quantitative electron-probe microanalysis. The reflec-
tance data are presented in tabular form in two different
formats: the first contains an alphabetical listing of the
mineral species with the mean reflectance at λ 546 nm, in
the second the mineral species are re-arranged in order
of increasing mean reflectance at λ 546 nm. In addition,
reflectance ranges at λ 470, 546, 589 and 650 nm, with white-
light and microhardness data from Bowie and Taylor (1958),
are included, together with the chemical formula and sym-
metry; this arrangement is specially suited to the identi-
fication of unknown minerals. The white-light values are
in general agreement with the new data. The methods of
measurement are designed to optimise precision and accuracy
in the collection of large amounts of data.

REFLECTIVITY OF ORE MINERALS AND METALLIC ELEMENTS

F.M.Nakhla, Cairo, Egypt

Recent study, dealing with reflectivity measurements of pol-
ished surfaces of some ore minerals and metals, using the
photomultiplier method with monochromatic light having a
wave length of 4900 Å, has revealed that reflectivity values
are dependent upon primary and secondary factors which are
as follows:

A. Primary Factors include physico-chemical and crystal struc-
ture characteristics of the mineral or metal. These factors
play a dominant role in determining the reflectivity charac-
teristics of the substance. Among the physical factors,
are atomic volume, electronic configuration of the element,
number of valency electrons, refractive and absorption in-
dices of the substance. Chemical factors include composi-
tion of the ore mineral, as well as isomorphism and solid
solutions. Structural factors include type of the crystal
structure, pattern and dimensions of unit-cell, nature of
chemical bonds and crystallographic orientation. There is
an intimate relationship between the crystal structure of a
certain metal and its relfectivity index, which is the ratio
between reflectivity value of the metal, at a certain wave
length, and its atomic volume. Consequently, by knowing the
atomic volume and the crystal structure of a certain metal,
then it would be possible to deduce its reflectivity value.
Reflectivity values postulated for some metals, such as
beryllium, manganese and hafnium, at a wave length of 4900Å,
are in close agreement with the measured values.

B. Secondary factors are mainly related to type of apparatus
adopted for reflectivity measurements, polishing technique,
and nature of standard material. Among instrumental factors
may be mentioned the medium used for reflectivity measure-
ments(air or oil), wave length of monochromatic light, area
of measurement, angle of acceptance of the photomultiplier,
numerical aperture (N.A.) of objectives and internal reflec-
tion of lenses used in the optical system. All secondary fac-
tors should be standardized before setting the apparatus
for reflectivity measurements.

HISTORY OF MINERALOGY IN BERLIN

H.Strunz, West-Berlin, Germany

The first academic course in mineralogy in Berlin started on
the First of November in 1770, which may be regarded as the
birthday of the Bergakademie Berlin. This Academy, with some
interruptions, existed up to 1916, when it was incorporated
in the Technische Hochschule Berlin-Charlottenburg (consti-
tuted 1879), since 1946 named Technische Universität Berlin.

In 1810 the Friedrich-Wilhelms-Universität zu Berlin was
founded, now called Humboldt-Universität, in memory of Wilhelm
and Alexander von Humboldt.

The first mineralogists in Berlin were C.A.Gerhard (1770-1789)
and L.G.Karsten (1789-1810). Lecturer in chemistry was Martin
Heinrich Klaproth (1784-1817), the discoverer of the elements
U and Zr (both 1789), Sr (1793), Ti and Ce (1795), who pub-
lished six volumes on the Chemistry of Minerals (1795-1815).

In 1810 Christian Samuel Weiß became Prcfessor of Mineralogy
at the University and Mining Academy (1810-1856). After his
translation of Haüy's famous "Traité de Minéralogie" (1801),
Weiß discovered the law of rationality by introducing crys-
tallographic axes (Kristallelemente, 1809), which are of basic
importance also in modern X-ray crystallography, as well as
in physics and chemistry of solids. - His assistant professor
for many years and his successor was Gustav Rose (1856-1872)
who discovered the minerals albite and anorthite, zinckenite,
miargyrite, polybasite, plagionite, fibroferrite, rhodizite,
perovskite, astrakanite, samarskite, carnallite, staßfurtite.

The mineralogists following Rose at the University were C.Klein
(1880-1908), Th.Liebisch (1908-1921), A.Johnsen (1921-1934),
P.Ramdohr (1934-1950) and W.Kleber (1953-1970).

At the Bergakademie and Technische Hochschule followed Ch.E.Weiß
(1872-1890), R.Scheibe (1890-1923) and W.Schmidt (1930-1945).
Mineralogist and petrologist at the Freie Universität in Ber-
lin-Dahlem (constituted 1948) is K.H.Mehnert (since 1953).

Mineralogy in Berlin, including crystallography and petrology,
has a 200 years continuous history, with periods more belong-
ing to mining and metallurgy and others more belonging to chem-
istry and physics or to modern geosciences.

HISTORY OF MINERALOGY IN BULGARIA

S. Stoynov, Sofia, Bulgaria

The development of the mineralogical studies in Bulgaria can
be devided into four periods, without taking into account the
traces of the use of minerals by the time of the tribal society,
as well as those ones by the Roman times and the end of the
Turkish yoke (18 and 19 centuries).During the first period,
which covers the times up to the liberation of Bulgaria from
the Turkish yoke, any special mineralogical investigations are
not carried out. Information about some minerals can be found
in the works of foreign geologists-Ami Boúe, Franz Toula etc.

The second period includes the times from the liberation of
Bulgaria from Turkish yoke up to the end of the World War I.
Just four years after the liberation of our country, in 1882,
the first Bulgarian geologist, professor Gueorgui Zlatarski
gives a description of 42 minerals in 74 pages. This is indis-
putably the first book on the mineralogy of Bulgaria. Having
in mind the great geological variety of his country, the author
prognosticates that many other minerals will be discovered.
During the same period, in 1900, the book of Gueorgui Bontchev
"A small contribution to the Mineralogy of Bulgaria" is pub-
lished, where in 10 pages 30 minerals are described.

The third period covers the time between the World War I and
the World War II. In 1923, G.Bontchev publishes his book "The
minerals in Bulgaria", covering 215 pages. A description is
given of 107 minerals, including a lot of crystallographic
and optic constants. In 1925 G.Bontchev makes a generalization
on the minerals from the Rhodope mountain, giving a descrip-
tion of about 50 minerals.

The fourth period begins after the World War II. This is a pe-
riod of an intensive development of the mineralogical studies
in Bulgaria. The great successes realized during this time are
summarized in the book "The minerals in Bulgaria", published
in 1964. It is written by a group of Bulgarian mineralogists
under the direction of our eminent scientist, academician
Ivan Kostov. A description is given of more than 350 minerals
in 540 pages.

ASPECTS OF FORM AND STRUCTURE; THE RENAISSANCE PRELUDE TO CRYSTALLOGRAPHY

C.J. Schneer, Durham, USA

The intellectual foundation for the sience of the Renais-
sance was in Koyre's words "... an unnatural alliance be-
tween Plato and Democritus" but the historical genesis of
crystallography was in the attempt to locate in the natural
world ideal harmonies of form and structure. Renaissance
artists and musicians were mathematical physicists in that
they worked toward exact sciences of modelling nature. They
were also Pythagoreans in that they found in nature the
harmonic proportions and geometric forms canonized by the
ancients. For Johann Kepler, the results were not only new
laws of astronomy but also the connection between the
Democritean concept of atomism and the new geometry born
out of the five perfect solids of Plato. Always the phys-
icist, Kepler found the celestial harmonies as well as the
Platonic solids in natural crystals. Through Descartes,
Bartholinus, Hooke, and Steno, the ground was prepared for
a natural science of crystals.

WILLIAM THOMSON, ENGLISH MINERALOGIST

Marjorie Hooker, Washington, USA, and Ch. C. Waterston,
Edinburgh, Scotland

Dr. William Thomson, an English physician in Oxford and a
Fellow of the Royal Society, left England in 1790 and took
up residence in Italy where he continued his interests in
natural history, built up an extensive mineral collection
which was considered to be one of the best in Europe, and
made valuable contributions to geology and mineralogy. One
of his contributions, long unrecognized, was the discovery
and first description and illustration of the Widmanstätten
pattern, the etching phenomenon found in meteoric iron. In
Naples he was known as Guglielmo Thomson and he signed his
articles either W. Thomson or G. Thomson, or even simply
with the initials W.T. or G.T. It was customary in those
times for letters to editors to be signed only with initials.
Letters written to other scientists were often quoted and
used in their articles, either with or without the writer's
initials. Thus, Thomson's writings appeared under a variety
of signatures and it was not until 1939 that the Oxford his-
torian, Dr.R.T.Gunther, recognized and published a brief
notice on the identity of G. Thomson with William Thomson,
formerly of Oxford. This paper will present a list, with
explanatory notes, of as many of Thomson's writings as it
has been possible to discover and identify.

A CRYSTAL CHEMICAL CLASSIFICATION OF SILICATES

F.Liebau, Kiel, Germany (FRG)

A suitable classification should on the one hand allow a
logical and unequivocal file on individuals to the various
pigeon-holes of the system. On the other hand for as many
properties as possible a classification should reflect re-
lationships between the individuals.

Since physical, chemical, morphological and many other prop-
erties of solids depend on their crystal structures, sili-
cates can reasonably be divided according to two principles:

(I) the linkage of $[SiO_4]$ tetrahedra,

(II) the coordination and linkage of cation-oxygen polyhedra.
While since Machatschki (1928) the linkage of $[SiO_4]$ tetra-
hedra is used to group silicates into neso-, soro-, cyclo-,
ino-, phyllo-, and tecto-silicates, Belov has emphasized the
significance of the cation-oxygen polyhedra.

A combination between these two principles is found if a sub-
division of chain, layer and framework silicates is based on
the type of chains of $[SiO_4]$ tetrahedra that exist in the
silicates concerned. This is due to the fact that the shapes
of the tetrahedral chains depend mainly on the size and
charge of the cations contained in the silicates. Since on
the other hand many mineralogical, chemical and other prop-
erties of silicates depend on their cations, a crystal chem-
ical classification of high-polymer silicates based on tetra-
hedral chain types fullfils very well the conditions demanded
from a suitable silicate classification.

The report will be illustrated by an exhibition of structural
models.

AUTOMATIC COLLECTION AND ASSESSMENT OF MINERALOGICAL DATA

M.P.Jones, London, U.K.

The mineralogical data that are now required by geological
research workers and by many people in the mineral industry
include detailed, quantitative information about the pro-
portions, the sizes, the shapes and the spatial inter-re-
lationships of minerals in rocks and in mineral products.

The paper shows that such information cannot be obtained
efficiently by manual measuring methods because the speed
at which they operate is much too slow for most practical
purposes. Furthermore, both the precision and the accuracy
of the manual methods are shown to be, in many instances,
too low to provide numerical information of any real value.

The paper proceeds to describe briefly the development of
some of the automatic measuring instruments that are now
available and which provide rapid, objective data from plane
sections of mineral specimens.

Since the raw data provided by these instruments are seldom
of direct interest to the mineralogist, details are given
of the manner in which these raw data are assessed and are
presented in acceptable forms.

The assessment of such data is primarily a stereological
problem and the transformation of one-dimensional or two-
dimensional measurements into three-dimensional values is
discussed in some detail. It is shown that volumetric mineral
proportions and sizes, and three-dimensional mineral shapes
can be rapidly determined with a high degree of accuracy but
that difficult problems still exist in the quantification of
three-dimensional spatial parameters such as fabric, texture
and mineral liberation.

Open Sessions:

Silicates
    Friday, September 13, 1974
            Chairmen: J.V. Smith
                      F. Liebau

Mineral Properties and Mineral Occurrences
    Friday, September 13, 1974
            Chairmen: M.H. Hey
                      O.W. Flörke

Petrology I
    Saturday, September 14, 1974
            Chairmen: N.V. Sobolev
                      K.R. Mehnert

Sulfides
    Saturday, September 14, 1974
            Chairmen: L.G. Berry
                      E.F. Stumpfl

Unclassified Papers
    Saturday, September 14, 1974
            Chairmen: C. Frondel
                      S.S. Hafner

DISTORTIONS IN THE COORDINATION POLYHEDRA OF M SITE ATOMS IN OLIVINES, CLINOPYROXENES AND AMPHIBOLES

M.E.Fleet, Ontario, Canada

Distortions resulting from shared edges in the coordination polyhedra of metal (M) site atoms in olivines, C2/c clino-pyroxenes and (Ca),Mg,Fe^{2+} amphiboles have been investigated using published crystal structure data. The principal distortions are associated with relative stretching of M-M and M-Si distances, apparently due to repulsive forces between the positively charged atoms. The effective atomic charges on the M atoms are estimated from electronegativity data. In the clinopyroxenes there is qualitative agreement between the apparent magnitudes of the M(1)-M(1) and M(2)-Si repulsions associated with shared edges and the calculated relative electrostatic potentials due to the M atoms, the repulsions decreasing in the sequences, $Al > Fe^{3+} > (Cr^{3+}, In) > Mg > Mn^{2+}$ for M(1) atoms and $Ca > Li > Na$ for M(2) atoms. Also, in Ca amphiboles, in agreement with calculated data, the repulsion due to Mg is apparently greater than that due to Fe^{2+}. However, in olivines the repulsion due to Fe^{2+} is greater than that due to Mg.

Although the t_{2g} orbitals on transition metal atoms must project toward octahedral edges, the coordination octahedra of transition metals do not show a consequent reduction in shared edge-related distortions. Thus, 3d electrons in t_{2g} orbitals do not appear to screen the effective atomic charges along M-M and M-Si directions.

ON A NEW TYPE OF CHAIN SILICATES WITH (Si_6O_{16}) RADICAL

V.A.Drits, Yu.I.Goncharov, Moscow, USSR

In studying the processes of mineral formation in the systems
$Na_2O-MgO-SiO_2-H_2O$ and $NaF-MgF_2-MgO-SiO_2$ fibrous OH- and F-
phases have been obtained, respectively, with earlier unknow
structural and diffraction characteristics. The composition
of the initial components was similar to that of Na-Mg richter-
ite. The synthesis of F- and OH-phases was carried out at tem-
peratures of $400-600^{\circ}C$.

For the OH-phase, a=10.132; b=27.12; c=5.257 Å; ß=$106^{\circ}54'$;
space group C2/c; for the F-phase, a=10.30; b=27.1; c=5.15 Å;
ß=104°; space group C2/c. The chief feature of the structure
of the phases under investigation is that it contains strips
of three pyroxene chains connected by common O atoms. In the
projection onto the plane (010) the structure of the OH- and
F-phases is analogous to those of the monoclinic pyroxenes and
amphiboles. The structural model under discussion has been ob-
tained on the basis of an analysis of intensities of reflec-
tions from point electron diffraction patterns and building
the projections of electrostatic potential. The crystallochem-
ical formula for the OH-phase is:

$(Na_{0.93}K_{0.02})_{0.95}(Mg_{3.94}Fe^{3+}_{0.01})_{3.95}[Si_6O_{14.86}(OH)_{1.14}|(OH)_2]$,

for the F-phase:

$(Na_{1.40}Mg_{0.40})_{1.90}Mg_{4.0}[Si_6O_{16}|(F_{1.8}O_{0.2})_2]$
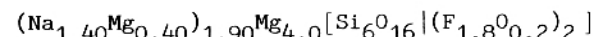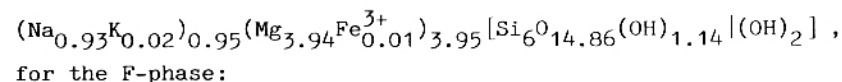
This shows the possibility of existence of structures with
$[Si_6O_{16}]$ strips that are an in-between "link" between layer
silicates and amphiboles.

THE CRYSTAL STRUCTURE DETERMINATION OF CHAPMANITE
$SbFe_2Si_2O_8(OH)$ BY HIGH-VOLTAGE ELECTRON DIFFRACTION

A.P.Zhoukhlistov, B.B.Zvyagin, S.V.Soboleva, L.B.Shlain,
Moscow, USSR

Two specimens of a rare mineral, chapmanite, from two locali-
ties - Cadamdjai (middle Asia) and Snilkov (Czechoslovakia)
have been investigated. For the determination of the structure
electron diffraction texture patterns obtained at acceleration
voltages 350 kV have been used. The unit cell is a = 5,188,
b = 8,985, c = 7,696 Å, ß = $101^{\circ}39'$. At ϱ = 3,8, Z = 2.

The resulting structure obtained by analysis of Patterson and
Fourier syntheses and by LS-refinement may be described as con-
sisting of 1:1 kaolinite-like layers with composition $Fe_2Si_2O_8$
(OH) arranged in a sequence $6_5T_O6_6$. In contrast to the kaolinite
case adjacent sheets of neighbouring layers are located with va-
cant octahedra just over the ditrigonal tetrahedral loops, form-
ing cavities occupied by Sb atoms. Just because of their pre-
sence in the interlayers the electrostatically unfavourable layer
sequence of the monoclinic structure (Cm) is stabilized.

This structure exhibits pronounced distortions. The tetrahedral
bases strongly differ from each other by the edge length. The
O atoms of these bases lying in mirror planes m have coordinates
$z > z_{Si}$ while for others $z < z_{Si}$, that results in a strong tilt
of tetrahedra. Under the action of Sb the octahedral apices O,OH
approach vacant octahedra and the apices of the outer octahedral
surface are occupied by O instead of OH. Furthermore Fe atoms
are displaced from the centres of octahedra to the inner O,OH
bases.

The structure of chapmanite appears to be the only example of
realization of kaolinite-like layers containing Fe^{3+} instead of
Al, and shows the same difference for 1:1 layer silicates, which
exists between micas and pyrophyllites in the case of 2:1 layers.

$A^{2+}[T_2^{3+} T_2^{4+} O_8]$, FELDSPARS AND DANBURITES:
THEIR STRUCTURAL AND CRYSTAL CHEMICAL PROPERTIES

H.Kroll and M.W.Phillips, Münster, Germany (FRG)

Both the danburite and feldspar structures can be thought of as beeing built up of double-crankshaft chains which consist of 4-membered rings of tetrahedra. Two of the adjacent tetrahedra have apical oxygen atoms pointing up (U) and two have those pointing down (D). The apical oxygen atoms serve to link similar four-membered rings.

The differences in the danburite and feldspar structures arise from the manner in which these chains are cross-linked to form the framework. In the danburite structure the successive chains are alternately rotated clockwise and counter-clockwise by approximately 90° whereas in the feldspar structure each chain is rotated approximately 180° from the neighboring chains. In both structures the cross-linking gives rise to a "sheet" of tetrahedra perpendicular to the chain axes. These sheets consist of 4-and 8-membered rings. However, whereas in the danburite structure there is only one type of 8-membered rings having the sequence of tetrahedra UUDUDDUD, the feldspar structure contains two types of 8-membered rings: one with the same sequence of tetrahedra as in danburite and another one in which the sequence is UUUUDDDD. These differences give rise to different coordination polyhedra for the large A^{2+} cations which lie in cavities between the 8-membered rings of successive "sheets". The coordination number of A^{2+} cations is 7 in feldspars and 9 in danburites.

Due to the perfect alternation of T^{3+} and T^{4+} cations in ordered feldspar structure all linkages are of the type $T^{3+}- O -T^{4+}$. This is also the usual case for the danburite type structures, although there is at least one exception: In danburite, $CaB_2Si_2O_8$ there is a perfect alternation of B^{3+} and Si^{4+} within the "sheets", however, within the double-crankshaft chains there are B-O-B and Si-O-Si linkages. Thus although the structure is perfectly ordered, only 75 % of the bonds are of the type $T^{3+}- O - T^{4+}$. A discussion of some structures newly refined will be given on the basis of this general description.

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ON STRONTIUM FELDSPAR, $Sr[Al_2Si_2O_8]$

Horst Pentinghaus, Münster, Germany (FRG)

Strontium feldspar, which lies in the middle of the alkaline earth feldspar series $A^{2+}[Al_2Si_2O_8]$, where $A^{2+}=$ Ca, Sr and Ba, displays intermediate fine-structural properties compared to anorthite, $Ca[Al_2Si_2O_8]$, and celsian, $Ba[Al_2Si_2O_8]$. For equilibrated anorthite, end-member of the important rock-forming plagioclase solid solution, four classes of reflections are observed by X-ray diffraction methods:

"a" h + k even, l even, which are mainly due to the framework

"b" h + k odd, l odd, which arise from an ordered distribution of Al and Si

"c" h + k even, l odd, as well as

"d" h + k odd, l even, which arise from an antiphase domain structure

However, the rather rare mineral celsian shows only "a" and "b" type reflections. Thus strontium feldspar, obtainable only by synthesis and revealing "a" and "b" and especially "d" type reflections when properly equilibrated with respect to temperature, offers an excellent opportunity to get a deeper insight into the dependence of domain structure formation on the expansion of the feldspar framework. Results based on X-ray single crystal and powder methods as well as on IR spectroscopy and intensity calculations are presented.

Strontium feldspar melts congruently at 1660 ± 10°C. The metastable hexagonal polymorph of $SrAl_2Si_2O_8$ can be prepared either by quenching an overheated melt or at lower temperatures under hydrothermal conditions whereas the strontium equivalent of the mineral paracelsian, $Ba[Al_2Si_2O_8]$, appears to be the stable low temperature polymorph of $SrAl_2Si_2O_8$.

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THE CRYSTAL STRUCTURE OF MAZZITE

Ermanno Galli, Modena, Italy

The crystal structure of mazzite, the natural counterpart
of synthetic molecular sieve Ω , has been determined from
single crystal X-ray data. The space group of mazzite is
$P6_3/mmc$ (a = 18.392 $\mathring{A}$, c = 7.646 $\mathring{A}$), hence different from
$P6/mmm$ previously deduced from powder data for phase Ω .
The structural model proposed by Barrer and Villiger (1969)
for the synthetic phase cannot be fit in the space group
$P6_3/mmc$, hence a new structure has been calculated. The
gmelinite cages, which are present in the Barrer-and-
Villiger's model, are part also of the new structure but
their interconnection is different, because the linked
cages are shifted of $c/2$.

BARRER, R.M. and VILLIGER, H.: Probable structure of
zeolite Ω. - Chem.Comm. 1969, 659-660.

DIMENSIONAL FIT AS THE CONTROL ON ORIENTATION ANGLES OF EXSOLUTION LAMELLAE IN PYROXENES AND AMPHIBOLES

Peter Robinson, Howard W. Jaffe, Amherst, Mass., and
Malcolm Ross, Washington, USA

When lamellae of one monoclinic pyroxene or amphibole exsolve
within another monoclinic host pyroxene or amphibole, the con-
tacts between lamellae and host develop along planes of best
fit between the two structures which are planes of minimal
strain. As the differences between the a and c lattice para-
meters of host and lamellae become larger, the differences be-
tween the actual contact planes and the rational planes (001)
and (100) become larger.

In the case of metamorphic augites with pigeonite lamellae, in
which lattice parameters have not changed greatly since exsolu-
tion, the orientations of exsolution lamellae are mainly a func-
tion of composition, particularly Fe/Mg ratio, and may be pre-
dicted from present lattice parameters. The most remarkable
confirmation of the dimensional fit theory is obtained from mag-
nesian metamorphic augites. Not only are observed angles of ex-
solution lamellae in close agreement with best fit planes cal-
culated from lattice parameters, but observed slight relative
rotations between lattices of host and lamellae are in close
agreement with rotations, calculated independently from lattice
parameters, that are required to achieve best fit.

In certain slowly cooled igneous augites, in which differences
in thermal contraction between host augite and pigeonite la-
mellae appear to have been large, exsolution took place in as
many as three cycles, where the angles of lamellae were appro-
priate for the relative lattice parameters under the T condi-
tions of that cycle. Study of such lamellae coupled with data
on lattice parameters measured at high T and P has some po-
tential as a geothermometer. The cyclical nature of the la-
mellae suggest that supersaturation, nucleation, and growth
was the mechanism by which exsolution took place. Thick ini-
tial portions have a consistently different angle from thin
later portions, suggesting gradual change in relative dimen-
sions due to differential thermal contraction as lamellae pro-
pagated longitudinally through the host crystal.

A COMPARISON OF THE STABILITIES OF OH- AND F-TREMOLITE

M.C.Gilbert, Blacksburg, USA, and G.Troll, München
Germany (FRG)

The calcic amphibole, OH-tremolite, $Ca_2Mg_5Si_8O_{22}(OH)_2$, stably
dissociates to diopside$_{ss}$ + enstatite$_{ss}$ + ß quartz + vapor at
low pressure, and to the same assemblage with α quartz substi-
tuted for ß quartz at higher pressure. The breakdown curve
changes from a very low dP/dT at about 550°C, 1 atm to a very
steep dP/dT and a temperature of about 875°C in the pressure
range 2 to 5 kb. Above this pressure the curve appears to pass
through a maximum and attain a negative slope chiefly because
of the compressibility of the vapor. This negative dP/dT is
augmented by the volume change of the ß quartz = α quartz tran-
sition at about 11 kb. OH-tremolite stability is limited at
higher pressure by the lower volume assemblage diopside + talc,
the maximum pressure being about 24 kb at 825°C.

In contrast the stable breakdown of F-tremolite, $Ca_2Mg_5Si_8O_{22}F_2$,
is to the assemblage protoenstatite$_{ss}$ + diopside$_{ss}$ + fluorite +
tridymite at 1 atm and about 1150°C. This reaction has as pos-
itive dP/dT at 1 atm. The slope is modified by the protoen-
statite=orthoenstatite change at some unknown low, but higher,
pressure. The highest temperature of stability for this amphi-
bole should be about 1175°C at the pressure of the tridymite =
ß quartz transition (~1 3/4 kb). At this transition, dP/dT
becomes negative because the volume change in the SiO_2 poly-
morphs results in a negative ΔV for the breakdown reaction.
dP/dT is about -340 bars/°C up to the α quartz = ß quartz bound-
ary (~24 kb).

Comparison of stabilities of OH- and F-tremolite indicates
that the 600°C difference in their upper thermal stabilities
at 1 atm decreases to about 250°C at 24 kb. Thus under some
conditions, the effects of fluorine on the temperature of
silicate equilibria may not be as dramatic at higher pres-
sure as at lower. On the other hand, whereas OH-tremolite is
not stable over 24 kb, F-tremolite appears to be stable to
at least 40 kb. Thus fluorine can extend the pressure stabil-
ities of some silicates.

STABILITY RELATIONS OF AMPHIBOLES IN THE TREMOLITE ¹ FERRO-
TREMOLITE - ANTHOPHYLLITE - GRUNERITE QUADRILATERAL

K.Schürmann, Marburg, Germany (FRG)

Experimental investigations at different temperatures and
water vapor pressures have been made on the joins:

(1) ferrotremolite - grunerite and

(2) $\frac{1}{2}$ tremolite $\frac{1}{2}$ anthophyllite (TAN) -

$\frac{1}{2}$ ferrotremolite $\frac{1}{2}$ grunerite (FTG)

using common hydrothermal techniques. For 3 investigated
compositions of the join (1), grunerite 25, 50, 75, we could
find a field of coexisting ferrotremolite and grunerite
between 450° and about 550°C and water vapor pressures up
to 6 kbars with oxygen fugacities defined by the magnetite-
iron and magnetite-wüstite buffers.

At medium pressures (1-3 kbars) and at temperatures between
530° and 580°C the only stable amphibole phase is grunerite
coexisting with hedenbergite + quartz + H_2O. Increasing p_{H_2O}
(up to 6 kbars) shifts the upper stability curve of ferro-
tremolite in a rate of about 25°/kbar to higher temperatures.

First runs on join (2) TAN - FTG at Fe/Fe + Mg-compositions
>40 yielded coexisting actinolites and cummingtonites at
temperatures up to 630°C and at p_{H_2O} up to 6 kbars.

UPPER STABILITY OF ORTHORHOMBIC AMPHIBOLES IN THE SYSTEM
MgO - FeO - Al_2O_3 - SiO_2 - H_2O

Th.Hinrichsen, Marburg, Germany (FRG)

Orthorhombic amphiboles of anthophyllite composition are
characteristic constituents of metamorphic rocks rich in
magnesia. Under high-grade metamorphic conditions antho-
phyllite becomes unstable and is transformed to H_2O-free
assemblages.

Synthetic aluminous anthophyllites with different Mg-Fe-
ratios were investigated experimentally at different tem-
peratures and H_2O-pressures to determine their stability
range. At 6 kb H_2O-pressure synthetic anthophyllites were
found to be stable up to 800°C.

The nature of the high-temperature breakdown assemblages
is dependent on the chemical composition and on the H_2O-
pressure. Mg-Fe-anthophyllitescontaining up to 5 weight-%
Al_2O_3 are transformed to (aluminous) hypersthene and
quartz while cordierite is stable in the breakdown prod-
ucts at higher Al-concentrations in the anthophyllite
phase.

THE STRUCTURAL AND GENETIC RELATIONS BETWEEN LAYER SILICATES
UNDER HYDROTHERMAL CONDITIONS AND SOME PROBLEMS OF THE CLAY
MINERALOGY

V.Frank-Kamenetsky, N.Kotov, E.Goilo, A.Tomashenko,
Nguen Tat Tram, Leningrad, USSR

The structural and genetic relations between layer silicates
were examined by phase transformations of kaolinite, mont-
morillonite, pyrophyllite, sepiolite, palygorskite under
hydrothermal conditions (P_{H_2O} = 1 - 2 kbar, T = 150 - 650°C)
with additions of K, Na, Ca, Mg-chlorides, sulphates and
carbonates. Practically, all most significant kinds of clay
minerals and many unlayered minerals were synthesized. On
the base of this material some main problems of genetic min-
eralogy and petrology of metamorphic processes are discussed.

It was established, that a significant feature of the alter-
ations of clay minerals is their alteration by stages, caused
by 3 groups of factors: 1) the thermodynamic factors (P-T-X-pH),
2) the phase stability - unstability, 3) the different velo-
city of their formation. The rise of temperature up to 200 -
500°C (P_{H_2O} = 1 - 2 kbar) at runs with addition of $MgCO_3$, leads
to a formation of (Al,Mg)-serpentine and further - forsterite
and spinel from kaolinite; from dioctahedral montmorillonite,
first of all, there is formed a trioctahedral montmorillonite.
The increase of concentration of $MgCO_3$ (montmorillonite:$MgCO_3$ =
2:3 in weight) as in runs with kaolinite, leads to a formation
of (Al,Mg)-serpentines, and the increase of temperature - to
formation of talk, chlorites, forsterite and spinel. The rise
of pH of the hydrothermal surrounding up to 7-8, promotes the
transition of Al^{VI} to Al^{IV}. This consequently leads to a for-
mation of kalsilite + leucite, and feldspars + leucite (ad-
dition of K_2CO_3) from kaolinite and montmorillonite instead
of micas. The latter are formed through the beidellite-like
and partly ordered mixed-layered mica-montmorillonite phases
below pH = 5-6, and with addition of KCL.

All processes examined are realized, as a rule, in the form of
transformational reactions, when the structure of initial ma-
terials is inherited by the newformed phases. The concrete ex-
amples of the alterations of clay minerals by stages might be
used as a model system for the investigation of the epigenetic
and hydrothermal-metasomatic processes.

PHASE EQUILIBRIA BETWEEN SOME ZEOLITES AND PLAGIOCLASE

H.Minato, H.Kusakabe, T.Yamanaka, M.Utada, Tokyo, Japan

In Japan, many kinds of zeolites from sedimentary rocks are investigated with respect to their mode of occurrence and mineralogical properties. The main varieties of these zeolites are clinoptilolite, mordenite, analcime and laumontite. And these zeolites, associated with plagioclase, quartz, opaline silica and some clay minerals, are formed from the acidic tuffs mainly by diagenesis.

Phase equilibria between these zeolites and plagioclase are studied in order to investigate their stability relationship using hydrothermal method from a view point of solution chemistry. Purified natural clinoptilolite as a starting material is treated with NaOH solution having variable concentrations in a Morey-type reactor. Equilibrium relations in the system of clinoptilolite, mordenite, analcime and albite are obtained in terms of temperature, pressure and pH. One of the results of these experiment is presented in the following table.

pH of NaOH solution	Temperature (^{o}C)	Pressure (bars)	Formed material	pH of reacted solution
10	280	500	clinoptilolite	6.05
12	300	620	mordenite	7.15
13	340	625	albite	11.10
14	380	300	analcime	13.1

THE APPLICATION OF PAULING'S FORMULA TO BOND-VALENCE SUMMATIONS

Rudolf Allmann, Marburg, Germany (FRG) and
Gabrielle Donnay, Montreal, Canada

Pauling's logarithmic relationship for covalent and metallic bonds:
$d_n = d_1 - 2k \cdot \log n$ (1947, J.Amer.Chem.Soc. 69, 542; d = atomic distance, n = bond number) may be used for ionic bonds too; as for V-O (Byström & Wilhelmi 1951, Acta Chem.Scand. 5, 1003; Evans 1960, Z.Krist. 114, 257), Mo-O (Åsbrink & Brandt 1971, Chem. Scripta, 1, 169), B-O (Donnay & Donnay 1973, Acta Cryst. B 29, 1417). We prefer the terms bond length L and bond valence v instead of d and n. To get the best fit, the two constants L(1) and 2k (in Å) in

$$(1) \quad L(v) = L(1) - 2k \cdot \log v$$

are chosen for the M-O bonds of the following cations as:

Li 1.262; 1.15 Al 1.644; 0.88 Ti 1.754; 1.12 Zn 1.675; 0.90
Be 1.374; 0.88 Si 1.63 ; 0.83 V 1.81 ; 0.78 Ga 1.73 ; 0.88
B 1.366; 0.85 P 1.64 ; 1.10 Cr 1.79 ; 0.78 Ge 1.75 ; 0.75
C 1.40 ; 0.60 S 1.614; 0.84 Mn 1.75 ; 0.91 As 1.77 ; 0.94
N 1.41 ; 0.90 K 1.659; 1.30 Fe 1.74 ; 0.88 Mo 1.90 ; 0.76
Na 1.661; 1.01 Ca 1.896; 0.95 Co 1.655; 0.97 W 1.91 ; 0.82
Mg 1.636; 0.97 Sc 1.877; 0.81 Cu 1.65 ; 0.91

(Pauling proposed 2k = 0.60 Å for all cases). (1) is not very sensitive to the 2k-value (except for strong bonds with $v > 1$), but for a given structure the L(1)-values may need some correction for the individual cations. If for a cation its valence = Σv_{ideal} is known and Σv_{real} deviates from this value, the following correction may be applied:

$(2) \quad L(1)_{cor} = L(1) + 2k \cdot \log f$, with $f = \Sigma v_{ideal} / \Sigma v_{real}$.

The logarithmic function leads to similar results as the potential function.

$(3) \quad v = v_i \cdot (\bar{L}/L)^p$ (Donnay & Allmann 1970, Amer.Mineral. 55, 1003, and 1972, Acta Cryst. A 28, 108; Brown & Shannon 1973, Acta Cryst. A 29, 266) if one takes $p = \bar{L}/2k \cdot \log e$). Some applications of the proposed procedure will be given.

OXIDES AND SULFIDES FROM THE FISKENAESSET COMPLEX, WEST GREENLAND

I.M.Steele, F.C.Bishop and J.V.Smith, Chicago, USA, and B.F.Windley, Leicester, U.K.

The textures and chemistry of opaque phases from the metamorphosed Fiskenaesset igneous complex, west Greenland, were investigated with reflected-light microscopy and an electron microprobe. Magnetite, Cr-magnetite, and ilmenite occur in the lower zones while spinel (near $MgAl_2O_4$), chromite, and rutile predominate in the upper zones. Extensive evidence (e.g. complex exsolution textures and chemical data for coexisting phases) is presented for subsolidus equilibration of opaques to low temperatures, probably in the range of 300 to 600°C.

Coexisting spinels outline a probable exsolution gap between $(Fe,Mg)Fe_2O_4$ and $(Fe,Mg)Al_2O_4$ which is truncated by entrance of about 40 % $(Fe,Mg)Cr_2O_4$. The supposed primary spinels have compositions indicating derivation of the Fiskenaesset complex from a liquid richer in Al than for other well-known layered intrusions.

The sulfide mineralogy is complex, and includes at least the following: pyrrhotite, pentlandite, chalcopyrite, pyrite and cubanite. Detailed parageneses and chemical compositions will be reported and correlated with the oxides. Preliminary observations indicate equilibration to very low temperatures.

COMPARISON "FLINT - CHERT" - BASED ON CHEMICAL DATA

P.Bettermann and D.Ackermand, Kiel, Germany (FRG)

Thirtytwo glacial-flint specimens from eight different deposits in Schleswig-Holstein and the western Baltic Sea have been analyzed for sodium, potassium, magnesium, calcium, aluminum, total iron, silicon, phosphorus, manganese, titanium, adsorptive and chemical bonded water and carbon-dioxide. The results are compared with corresponding published data of flint and chert (as shown for example in the figure below) in order to search for characteristic differences in their chemical composition.
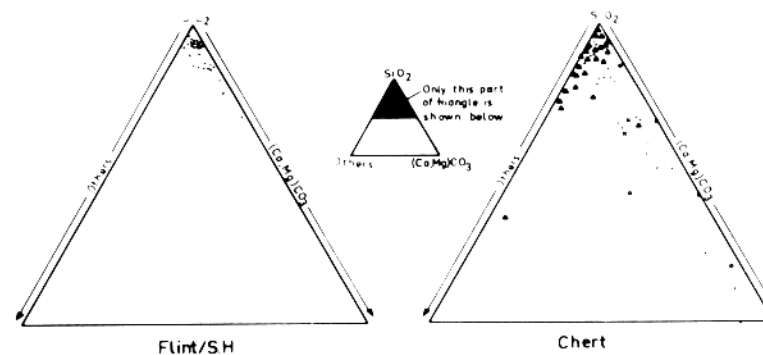
Flint/S.H   Chert

Subsequently an attempt will be made to define the terms: "Flint" - "flints" - "Hornstein" - "chert" - "silex" etc. by means of chemical data and genetic consideration.

In addition optical and electron-optical investigations together with some work on an electron microprobe were made. The aim was to find out the distribution-relations of the analyzed elements and the mineral composition of flint. Beside the main-phase silica in various modifications and crystal-size distributions and beside accessory phases as clay, carbonatic and sulphidic minerals there were found out some interesting silification-phenomena.

THE MODIFICATIONS OF Mg-Fe-BORACITES

R.v.Hodenberg and R.Kühn, Hannover, Germany (FRG)

Nine samples of Boracites from different occurrences have
been found with compositions covering the entire range of
Mg-Fe solid solution. The average content of Mn-Boracite
in all specimens was 2,6 mol %. The crystals are extra-
ordinary fine twinned and showed cubic morphology with
faces (100), (111), (111) and (110).

The crystals were investigated by DTA, optical- and X-ray-
methods. In spite of the limited amount of the available
material and of their slight inhomogenity with respect
to the composition, the following preliminary observations
could be made on the different modifications and their
fields of existence:

1. All the crystals of the series are cubic above tempe-
   ratures ranging from $265^{\circ}C$ (Mg-rich) to $340^{\circ}C$ (Fe-rich).

2. An orthorhombic modification appears below these tempe-
   ratures, the stability of which extends to room tempera-
   ture in the case of Mg-rich members.

3. Crystals which contain more than approximately 40 mol %
   Fe-Boracite, possess an additional - probably monoclinic
   - modification.

4. In the case of samples with contents of Fe-Boracite be-
   tween 42 mol % and approximately 90 mol % another mono-
   clinic phase could be observed with quite different op-
   tical properties. The transition temperature to this
   modification is dependent on the mole ratio Mg Fe. It
   increases with increasing amounts of Fe from 50 up to ca.
   $220^{\circ}C$.

5. Boracites, very rich in Fe (from ca. 90 mol %) are uni-
   axial, in analogy to the synthetic Fe-Boracite. In this
   cases the crystals are trigonal.

THEORETICAL AND EXPERIMENTAL BASIS OF DISTINGUISHING THE
GROUPS OF ALUNITE AND ITS STRUCTURAL ANALOGUES

M.A.Kashkai and C.M.Kashkai, Bacu, USSR

34 minerals of different classes - sulfates, phosphates, and
arsenates, possessing analogous structures with alunite and
jarosite are classified as a "Group of alunite and its struc-
tural analogues".

The general chemical formula, reflecting the complex reactive
ions for the whole group is expressed as follows:
$$R[R^{3+}(OH)_2]_3[AO_4]_2$$
where R = K^+, Na^+, H_3O^+, NH_4^+, Ag^+, Rb^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, Pb^{2+},
Bi^{3+}, Y^{3+}, Ce^{3+}, Th^{4+}, U^{4+},
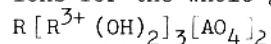
$R^{3+}(OH)_2 = Al(OH)_2^+$ and $Fe(OH)_2^+$
$AO_4 = SO_4^{2-}$, PO_4^{3-} and AsO_4^{3-}
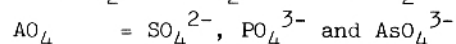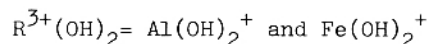
For formation of crystal structure of alunite type a great
importance belongs to hydrocomplexes of aluminium and iron
and more likely to ions $Al(OH)_2^+$ and $Fe(OH)_2^+$.

Minerals of the alunite group and their structural analogues
have common energy character. Thermodynamical constants of
the reactions for the most minerals obtained experimentally
are almost similar.

Taking into consideration the complex ions of the system and
the variation of their concentration during reaction the com-
mon equations is obtained. It is a thermodynamic model of the
formation pattern of isostructural minerals of the alunite
group. Using the computer program "Alunite" the model gives
the possibility to consider simultaneously and separately the
role of temperature, pH, concentration of all reacting ions,
the influence of ion power of solution on mineralforming re-
action.

BASALUMINITE, THE NEW MINERAL OF CZECHOSLOVAKIA

J.Hrusková, Prague, CSSR

In the Ždánice unit which forms part of the flysch zone of
the Carpathians, at Nikolčice near Brno (Moravia) on the
surface of carbonate concretions in the beds of the Meni-
litic Formation, a white nodular mineral was found, which
was identified as hydrobasaluminite and basaluminite by a
detailed study. On the territory of Czechoslovakia, these
minerals have not so far been found.

As the main method of identification X-ray diffraction was
used. Chemical composition was determined. Under electron
microscope, thin flaky transparent crystals, rhombic in
shape, with good cleavage, were observed.

In the conclusion of the paper the data on the basaluminite
and hydrobasaluminite, obtained by means of X-ray methods,
thermal study, chemical analysis and electron microanalysis
are summarized.

CLASSIFICATION OF MINERALS OF THE GROUP OF TOURMALINE

V.A.Kornetova, Moscow, USSR

According to their crystallochemical nature, especially the
mode of substitution, the following types of tourmalines are
distinguishable: schorl, gabriellite ("ferric iron tourma-
line"), buergerite, elbaite and jakovlevite. Peculiarities
of every type, in their turn, permit to classify all known
tourmalines. Analytical diagnosis of valencies of some
chemical elements and their position in the structure of
tourmalines are of especial significance. The description
of a new type - jakovlevite - is given.

XONOTLITE FROM HEGURI, CHIBA PREFECTURE, JAPAN

Akira Kato and Satoshi Matsubara, Tokyo, Japan

Xonotlite from Heguri, Chiba Prefecture, Japan, is monoclinic, space group P2/a, a = 17.0217 Å, b = 7.3486 Å, c = 7.0076 Å, β = 90.326°, Z = 2 ($Ca[(OH)_2|Si_6O_{17}]$), according to the four-circle goniometric study by Takeuchi and Kudo, Mineralogical Institute, University of Tokyo. Optically biaxial positive, 2V = 20-25°, r < v weak, ns α = 1.584, β = 1.584, γ = 1.595 (all ± 0.002); optic plane nearly parallel to {100}, b = Z. Chemical analysis by Tiba, Department of Geology, National Science Museum, gives SiO_2 49.99, Fe_2O_3 0.48, FeO none, MnO 0.16, CaO 46.19, Na_2O 0.17, K_2O 0.02, H_2O(+) 2.95, H_2O(-) 0.10, sum 100.06 %. Specific gravity 2.70 (meas.), 2.711 (calc.); cleavage {001} perfect. Elongated parallel to b, dominant faces are (100), (010), (001) and (001) observed under the electron microscope.

It occurs 1) as principal fissure-filling material in veinlets cutting an altered dolerite and 2) as accessoric member of veinlets of strontium-bearing tobermorite (SrO 1.65 %) cutting a prehnite-rich greenstone.

HARADAITE, $Sr_2V_2[O_2|Si_4O_{12}]$, A NEW MINERAL FROM THE NODA TAMAGAWA MINE, IWATE PREFECTURE, AND THE YAMATO MINE, KAGOSHIMA PREFECTURE, JAPAN

Takeo Watanabe, Akita, Japan
& A.Kato, J.Ito, T.Yoshimura, H.Momoi, K.Fukuda

Haradaite, $Sr_2V_2[O_2|Si_4O_{12}]$, is found from the Noda-Tamagawa Mine, Iwate Prefecture and the Yamato Mine, Kagoshima Prefecture, Japan, as an accessoric member in bedded manganese ore deposits. The chemical analysis by J.Ito on the Yamato material gives SiO_2 38.38, Al_2O_3 0.36, TiO_2 0.06, VO_2 26.16 CaO 1.27, SrO 27.08, BaO 4.90, MnO 0.19, FeO 0.12, Na_2O 0.01, K_2O 0.04, H_2O(+) 1.24, H_2O(-) 0.20, Pb 0.02, Cu 0.20, sum 100,23 %. Colour bright green, luster glassy. Cleavages, {010} perfect, {100} and {001} distinct. Hardness(Mohs) 4 1/2. Specific gravity 3.80(meas.), 3.83(calc.).

It is orthorhombic, space group Ama2, a = 7.001Å, b = 14.67Å, c = 5.324Å (Noda-Tamagawa Mine); a = 7.001Å, b = 14.64Å, c = 5.312Å (Yamato Mine), respectively. Unit cell content $(Sr,Ba)_4V_4Si_8O_{28}$. Optically biaxial negative, (-)2V = 75°, r < v very strong, ns α = 1.713, β = 1.721, γ = 1.734(all ± 0.002), $\gamma - \alpha$ = 0.021; optic orientation a = X, b = Y, c = Z; axial colours X = colourless to very pale green, Y = colourless to light yellowish green, Z = bluish green.

It occurs with quartz in coarse-grained rhodonite ore at the Noda-Tamagawa Mine and as veinlets cutting manganoan goldmanite-rhodonite ore at the Yamato Mine.

The present name covers the solid solution $(Sr,Ba)_4 V_4Si_8O_{28}$ with Sr ≥ Ba, and unnamed natural $(Ba,Sr)_4V_4Si_8O_{28}$ found at the Tanohata Mine, Iwate Prefecture and synthetic $Ba_4V_4Si_8O_{28}$ are probably isostructural.
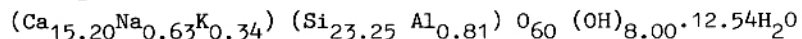
The name is given in honour of Dr.Zyumpei Harada, Emeritus Professor of Hokkaido University, Sapporo.

THE GYROLITE - APOPHYLLITE MINERAL ASSEMBLAGE OF THE
RANSKO INTRUSIVE BODY (EAST BOHEMIA)

K.Melka, J.Pokorný and D.Ulrichová, Prague, CSSR

This rare assemblage of the secondary minerals together
with other alkali-lime minerals found in the mafic and
ultramafic rocks of the Ransko-Massif (associated with
both copper-nickel liquation magmatic and sulphide
copper-zinc ores) has originated by the hydrothermal
leaching of the main chemical components of plagioclases.

Special attention in this contribution has been paid to
the mineralogical determination of the rare gyrolite -
hydrous calcium silicate - which shows a significant $22.3\overset{\circ}{A}$
X-ray reflection. X-ray microanalysis has shown that the
micaceous flakes with pearl lustre separatable from the
spherulitic aggregate did not consist of gyrolite only
but of the gyrolite alternating with apopyllite intimately
intergrown. The structural formula
$(Ca_{15.20}Na_{0.63}K_{0.34}) (Si_{23.25} Al_{0.81}) O_{60} (OH)_{8.00}.12.54H_2O$
has been calculated from the chemical analysis of the re-
latively pure gyrolite. This formula has shown a fair
agreement with that which has been calculated from the
point X-ray microanalysis.

The special feature of the gyrolite sample from Ransko is
characterized by the presence of hydrocarbons. These hydro-
carbons have been confirmed especially by the infrared ab-
sorption spectroscopy and gas chromatography. The electron
and X-ray images which were carried out on the X-ray micro-
analyser and on the scanning electron microscope have shown
that hydrocarbons are concentrated in the channel spaces
present in gyrolite.

LITHIUM MICAS FROM JAPANESE PEGMATITES

Kozo Nagashima, Mariko Honda, Junko Iino and Kazuo Harada,
Tokyo, Japan

Chemical composition, optical and X-ray properties,
infrared and far-infrared absorption spectra of the
following lithium micas from Japan have been studied.

(1) Pink Li mica (lepidolite) from Nagatare, Fukuoka
    Prefecture.

(2) Pink Li mica (lepidolite) from Sakihama, Iwate
    Prefecture.

(3) Pale pink Li mica (lepidolite) from Suisawa, Mie
    Prefecture.

(4) Pale pink Li mica from Minagi, Okayama Prefecture.

(5) Pale brown Li mica (zinnwaldite) from Dairi and
    Tahara, Gifu Prefecture.

(6) Pale brown Li mica from Miyazuma, Mie Prefecture.

For comparison, taeniolite, an aluminum free lithium
mica, from Kola, USSR, has also been studied. The re-
lationship between lithium content and the polymorphic
type will be discussed.

CRYSTALCHEMICAL VARIABILITY OF CHLORITE AND CORRENSITE AS
AN INDICATOR OF THEIR GENESIS

A.G.Kossovskaya, V.A.Drits, Moscow, USSR

The crystalchemical features of a number of minerals with
sheet structures may convey important information relating
to their genesis.

Chlorites. In contrast to the earlier notions that only Fe-
chlorites occur in sedimentary rocks, magnesium chlorites
have been established to be wide-spread in terrigene-evap-
oritic deposits. Crystalchemical distinctions of authigenic
Mg-chlorites of sedimentary rocks from Mg-chlorites formed
on ultrabasites and serpentinites are shown. A group of Fe-
Mg-chlorites of sedimentary and magmatic rocks is studied.
The pattern of settlement of Al, Mg, Fe in octahedra has
been established to be an indicator of the genesis of the
chlorites that can be used for "eliminating metamorphism"
and diagnosis of para- and orthorocks.

Corrensites. In various types of geological units 28 Å or
dered mixed-layer chlorite-montmorillonite minerals have
been established to be wide-spread. Four types are distin-
guished: (1) sedimentary evaporitic complexes; (2) sedimen-
tary coalbearing formations; (3) hydrothermal formations
associated with basalts and andesites and (4) metasomatites
formed on gabbroids and ultrabasites. The crystalchemical
features of the corrensites of all the four types have been
identified and their "cognateness" to the chlorites of the
corresponding geological environments established.

PARAGENESIS OF FAUJASITE AND PHILLIPSITE AT SASBACH,
KAISERSTUHL

R.Rinaldi and J.V.Smith, Chicago, USA

The crystallization sequence in amygdules of limburgite rock
is: faujasite (octahedra, some spinel-twins, not present in
all amygdules), amorphous coating (mostly hydrated silica-
alumina: $SiO_2 \sim 52$, $Al_2O_3 \sim 33$ wt. %), phillipsite (radial
twinned aggregates in tufts and spherules), calcite and amor-
phous black material. No evidence was seen for breakdown of
faujasite. Not all amygdules contain the complete sequence,
suggesting erratic entrance of incoming solutions.

Both faujasite and phillipsite have $Si/Al \sim 2.5$ (electron micro-
probe analyses) and considerable MgO content: mean values are

	SiO_2	Al_2O_3	MgO	CaO	Na_2O	K_2O	Total
faujasite	58.2	18.3	3.0	3.9	1.8	0.2	85.5
phillipsite (fine grained)	56.6	19.5	1.7	4.1	0.4	3.8	86.1
phillipsite (coarse)	62.4	19.1	0.05	4.6	1.9	6.2	94.3

All the specimens were collected in 1969 from one small area
of the quarry (with kind assistance of G.Jung). Analyses of
random faujasite crystals from mineral collections show dif-
ferent values suggesting variability in the quarry.

The limburgite contains euhedral pyroxene (coarse twinning,
oscillatory and hour-glass zoning) and olivine (altered margins)
set in a devitrified or glassy matrix.

The data on faujasite are consistent with primary crystalli-
zation from solutions entering amygdules, with no breakdown
to other phases. The source of the solutions is unknown.

QUARTZ-FELDSPAR-CALCITE-H_2O OXYGEN ISOTOPE GEOTHERMOMETERS:
NEW EXPERIMENTAL RESULTS FOR 600°C AND GEOTHERMAL DATA
FOR 250°C

Peter Blattner and G.W.Bird, Lower Hutt, New Zealand

Experimental calibrations of quartz-H_2O, feldspar-H_2O, and
calcite-H_2O oxygen isotope 'geothermometers' are available
in the literature, and in the case of quartz and calcite
have been backed up by partition function calculations. For
geological applications of mineral-pair thermometers, cali-
brations need to be very precise. We have attempted a re-
finement of earlier experimental studies, placing particu-
lar emphasis on the relationships between the isotopic com-
positions of the solids.

In the experiments at 600°C quartz and alkali feldspar were
equilibrated with a common solution and analyzed as pairs.
Identical quartz-feldspar oxygen isotope fractionations were
obtained for quartz and silicagel starting materials, and
for water and 1M KCl solution. For silicagel starting ma-
terial identical quartz-feldspar fractionations were obtained
for fluids of widely differing δO^{18} (reversal runs).

The geothermal data from Boadlands no.7 drillhole are impor-
tant for quartz and feldspar, which to date have not been
equilibrated in the laboratory at low temperatures. The pos-
sibility of equilibrium among the geothermal phases, includ-
ing quartz, is real and is critically discussed.

Significantly improved mineral-pair calibration curves are
proposed and are compared with geological data.

CONDITIONS OF STABILITY AND PARAGENESES OF MERWINITE

N.N.Pertsev, Moscow, USSR

Ca-Mg-orthosilicate merwinite, $Ca_3MgSi_2O_8$, occurs only in carbonate hornfels and skarns formed at higher temperatures and shallow depths. The mineral is interesting with a great variety of its assemblages and their carbonization and hydration conditions. Natural equilibrium merwinite assemblages give possibilities to calculate temperatures, CO_2-pressures, MgO and SiO_2 activities and some other parameters of their formation.

New experiments at p_{H_2O} more than 250 atm have showed that merwinite converts into dellaite-monticellite paragenesis by hydration. At 1000 and 500 atm of H_2O the mineral decomposes at 710 and 690°C respectively. The merwinite skarns from Iglica (Bulgaria) gives a good example of such hydration reaction.

Carbonization reduces merwinite stability field much more. The mineral can be converted to akermanite-calcite paragenesis at above 820°C and more than 75 atm of CO_2-pressures. At lower parameters merwinite can be changed into akermanite + spurrite + monticellite or kilchoanite + monticellite + spurrite.

$T - p_{CO_2}$, $T - x_{CO_2}$, log activity - log activity diagrams of merwinite assemblages help to estimate parameters of formation of its occurrences. The conditions of merwinite parageneses formation of several occurrences are discussed.

DISTRIBUTION OF CALCIUM BETWEEN PLAGIOCLASE AND GARNET AND ITS PARAGENETIC SIGNIFICANCE

Roland Gorbatschev, Lund, Sweden

Large changes of volume in reactions relating grossular and anorthite demonstrate that the distribution of Ca between garnet and plagioclase may be employed in geobarometry. In a variety of metamorphic terrains there is good correlation between the Ca-distribution and the pressure environment as suggested by other indicators. The Ca-distribution has been checked for the possible influence of compositional factors like Ca-concentration, cation substitutions and the peristerite solvus, which appear to be of none or minor importance. The influence of the Ca-distribution/pressure relation on the stability of garnet and the paragenetic development of rocks is surveyed.

THERMODYNAMIC REGIME OF METAMORPHISM AND GRANITIZATION

L.L.Perchuk, Moscow, USSR

Mineralogical thermometry and barometry were used to study thermodynamic regime, that is, change in temperature (T), pressure (P_s), partial pressure of volatile components (P_i) with the depth of metamorphism (M) and granitization (G). The following effect was used as a basis for temperature measurements: the greater the difference in the strength of silicic acid radicals and in the symmetry of natural equilibrium minerals, the higher the degree of redistribution of the two isomorphous components between silicates with T; maximum effects have been noted for hydrous minerals in equilibrium with anhydrous ones. This rule is best shown by the exchange equilibria of ferromagnesian minerals. Based on calibration of this effect, numerous diagrams of the phase relations, "mineralogical thermometers", have been developed. Pyroxene-garnet barometers and a number of diagrams of the P_s-X_M type allowed the P_s at M and G to be evaluated. With T and P_s known, fugacities and partial pressures of the volatile components have been calculated for hydration-dehydration, carbonatization-decarbonatization and oxidation-reduction reactions. The relations between P_s and the mean values of other thermodynamic parameters at M of terigene geosynclines are illustrated in the table.

	P_s kb	1	3	4	5	6	8	10	11
	$T^\circ C$	-	430	550	615	660	750	820	870
M	P_{CO_2} kb	0,1	0,6	1	1,6	2,2	4	6	7
	P_{H_2O} kb	-	1,5	2,3	3	2,6	1,8	1	0,5
	lg P_{O_2} bar	13,6	16,6	17,3	18,0	18,2	18,6	19,0	19,2
G	P_{H_2O} kb	0,8	2,7	3,5	4,2	4,5	3,5	2,8	2,0
	$T^\circ C$	725	670	615	615	675	720	785	820

Thermo- and barometry of the pyroxene- garnet inclusions in basaltes and kimberlites indicates the possibility of the temperature maximum to occur in the area of "the waveguide" (h 150 km).

THE CHEMISTRY OF BIOTITES AS A GUIDE TO THE PETROGENESIS OF EL-INEIGI GRANITIC ROCKS, EASTERN DESERT, EGYPT

M.L.Kabesh, M.L.Abdel Khalek and M.A.Heikal, Cairo, Egypt

Biotites recovered from the granitic rocks of El-Ineigi stock in the Eastern Desert, Egypt, have been investigated by chemical methods. The chemical data of 12 newly analyzed biotites are presented and projected on variation diagrams originally constructed by Heinrich and Nockolds, slightly modified by Gokhale. The significance of biotite - the sole mafic in these granites - as an index mineral in the petrogenesis of El-Ineigi granitic complex is discussed.

SPECIFIC FEATURES OF THE MINERALOGY OF ALKALINE (NEPHELINE-BEARING) ROCKS

V.I.Gerasimovsky, Moscow, USSR

1. The mineralogy of nepheline syenites is very diverse. Two different groups can be distinguished among the typomorphic minerals of these rocks and related pegmatites and hydrother- malites: one of them is typical of agpaitic nepheline syenites, the other of miaskitic ones. Agpaitic rocks are characterized by wide development of minerals containing sodium and rare lithophilic elements, miaskitic rocks by minerals containing calcium. Such difference is mainly due to peculiarities of melt composition which give rise to these rocks, and in the first place to relative amounts of alkalies and aluminium and the different content of rare lithophilic elements and volatiles.

2. One of the most important characteristic features of nephe- line syenites is a joint occurrence in minerals of sodium or calcium with elements defining the specificity of the mentioned rocks: Cl and S (sodalite); F (villiaumite, fluorite); P (lomo- nosovite, apatite); Nb (murmanite, pyrochlore); TR (rinkite, steenstrupine, apatite); Zr (eudialyte, zircon etc.).

3. The mineralogy and geochemistry of Cl, F, P and S are very peculiar. The bulk of these elements enter the composition of minerals being formed at the magmatic stage.

4. Distribution regularities of rare lithophilic elements and some other (F, Cl, P, S) elements is conditioned by the geo- chemical history of petrogenic elements. The concentration of rare elements in dark coloured rock-forming minerals, being formed later than leucocratic minerals, is considerably higher and is usually highest in accessory minerals. The latter are frequently found in considerable amounts and sometimes they are rock-forming minerals (eudialyte, lovozerite, etc.).

5. Pegmatite and hydrothermalite minerals are more diverse in comparison with rock-forming minerals. This is due to the fact that many trace elements are accumulated towards the end of the magmatic process, because their isomorphic entrance into leuco- cratic rock-forming minerals (microcline, nepheline) is impeded.

6. Secondary processes of mineral formation were wide developed at the final formation stages of alkaline rocks and pegmatites, during which water played an important role.

SYNGENETIC CRYSTALLINE INCLUSIONS IN NATURAL DIAMONDS

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Natural diamonds from kimberlites of Yakutia and other depo- sits of the World contain inclusions of olivine, chromite, garnet, clinopyroxene, enstatite and rutile. Among the newly found evidence of simultaneous growth of inclusions and dia- monds are the octahedral faces of numerous inclusions repre- sented by negative diamond octahedra oriented parallel to the external diamond faces.

The results of determination of the composition of more than 100 inclusions from the diamonds of Yakutia and Urals obtained by electron probe technique confirm both the similarity with corresponding kimberlitic minerals and some differences which are most distinct in Cr-rich Ca-poor pyropes and magnesian chromespinelides approximating pure chromites in the composi- tion. It has been proved that garnets and chromites similar to those included in diamonds are present in heavy concentrates of diamantiferous kimberlites.

Examination of inclusions have permitted one to establish the entire series of polymineral combinations in individual diamond crystals and to identify stable parageneses of the ultramafic and basic types which may be considered as primary parageneses of the diamond. To the ultramafic type (with olivine) belong: a) Ca-poor Cr-pyrope + chromite $\pm$ enstatite; b) Cr-garnet + enstatite + Cr-diopside; c) Ca-rich Cr-garnet + Cr-diopside. Few of the diamonds contain basic, eclogitic paragenesis of inclusions: Mg-Fe garnet + omphacite $\pm$ rutile. The range of these parageneses embrace all possible types of ultramafic and basic compositions with marked predominance, however, of dunitic paragenesis - "a". The study of inclu- sions justify that diamonds crystallized within the Upper Mantle in the depth ranging between 150 and 200 km in equili- brium with included minerals and the melt in igneous events.

OSCILLATORY ZONING OF AUGITIC PYROXENES IN PLATEAU BASALTS

S.S.Augustithis, Athen, Greece

Augitic pyroxenes have been found in basaltic lava of the
Ethiopian Plateau consisting of up to 250 fine zones.

Microprobe point-analysis by J.Ottemann along a traverse,
perpendicular to the zoning of the augitic phenocrysts, shows
oscillation in the Mg, Fe and Ti contents of the fine zones.

Often two distinct generations of oscillatory zoned augites
have been determined; generation I forms the nucleus and is
surrounded by generation II.

The oscillation of Mg is reversed to that of Fe and the Ti
coincides rather with the Fe. There is little difference in
the Mg percentage and also in the oscillatory percentage
fluctuations between the nucleus of the pyroxene, generation I,
and the outer augite, generation II. However, a noticeable
increase in Ti content is determined in the outer augite (gen-
eration II) as compared with the nucleus.

The oscillatory zonal development of the augite phenocrysts
seem to result in the formation of "Sand Uhr" structures in
some of the studied cases.

In addition, the paper describes the phenomenology of the
zonal growths and particularly the anomalies and interruptions
in the development of zoning. Also an attempt is made to under-
stand the presence of orientated and at random occurring fine
needles in respect to the oscillatory zoning of the pyroxenes.

Furthermore, attention is drawn to the relationship between
oscillatory zoning and simple and polysynthetic twinning de-
veloped in these augites.

PARAGENESIS AND PETROGENESIS OF A CORUNDUM-BEARING MARBLE,
PAKISTAN

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H.Bank, Idar-Oberstein, Germany (FRG)

In the northwestern part of the Himalaya mountains, Pakistan,
a calcite-marble containing gem-quality ruby has been detected,
material of which was submitted to us for gemological and min-
eralogical investigations.

The following mineral assemblages are recognized in the corun-
dum-bearing marble ($\pm$ tourmaline, sphene, rutile, pyrite,
pyrrhotite):

Calcite + corundum $\pm$ margarite $\pm$ phlogopite $\pm$ corundophyllite
   $\pm$ plagioclase $\pm$ hornblende;
calcite + corundum + spinel + phlogopite + corundophyllite;
calcite + spinel + phlogopite.

Microprobe analyses of the prominent minerals are presented.

P-T conditions of metamorphism can be estimated using the ex-
perimental data in the system $CaO - Al_2O_3 - SiO_2 - H_2O - CO_2$
(e.g. Storre, 1973).
The uppermost stability limit is given by the reaction.
  (1) margarite $\rightleftharpoons$ anorthite + corundum + H_2O
which proceeds at about $500^{o}C$ (2 kb water pressure) and $600^{o}C$
(6 kb) according to the investigations of Velde (1971),
Chatterjee (1971) and Storre and Nitsch (1974).
An upper pressure limit is given by the reaction
  (2) margarite + anorthite $\rightleftharpoons$ zoisite + kyanite
at about 9 kb (Storre, 1973).
Judging from the stable occurrence of margarite and of the
assemblage calcite + anorthite, the mole fraction of CO_2 in
the fluid phase must have been confined to rather low values
within a very limited range, e.g., at 2 kb total pressure,
X_{CO_2} would range between 0.02 and 0.13 (Nitsch and Storre,
1972; Storre and Nitsch, 1972).
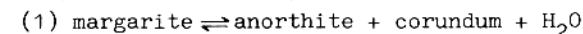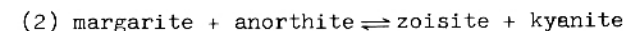
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CHANGE IN PHYSICAL PROPERTIES OF COALIFIED AND GRAPHITISED PHYTOCLASTS WITH GRADE OF METAMORPHISM

C.F.K.Diessel and R.Offler, Newcastle, Australia

Phytoclasts are dispersed plant fragments which occur together with inorganic detritus in sediments and their metamorphic counterparts. Because of their origin and composition the organic particles are subjected to the same post-depositional changes that lead to the formation of coal and eventually graphite. In this paper the results of microscopic reflectance measurements, differential thermal and X-ray diffraction analyses of coalified and graphitised phytoclasts from two Australian fold belts are presented and related to the respective metamorphic grades of the host rocks. Further comparisons are made with samples from other continents.

The results show that from the zeolite facies to the lower greenschist facies, phytoclasts occur in coalified form with the various coal macerals being clearly distinguishable under the microscope. The main physical expression of the progressing anthracitization is an increase in mean maximum reflectance to approximately 7 % (in oil). Rocks from the upper portion of the chlorite zone of the greenschist facies contain both coalified and graphitised phytoclasts. In the coalified portion only inertodetrinite remains unaffected while all vitrinite has disappeared and appears to be represented by several graphite varieties. Within the biotite zone, all phytoclasts have been converted into graphite which in the amphibolite facies experiences an increasing lattice perfection. This is shown by a rise in both maximum reflectance up to approximately 15 % (in oil) and optical anisotropy, by an increase in intensity of the (002) X-ray reflection at 3.35-3.36$\overset{\circ}{A}$, and by a rise of the exothermic peak temperature from $500^{\circ}C$ to $660^{\circ}C$. The nature of the transformation of coal into graphite, as well as the significance of the relationship between metamorphic grade and the changes that occur in graphite are discussed.

ARSENIAN VARIETIES OF BRAVOITE AND PYRITE

T.N.Shadlun and N.V.Troneva, Moscow, USSR

During the last years new data concerning the chemical composition of iron disulfides become available from lead-zinc-deposits, deposits of Ag-arsenides, and hot springs in regions of volcanic activity.

Additional to some Co and Ni various amounts of As have been determined. The variability of As content allows the devision into two groups: arsenian (less than 1 % As) and arsen-pyrites or arsen-bravoites resp. (more than 1 % As).

A high As content was detectable by microprobe in bravoites from Sedmotshislenizi, Bulgaria (8.2 - 13.8 %) and from Silverfield, Ontario (8.7 %). Pyrites from the same provenance also have an extraordinary high As content (0.88 - 5.2 %). Those As containing (or As-Co-Ni-containing) iron disulfides microscopically show a reniform, fine concentric zonality. In reflecting light such zones with the highest content of the elements mentioned above have yellowish-white colors with rose tinge.

The anionic content of As and S as well as the cationic content of Co, Ni, Fe is explained by isomorphic substitution.

GENETIC SIGNIFICANCE OF THE ZONING OF BRAVOITE AND
SPHALERITE

J.Mincheva-Stefanova, Sofia, Bulgaria

Two types of zoning in the crystals of minerals are dis-
cerned: a polygeneration and a monogeneration one. The
former results when crystals of the earlier generations
of a given mineral are regularly overgrown by a crystal
or crystals of its later generations. It is typical of
minerals from high- and medium-temperature deposits. The
crystals of the individual generations in the polygene-
ration type may also be zoned. The monogeneration type
of zoning caused by the non-uniform chemical composition
of the mixed crystals is of special interest. The develop-
ment of this type of zoning exhibits varying trends de-
pending on the physico-chemical conditions under which
it is formed in accordance with the crystallochemical
and structural relations between the main components in
the mixed crystals. Therefore, it may be used as a gene-
tic criterion.

The phenomenon is exemplified by the widely occurring
zoning in bravoite and sphalerite crystals.

Bravoite represents mixed crystals of the three compo-
nents of the ternary system $FeS_2-NiS_2-CoS_2$. Its zoning
is controlled by the relative concentration of the re-
spective metal ions in the solution. Generally, the for-
mation of mixed crystals takes place in neutral solutions
and the variation of the chemical composition of the suc-
cessive zones is accounted for by the solubilities of
the three disulphides.

Sphalerite crystals frequently exhibit both types of
zoning. Its monogeneration zoning greatly restricts the
possibility of using sphalerite as a "geobarometer" and
"geothermometer". This type of zoning shows two basic
trends - either towards decreasing, or towards increasing
of the iron content from the central to the outer crystal
zones. The latter case is rare and is observed when high-
and medium-temperature cleiophanes have been formed under
conditions of raised Eh.

THERMAL CHANGES OF PYRRHOTITE

Goro Shibuya, Yamaguchi, Japan

Many natural and synthetic pyrrhotites showing various
chemical compositions have been investigated to know the
changes on heating up to $650^\circ C$ in vacuum and in air by
main means of differential thermal analysis, magnetic ba-
lance and X-ray powder diffractogram. On the DTA curve for
the paramagnetic hexagonal pyrrhotite treated in air, a
small exothermic peak at γ-anomaly point, $220^\circ C$, and a
plateau-like exothermic reaction starting from β-transi-
tion point, $320^\circ C$, following a very remarkable endothermic
peak centered at $580^\circ C$ were recognized. Besides, if the
specimen is heated up to about $200^\circ C$, the magnetic charac-
ter turns abruptly from paramagnetism to ferrimagnetism.
Being ferrimagnetized at once, the specimen can not restore
the original paramagnetism by any heat-treatments there-
after. The cause of the ferrimagnetization is not based
upon the formation of magnetite or ferrimagnetic mono-
clinic pyrrhotite, judging from the results of thermo-mag-
netic experiments. The author here presents a new idea
that the formation of so-called "ferrimagnetic oxidized
pyrrhotite" is supposed due to a reaction: $FeS_{1+x} \xrightarrow{+O_2} Fe(S_{1+x} \cdot O_y)$, where $x + y = 0.14$. It retains a hexagonal
symmetry as well in the X-ray powder diffractogram. If the
heating-experiment is applied higher than $320^\circ C$, it is sur-
mised that the ferrimagnetic hexagonal phase changes to
"ferrimagnetic monoclinic oxidized pyrrhotite" which may
solve oxygen at its extreme in the pyrrhotite structure.
The remarkable endothermic peak centering about $580^\circ C$ means
the generation of SO_2 gas with simultaneous formation of
magnetite. The thermal changes of the synthetic pyrrhotite,
which has nearly the same composition as the natural pyrrho-
tite, measured by use of Arnold's X-ray determinative curve
are very poor in general compared with the natural specimen.

HOMOLOGOUS SERIES OF SULPHOSALTS (COMPLEX SULPHIDES)

N.N.Mozgova, Moscow, USSR

In the isochemical sulphosalt groups there are homologous
series of compounds, which are characterized as follows:
1) Every series corresponds to some interval of composi-
tions and is represented by a totality of compounds. Me-
tal and semimetal contents of these compounds are in in-
verse ratio and their sum to sulphur ratio changes in des-
ultory way. Sometimes the adjacent members are very simi-
lar and composition of the series changes almost continu-
ously. As a rule in each interval there are more natural
compounds than the number of the known mineral species.
In this connection problem of their names arises. 2) The
changing composition of the series is accompanied by their
regular structural alteration. Two of the unit cell para-
meters keep constant over the whole series while the third
one increases along with the growth of the relative metal
amount. This increase can be a multiple of the unit cell
length and then the series members have different super-
structures. A similar dependence is revealed for the gonio-
metric relationship of axes. X-ray powder patterns of all
members of one series are very similar, but have some light
regular differences mainly in the field of small reflection
angles (splitting of some reflections, their insignificant
shifts and change of intensity). The lesser is the differ-
ence in composition of members the closer are their powder
patterns. 3) The physical properties of series members
change regularly, gradually along with alteration of their
composition. 4) Regular intergrowth of members of single
series are very characteristic and have been formed during
exsolution as a result of ordering.

Such series can be considered as series of ordered berthol-
lide phases (WEDSLEY, 1971) and may be taken as basis for
a rational classification of these minerals.

THREEDIMENSIONAL INTERGROWTH OF ORE MINERALS IN PEGMATITES:
EXAMPLE FOR APPLICATION AND VALIDITY OF A GEOCHEMICAL VOLUME-RULE

Heiko Rabe, West-Berlin, Germany

Separated special paragenesis of sulphides, phosphates and sili-
cates in pegmatites of the type Hagendorf/Opf. are differing in
its trace element contents as a result of selection. In the sul-
phides, and for example in sphalerite, many trace elements can-
not be explained by diadochy. Replacement of Zn by Bi or Ag prob-
ably cannot be assumed. Therefore a geochemical volume-rule seems
to exist: Under conditions of high pressures in presence of fluid
components and in overcritical pT-range, guest elements will be
integrated in form of anomalous-solid-solutions in host-crystals.

During the decomposition exsolution bodies with nearly coincident
cell volumes are originated and diataxy (= threedimensional ori-
entated intergrowth) is resulting. - ZnS e.g. includes crystals of
Bi and compounds like $AgBiS_2$, Bi_2S_3, etc., and nearly all trace
elements are fixed in this way in the host-lattices.

Crush-structures as usually common in the neighbourhood of in-
clusions of Bi are not to be observed in sphalerite. This shows
that the stress in coherent lattice-planes becomes compensated
by diataxy. Deformations of the host-crystal keep small and are
comparable with those in mosaic-crystals. If exsolution bodies
different in chemical composition appear in diataxy with one and
the same host, each guest can be in diataxy with each other guest.

The metrical relationship of host and guest derivable from the
volume-rule could be verified for the first time by ore micro-
scopy, using the Laves-Ernst-Compensator for determination of
the main directions of optical properties for anisotropic opaque
exsolution bodies of FeS, Bi_2S_3, $AgBiS_2$, Bi etc. Observed exam-
ples of diataxy in Hagendorf are:

	ZnS	FeS	Bi [1]	Bi_2S_3	$AgBiS_2$
planes of intergrowth	110	(00.1)	($\bar{1}$21)	(010)	(100)
zone axis with	110	00.1	210	010	100
equivalent positions	$\bar{1}$10	01.0	12$\bar{1}$	001	0$\bar{1}$0
of host and guest	00$\bar{1}$	21.0	1$\bar{1}$3	$\bar{1}$00	00$\bar{1}$

1) indexing refers to pseudocubic cell: a_{rh} = 6.56 Å; α = 87.4°

THE CRYSTAL CHEMISTRY OF SELENIUM AND TELLURIUM MINERALS, A COMPARISON WITH SULFUR MINERALS

Josef Zemann, Vienna, Austria

Selenium and tellurium have the same configuration of the outermost electron shell as sulfur; therefore, Se- and Te- compounds often show crystal chemical smilarities to S-compounds. However, the increasing effective radii and the decreasing electronegativities with increasing atomic number, as well as an increasing preference of the 4-valent oxidation state as compared with the 6-valent oxidation state with increasing atomic number cause quite remarkable differences in the crystal chemistry of tellurium minerals as compared with sulfur minerals, selenium showing an intermediate behaviour.

Examples:

(1) Tellurium can substitute sulfur in sulfides, but it can also form a pyramidal TeS_3-group, as in the fahlores, where it substitutes for Sb and As, resp.;

(2) sulfites seem to be unknown among minerals, but in the oxidation zone of tellurium deposits, Te(IV)-minerals - and not Te(VI)-minerals - definitely dominate, and perhaps even occur exclusively.

CRYSTALLOCHEMICAL REGULARITIES OF METASOMATIC PSEUDOMORPHISM

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Two main types of metasomatic processes are distinguished. The
former take place under progressive conditions (granitization,
regional skarning etc.) the latter - under regressive ones (near-
ore rocks of hydrothermal deposits). Mechanism of metasomatic
mineral formation is determined in both cases by the formation
of replacement pseudomorphs under the conditions of differential
mobility of components and constancy of the geometrical volume.
In a general case when mineral A with the volume V being re-
placed, inert-pseudomorph mineral with the volume Vn and defect
of the volume $\pm \Delta V$ are formed. The latter is either compensated
by a released mineral with the volume Vo by precipitated mineral
with the volume Vk and a displaced mineral with the volume Vb,
or it remains unfilled.

On condition of an obligatory conformity of the volume of final
products is, as a rule, not equal to the mass of the initial
ones. The structure looseness, mean atomic density and isomorph
capacity of lattices of the initial mineral and products of pseu-
domorphism also vary depending on a type.

In the course of granitization the replacement of basic plagio-
clase and amphibole by orthoclase is a leading process. The re-
placement takes place with increasing of a resultant volume and
structure looseness of newly formed products. Mean atomic densi-
ty decreases when the average mass of atoms being increase. Ac-
cording to data of microprobe investigations isomorph capacity
of metasomatic new formations decreases.

Under the conditions of regressive metasomatism of near-ore
transformations pseudomorphism takes place with decreasing of
structure looseness of lattices, the average mass of newly formed
products decreases, and the mean atomic density increases.

MORPHOLOGICAL ZONALITY IN MINERAL DEPOSITION

Ivan Kostov, Sofia, Bulgaria

In addition to zonalities concerning mineral species and trace
elements in the composition of minerals, zonality after morpho-
logy of crystal forms of minerals and kind of mineral aggre-
gates is considered of no lesser significance when the inter-
pretation of mineral deposition is concerned. The three types
of zonalities, mineralogical, geochemical and morphological,
are supplementary and should have to be account always together.

The morphological zonality comprises (a) variation of crystal
habits of a mineral and richness of its combination forms
coupled with observations on size and degree of perfection
of its crystals, and (b) if no crystal forms are presented,
variation of mineral aggregates, again paying attention to
the morphology ('pseudomorphology') of the separate indivi-
duals, their size and pseudosymmetry, as well as their spa-
tial arrangement. Rate of crystallization, temperature and
admixtures on one hand and kind of crystallization locus on
the other are of primary importance for the development of
minerals with changing morphology. From detailed observation
on the distribution of the different morphological types of
a mineral can thus be gathered direct evidence about the
condition of crystallization in a mineral deposit.

The morphological zonality can be normal or reverse, depend-
ing on the trend of the crystallization rate. Recurrences due
to changing conditions of crystallization may lead to tele-
scoping of different crystal habits and aggregates.It can be
further local, regional, concentric, linear, vertical, hori-
zontal, etc.

A STUDY OF THE IRON ORE DEPOSITS OF KUDREMUKH,
KARNATAKA STATE, INDIA

C.Naganna, B.S.Shivakumar and N.B.Nagesh, Bangalore, India

Kudremukh Iron ore deposit, which is regarded as one of the
largest Iron ore deposits in Asia, with proved reserves of
about 600 million tons of good grade ore, has been studied,
in respect of the ore mineralogy and the mineral paragenesis.
The Iron ore formations are a part of the Pre-cambrian schis-
tose formation called the Dharwars, consisting of banded mag-
netite quartzite, chlorite schist, coarse grained amphibolite
and fine and coarse grained hornblende schist.

The formations are tectonically folded into an overturned
asymmetrical fold. The youngest banded magnetite quartzite
assumes varying thickness, in different parts of the region
as one moves across the folds. Through a prolonged process
of weathering ore concentration has been brought about in
the weathered zone, which varies in depth from place to
place, depending on the structural and geomorphological fa-
cilities for the circulation of ground water.

Through a detailed study of the ores drawn from different
depths in the weathered zone and beyond, the presence of
ore minerals like magnetite, martite, specularite and hae-
matite, is established.

Further, the occurrence of sulphide minerals like pyrite,
chalcopyrite and pyrrhotite along with the iron ore miner-
als is recorded. The mineral paragenesis of these minerals
and the origin of these minerals are discussed.

A NEW METHOD TO DETERMINE THE REFRACTIVE INDEX OF LIQUIDS
TO ANY AMOUNT

E.Seeliger, West-Berlin, Germany

The method, practised by Duc de CHAULNES, SORBY etc., for
determination of refractive indices of isotropic or an[1]
isotropic plan-parallel glass- or crystal-plates with the
microscope will not be used to-day and seems to be only of
historical interest.

But in course of time the tube lifting mechanics of micro-
scopes were developed to a high degree of accuracy. In combi-
nation with the BECKE-method this old method to-day is use-
full to determine the refractive index of liquids in general
and especially of liquids with high or very high n-values in
a very short time.

Test-slides are fine glass grains, embedded in air under a
cover glass. A drop of a liquid (as used for the immersion
liquid-method) must be brought into the room between the
front-lense of the objective and the test-slide after having
focussed a single glass grain in air by BECKE-line. Because
the liquid layer can vary its thickness, when lifting the
tube, the thickness of liquid-layer depends only from n; as
the amount of tube lifting too.

A mechanic counter should be used. To held the error small,
it needs to determine a test curve of the fine lifting me-
chanics for each instrument and to select usefull objectives,
which seem to be best if of medium power (25 - 40) and medium
aperture (0,5 - 0,7). Best results in measuring are in the
range of n ± 0,003.

DETERMINATION OF VOLUME CHANGE OF MELTING AT HIGH PRESSURE

P.W.Mirwald, München, Germany (FRG), and G.C.Kennedy,
Los Angeles, USA

A method for measuring volume change associated with melting
has been developed for solid medium piston cylinder apparatus.
A first study to 40 Kb was conducted on metal melting curves.
In order to explore this method over a wide temperature range
(100 - 1200°C) sodium, lead and silver were selected as samples.
The pressure vessel used has a bore diameter of 1.25 cm. A low
friction cell recently developed for melting curve determina-
tions was modified for this study to accommodate samples of
volume up to 0.3 cm^3. This new cell permitted observation of
these small volume changes by sensitive monitoring of piston
displacement and associated pressure change while slowly heat-
ing through melting. A differential thermoanalyse (DTA) arrange-
ment was used to monitor sample melting and thermal gradients.
Results at 40 Kb for the three metals studied show a substantial
decrease of volume change on melting compared with the one at-
mosphere value: 70±10 % for sodium, 60±10 % for lead and 50±10 %
for silver. This implies considerable decreases in the change
of entropy of melting.

ABSTRACTS OF PAPERS PRESENTED AT REGENSBURG

Main Session:

Mineral Genesis and Crystal Growth
    Tuesday, September 17, 1974
            Part I, Chairmen: C. Guillemin
                               H.v. Philipsborn
    Wednesday, September 18, 1974
            Part II, Chairmen: I. Sunagawa
                               K. Weber

Main Session: MINERAL GENESIS AND CRYSTAL GROWTH
                  Introductory lecture
                  HYDROTHERMAL GENESIS OF MINERALS

J.Wyart, Paris, France

Hydrothermal genesis of minerals - a review of the role
of water at high temperatures and pressures in the genesis
of minerals is given. At first the experiments have been
made in mineralogical laboratories. The importance of crys-
tals in different industries, which can be prepared only
from aqueous solutions at high temperatures and pressures
has been at the origin of accurate thermodynamical measures
of the properties of these solutions. The results have been
very useful for the explanation of the origin of different
minerals. Examples are given for some sulfides, oxides,
silicates, and among them feldspars.

HYDROTHERMAL SYNTHESIS OF REFRACTORY SULFIDE MINERALS

S.D.Scott, Ontario, Canada

Standard methods of synthesis and determination of stability relations among refractory sulfide minerals are often frustrated at low temperatures by the failure to achieve equilibrium. This inertia towards reaction can be easily overcome by recrystallizing the sulfides in appropriate aqueous solutions over small (usually 10-15°C) temperature gradients. In practice, the powdered sulfide charges and aqueous solution are sealed into gold tubes and heated in a specially-designed, stainless steel pressure vessel along which a linear temperature gradient is applied. The sulfides are dissolved at the hotter (usually bottom) end of each tube and transported by convection to the cooler (top) end where slow precipitation of crystals takes place. Because of the very small temperature gradients at the site of crystallization, the precipitating phases are at or near equilibrium with the aqueous solution and with each other. This technique has the advantages of producing large, chemically-homogeneous crystals of refractory sulfides suitable for single crystal x-ray study from assemblages equilibrated at temperatures ($100°$ - $700°C$) and pressures (0 - 10 kb) of geological interest. As well, sulfur fugacity which is an important variable in most sulfide reactions can be varied continuously over many orders of magnitude by carefully controlling the f_{O_2} and pH of the aqueous solution.

The hydrothermal method has been used to (1) synthesize single crystals of cinnabar, sphalerite, wurtzite, hexagonal and monoclinic pyrrhotite and pyrite of high purity and perfection; (2) examine the growth mechanics and kinetics of single crystal sphalerite and wurtzite; (3) measure the partitioning of trace elements and of sulfur isotopes among sphalerite, galena, pyrrhotite and pyrite; and, (4) determine equilibrium phase relations in portions of the mineralogically-important systems Fe-S and Zn-Fe-S at low temperatures and at high pressure which were unattainable in previous studies.

CRYSTAL GROWTH AND STRUCTURAL CHARACTERIZATION OF TRANSITION-METAL SULFIDES

C.T.Prewitt and V.Rajamani, New York, USA

As part of a study of transition-metal sulfides, crystals of Co_9S_8 (pentlandite structure), $Co_{1-x}S$ (jaipurite), and $Ni_{3+x}S_2$ (heazlewoodite) have been grown in a multi-zone furnace using iodine-vapor transport techniques. The crystals of Co_9S_8 are of excellent quality, show well-developed faces, and have been used for diffraction studies of the pentlandite-type structures. Those of $Co_{1-x}S$ are not as good and give precession photographs with somewhat diffuse diffraction spots. A few crystals show exsolution features. Morphologically, the $Ni_{3+x}S_2$ crystals appear to be single and of good quality, but the diffraction patterns are very poor, indicating a possible phase transition in cooling.

In addition to the X-ray examination mentioned above, the crystal morphologies have been simulated using computer graphics techniques similar to those first proposed by Keester and Giddings (1971) and Schneer (1973). This allows complete determination of Miller indices, Wulff vectors, and axial ratios which can be used to determine relative growth rates of crystal faces and to compare crystals grown under different experimental conditions.

DETERMINATION OF THE SPECIFIC FREE SURFACE ENERGY OF
ENERGETICALLY HETEROGENEOUS SINGLE CRYSTAL FACES

W.Bayh and M.Sellschopp, Tübingen, Germany (FRG)

In a previous paper (Z.Kristallog. 132 (1970) 443) we showed
that it is possible to determine the specific free surface
energy, γ_s^{hkl}, of single crystal faces by measuring the
contact angle, θ^{hkl}, and the surface tension, γ_L, of a ses-
sile drop resting on the substrate to be examined. Combining
YOUNG's equation and ANTONOW's rule the specific free sur-
face energy will be given by:

$$\gamma_s^{hkl} = \frac{1}{2}\,\gamma_L\,(1 + \cos\theta^{hkl})$$

A special problem results from energetic surface heterogene-
ity caused by patchwise adsorption of vapor molecules. In
this case the substrate surface will consist of high-energy
regions (clean crystal surface) and low-energy regions (ad-
sorption layer), and hence a contact angle hysteresis will
be caused. Therefore one has to distinguish between ad-
vancing contact angles, θ_A, and receding contact angles,
θ_R, for drops which are advanced or receded, respectively,
over the solid surface. According to the theoretical treat-
ment of JOHNSON and DETTRE (J.Phys.Chem. 68 (1964) 1744) those
angles should be equal to the intrinsic contact angles of
low-energy regions and high-energy regions, respectively.

In order to test this theoretical treatment an apparatus
was constructed which allows to measure advancing and re-
ceding angles in high vacuum. With this method a vertical
crystal plate is dipped into a liquid and slowly moved down-
ward and upward in which cases the liquid advances or re-
cedes over the solid surface. By simultaneous measurement
of the capillary rise during the time in which the plate
is moving, and of the liquid surface tension, the contact
angles θ_A and θ_R could be determined using capillary theory.
The results obtained so far with alkali halide cleavage
plates covered with water molecules, and with mercury as
wetting liquid confirm the predicted thermodynamical sig-
nificance of contact angle hysteresis.

QUANTITATIVE ANALYSIS OF PLAGIOCLASE CRYSTAL HABIT IN A
RHYOLITE LAVA FLOW

Richard Haefner, New York, USA

Although mineralogists have studied the size and shape of the
unit cells of crystals for many years, relatively few attempts
have been made at quantitatively studying the overall size and
shape (crystal habit) of crystals.

Andesine phenocrysts from a single rhyolite lave flow in the
Dublin Hills, near Death Valley, Calif., were chosen for anal-
ysis. Crystal lengths (a-axes) and widths (b-axes) were meas-
ured in phi units in 24 randomly oriented thin sections, which
were spaced along the length of the flow's exposure and near
the top, middle, and base of the flow. Lengths and widths are
measures of crystal size; their ratios b/a are measures of shape.

Frequency distributions of a-phi and b/a do not differ signi-
ficantly from the expected normal distributions. The distribu-
tion of b-phi, however, is a relatively poor fit to the normal
distribution, perhaps reflecting a bias in the sampling proce-
dure, or the sampling of two populations of b-phi axes. These
two populations may represent broken and unbroken crystals.

Correlation of b-phi with a-phi reveals that broken crystals
differ from unbroken crystals; b-phi and a-phi of broken crys-
tals are not significantly correlated. As axes of the total
group of sampled crystals are highly correlated (r= .81), it is
inferred that few crystals were broken during the eruption and
emplacement of the lava flow. The common occurrence of crystals
in swirls of groundmass laminae suggests that most crystals were
simply rotated between shear planes in the moving lava.

Regression of b-phi vs. a-phi reveals that the crystals changed
shape significantly as they grew: small crystals in thin section
are elongate (b/a = .21 at +4 a-phi), whereas large crystals
are nearly equant (b/a = .81 at -1 a-phi). The rate of change of
shape, b/a, is given by the slope of the regression line: a-phi
= -.37 + .75 (b-phi), which amounts to 0.12 per unit of a-phi.

Analyses of variance and covariance reveal no evidence that
crystal shape or size varies either laterally or vertically
within the lava flow. - This result contrasts with recent ob-
servations of some rhyolitic ash-flow deposits.

C.F.Woensdregt, Leiden, Netherlands

The following Periodic Bond Chains according to the theory
of Hartman and Perdok can be distinguished in the potassium
feldspar structures:
$[001]$, $[\frac{11}{22}0]$, $[\frac{11}{22}1]$, $[100]$ and $[010]$.

F(lat)-faces growing slowly are:
$\{110\}$, $\{001\}$, $\{010\}$ and $\{201\}$.

Calculations of surface energies in an electrostatic model
show, that the growth form of potassium feldspar consists
only of $\{110\}$, $\{001\}$ and $\{010\}$. This growth form is very
similar to crystals found in alpine veins (adularia) and in
lacustrine deposits (Olduvai, Green River and Barstow).

Kenneth L.Keester, Aachen, Germany (FRG)

A quantitative description of the morphology for various
secondary pegmatite phosphate minerals has been derived by
a movel method utilizing interactive computer graphics. The
method uses a Fortran program written for an IBM 2250 graphics
display terminal. The input parameters are cell constants,
crystal class, and a set of hkl's describing closed, convex
polyhedra. A parameter called "D" must also be specified for
each form. The D parameter is interactively varied so as to
duplicate the external appearance of the real crystal. D is a vector from the origin, normal to the crystal face. The output is crystal drawings, either photographed directly from the cathode ray screen or drafted by a drum-pen plotter. The significant aspect of this study is that a numerical description of habit is obtained in terms of meaningful
values. The set of D values characterize relative growth
velocities for each hkl form and are related to surface free
energies.

LEUCOPHOSPHITE

Form	hkl	D
h	$\bar{1}01$	0.550
e	$\bar{1}11$	0.875
f	011	0.950
g	110	0.825
c	001	0.900
d	101	1.350
a	100	0.650
i	201	1.975

Form	hkl	D
h	$\bar{1}01$	0.550
e	$\bar{1}11$	0.825
f	011	1.000
g	110	1.000

The minerals studied were: laueite, reddingite, ludlamite,
whitlockite, vivianite, hureaulite, augelite, strengite,
metastrengite, bjarbyite, and leucophosphite from localities
in the Black Hills, New England, Minas Gerais, and Hagendorf.
Crystal drawings are presented and compared with different
pegmatites or contrasting environments, e.g. hydrothermal ore
veins. An example of typical results is given above.
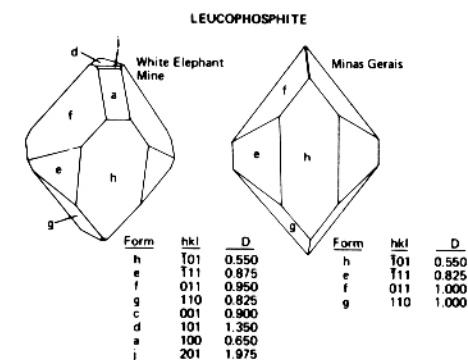
MORPHOLOGICAL RELATIONSHIPS BETWEEN HEMATITE CRYSTALS AND
ETCH FIGURES

Christiane Baltzinger and R. Baro, Metz, France

The shape and the development of etch figures formed on crys-
tals of hematite, not only depend on the type of the faces,
but also on their perfection and their growing conditions.
We have etched with boiling HCl 6N hematite crystals from
Elba, Brazil, Mexico, and synthetic crystals. The observations
have been made by means of optical and electronic microscopes.

Certain directions, that can be related to the lattice, char-
acterize the etch figures. However, those directions do not
appear at random frequency but depend on the density of the
"molecules" on the corresponding row.
We have studied more particularly the most stable face, that
is to say, the one parallel to a plane of the morphological
rhombohedron. The values of the bonding energies between the
ions of the crystal allow to justify for the frequency of the
presence of certain directions. The probability is based upon
the predominance of the bonds between the closest "molecules"
of the morphological rhombohedron.

In generalizing to other faces with different types of symmetry,
a mechanism of etching of hematite crystals can be suggested.

QUARTZ INTERGROWTH PIERCING (120) FACES OF ILVAITE CRYSTALS

Yukio Takano, London, United Kingdom
T.Nishida and Y.Endo, Tokyo, Japan

Beautiful black crystals of ilvaite of vitreous lustre were
collected in the Kamioka mine, Japan. They were found in
skarn druses, associated with quartz-hedenbergite and calcite
crystals. Crystals show s (120)· m(110)· o(111) and r (101)
faces. Prismatic faces s and m , and pyramidal faces o and
r are similarly striated in the directions of the edges of
b (010) faces, where these are missing.

Prismatic faces s are the most developed forms in these crys-
tals and consist of several domains, which have slightly dif-
ferent orientations to each other. In each domain there are
many growth layers elongated in the direction of the c-axes,
and on the boundaries of the domains there are many growth
pits. Many prismatic crystals of quartz pierce s faces of
ilvaite crystals. According to observations with the scan-
ning electron microscope and Laue photography, in some cases
one of the a-axes of intergrowth quartz crystals are oblique
by 2-15° to the c-axes of ilvaite crystals instead of having
the c-axes of the former in the direction on the a-axes of the
latter. In other cases the c-axes of quartz are oblique by
about 18° to the a-axes of ilvaite, instead of having one of
the a-axes of the former parallel to the c-axes of the latter.

Crystals of intergrown quartz had the same habits as their
elongated outcrops, without contracting inside the walls of
the ilvaite crystals. These are extraordinary intergrowths.
The contact relation is discussed in connection with the
crystal growth of s faces of ilvaites, which are the primary
growth faces.

THE GROWTH ASPECT OF POLYMORPHISM/POLYTYPISM IN SYNTHETIC
MICAS OF PETROLOGICAL INTEREST

A.Baronnet, Marseille, France

By means of conventional techniques of hydrothermal synthesis,
the most important tri- and dioctahedral end-members of the
mica group are crystallized from their respective stoechio-
metric oxide mixtures under various P,T conditions and run
durations. The self-nucleated crystallites obtained are care-
fully examined using decoration and shadowing microtopographic
methods of electron microscopy. Thus, the different mechanisms
by which the $\{001\}$ form may grow are shown: layer-by-layer growth
is regularly followed by Frank's spiral mechanism when the
crystals are grown in "wet" conditions. The interpretation of
the more or less complex spiral growth patterns leads to the
knowledge of the layer-stacking sequences (L.S.S.) involved
in the exposed ledges of the associated screw dislocations i.e.
of the generated polytypes.

Furthermore, in the case of high strength grown-in disloca-
tions, we demonstrate that the short period substructures, on
which the L.S.S. are based, correspond to the mica basic struc-
tures. These basic structures, which are polymorphs in the
usual sense, were growing during the earlier nucleation and
layer-growth stages. The nature as well as the number of the
various polymorphs and polytypes found on the investigated
mica species are reported. It is shown that the widespread
short period L.S.S. of micas may be either polymorphic or
polytypic structures, depending on their growth mechanisms.
Moreover, the fact that long period L.S.S. of these synthetic
crystals are generated from spiral growth strongly suggests
that this latter growth process may originate natural complex
polytypes too.

GROWTH MECHANISM OF SOME CLAY MINERALS

I.Sunagawa, Y.Koshino, M.Asakura and T.Yamamoto,
Sendai, Japan

To investigate the growth mechanism of some clay minerals,
gold decoration method of electron microscopy was applied
to kaolinite, dickite, nacrite, sericite, and chlorite of
different origins. A small amount of gold was evaporated
onto the samples which were heated at about 400°C in vacuum
of 10^{-5} Torr, followed by carbon coating. The samples were
then dissolved in HF solution to obtain carbon coated foils
for observations under the electron microscope. Since gold
crystallites are preferentially nucleated along the growth
steps of mono-molecular heights if adequate amount of gold
is evaporated, microtopographs of as-grown surfaces of such
tiny crystals as clay minerals can be investigated in detail,
which otherwise is almost impossible to study.

It was found that all crystals, which have been investigated
so far, of kaolinite, dickite, nacrite, sericite and chlorite
formed by hydrothermal metasomatism exhibit beautiful growth
spirals of various types, definitely proving that they were
grown by spiral mechanism. This in turn suggests that these
crystals should have been grown from solution phases, and not
by solid state crystallization. Various interlacing patterns
are also universally seen on the corners of growth spirals of
dickite, nacrite and sericite, but not on kaolinite. On the
basis of morphological analyses of the interlacing patterns,
it was possible to deduce the stacking modes of unit layers
in each structure, thus identifying polytypes.

Sericite and chlorite in metamorphic rocks exhibit quite
different surface microtopographic characteristics from
those formed by hydrothermal metasomatism, suggesting that
the growth mechanism of crystals in regional metamorphic
environment is somewhat different from that in hydrothermal
metasomatic environment. However, these crystals also ex-
hibit mono-molecular growth layers, showing that they were
formed by layer-by-layer mechanism, which in turn proves the
growth from solution phases.

INVESTIGATION OF PHYSICOCHEMICAL CONDITIONS OF NATIVE GOLD
DEPOSITION

M.S.Sakharova, Yu.A.Batrakova, S.K.Ryakovskaya, Moscow, USSR

Process of gold accumulation on sulfide minerals from water
gold-containing solutions and Au-Ag systems in the tempera-
ture interval from 20 to $80^{o}C$ and normal pressure have been
experimentally studied. It has been established that the
process of Au deposition on sulfides take place due to elec-
trochemical interaction of Au-containing solution and minerals.
There has been shown the dependence of this process on elec-
trochemical properties of minerals in particular on their po-
sitions in the row of tension. Cathodic and anodic processes
occuring on pyrite, pyrrhotite and galena were studied by the
polarisation curves method for the elucidation of the gold
deposition kinetics. The high electrochemical activity of
pyrite and the possibility of gold being deposited on it in
the wide interval of Eh(+820 - -200mv) has been confirmed.
The narrower interval of Eh during gold deposition on pyrrho-
tite (+720 - +40mv) and galena (+380 - +50mv) has been found.
The codeposition of Au and Ag out of Au-Ag systems has been
studied and solid Au-Ag solutions identical with native gold
have been produced. The dependence of the composition of this
solid solutions from an Au-Ag ratio in water solutions has
been studied. Experimental data explain the close connection
of gold with pyrite in natural deposits. They can be used for
the determination of physicochemical conditions and a mechanism
of native gold formation during hydrothermal process.

THE "STRUCTURE" OF HYDROTHERMAL SOLUTIONS AND THE GROWTH
OF CRYSTALS

I.G.Ganeev , USSR

The theory of mineral genesis and growth of crystals is
based partially on hydrothermal synthesis with its typical
temperature gradient. In general it is assumed that the
growth of crystals is the result of the formation of over-
saturated solutions. The hydrothermal synthesis of quartz
and corundum however shows that this is necessary but not
sufficient for the growth of crystals.

The temperature gradient of electrolyte solutions (NaCl,
NaF, Na_2CO_3, $CaCO_3$) shows a differentiation of acid and
alkaline solution caused by the hydrolysis of the salts.
There exists a direct dependence of the composition of the
solution on the temperature and the temperature gradient.

From these results a model for hydrothermal growth of crys-
tals is deduced. The material is dissolved in a lower alka-
line zone, the solution migrates upwards where it is hydro-
lized by the acid solution whereby the material crystallizes.

This model is verified by the cinetics of hydrothermal growth
of quartz and corundum depending on the temperature gradient.
The process described is probably the same in natural crys-
tallization of minerals.

Symposia:

Commission on Cosmic Mineralogy
    Tuesday, September 17, 1974
                Chairman: D.P. Grigoriev
                Secretary: K. Keil

Thermodynamics in Experimental Mineralogy and Petrology
(IUGS-Commission on Experimental Petrology)
    Tuesday, September 17,1974
            Part I: Chairmen: W.S. Mackenzie
                             W. Schreyer
    Wednesday, September 18, 1974
            Part II: Chairmen: P.J. Wyllie
                             E. Althaus

Mineral Physics
(Inter-Union Commission on Geodynamics, Working Group 5)
    Tuesday, September 17, 1974
                Chairmen: O.L. Anderson
                        R. Leckebusch

COMPOSITION, ORIGIN AND IMPLICATIONS OF LUNAR GLASSES

Klaus Keil, Albuquerque, New Mexico, USA

At least two types of glasses have been recognized in lunar samples, those of igneous and those of shock origin. Others (e.g. the orange glass of Apollo 17) are of uncertain origin, and are interpreted as being formed by fire-fountaining or by impacts into a liquid lava lake. Igneous glasses, for example, occur in the interstices of mare basalts and are interpreted as in situ late stage differentiation products, sometimes representing two immiscible liquids, one iron- and one silica-rich. Glasses of shock origin are the rare diaplectic variety (formed by solid state transformation of plagioclase), and the common shock-melted glass fragments and beads that are abundant constituents of the loose fines and breccias.

Here, textures, physical properties, and compositions of glasses are reviewed in an attempt to unravel their origin. In particular, emphasis is given to the shock-melted glasses and it will be shown that, although they sometimes represent mixtures formed in the regolith and are slightly affected by vapor fractionation and condensation, most appear to be the compositional equivalents of major lunar mare and highland rock types. In fact, most major lunar rock types [e.g. mare basalts; ANT(anorthositic-noritic-troctolitic rocks); alkalic high-alumina basalt (KREEP); low-alkali high-alumina basalt; peridotite] are represented among the shock-melted glasses. Together with lithic fragments, rake samples, and hand specimens, glasses are valuable indicators of the petrogenetic history of the moon, lending additional support to the proposition, that lunar petrogenesis can be explained in terms of the following four basic events or processes: (1) differentiation of at least the outer part of the moon, with creation of the cumulate feldspathic crust and deeper, more mafic layers; (2) a melting or remelting event which produced KREEP basalt and perhaps other similar materials from the feldspathic part of the crust; (3) intense bombardment by planetesimals and/or meteorites which fragmented, dispersed, mixed, and locally remelted the cumulate rocks and KREEP materials; (4) a melting or remelting event which produced mare basalts from the mafic rocks in the interior, most likely from the residual iron-rich, radioactive-element-rich fraction of the early differentiation.

DIAPLECTIC MINERALS, GLASSES AND HIGH-PRESSURE PHASES FROM IMPACT STRUCTURES OF THE USSR

V.L.Masaitis, Leningrad, USSR

On the USSR territory diaplectic minerals, diaplectic glasses and high-pressure phases at the first time were found in Popigaian astrobleme in 1970 and following years. After that diaplectic minerals and glasses were discovered in some other round morphostructures the genesis of which was not clear. According to the known geological data it is possible to recognize these ring structures as astroblemes: Puchez-Katunki, Kara, Boltysh, Kaluga, Jänisjärvi, Iljinzy, Mishina Gora, Rotmistrovka. Their diameters are from 2 to 80 km.

Diaplectic minerals and diaplectic glasses are found in shock-metamorphosed crystalline rocks included as fragments in different types of breccias or forming the fractured base of impact structures and also in impactites of all named astroblemes. Diaplectic minerals are quartz, feldspars, pyroxenes, amphiboles, biotite and other having fractures, cleavage, planar features, shock twinning, and kink bands. Diaplectic glasses (tectomorphic minerals) have the composition of quartz and feldspars, they are often recrystallized due to the influence of high resistant temperature.

In impactites of Popigaian astrobleme there were found high-pressure phases - coesite and diamond. Coesite is included in quartz diaplectic glass, due to the action of heat it was partly inverted to crystobalite and quartz. Products of the same inversion were observed in shocked rocks of some other astroblemes. Diamond with lonsdaleite originated due to polymorphic transformation of graphite from the crystalline rocks of the base of astrobleme.

The investigation of some transformations of minerals and the comparison with the experimental data allow to draw a conclusion about the dynamic and temperature conditions in the impact structures of cosmic origin.

THE ROCHECHOUART-CHASSENON IMPACTITES: A PROGRESS REPORT

F.Kraut, Paris, France

A study of the spatial distribution of the rocks directly related, or owing their specific properties, to impact effects in the Rochechouart-Chassenon area show that they are restricted inside a ring 13 km in diameter. The breccias of highest shock grade are located in the central parts of the ring, between the localities of Babaudu and Valette.

Shock-effects, through mineralogical evidence, are seen to increase upwards, from the shatter cone zone in the structure basement. Are successively observed from the bottom:

1) breccias in which the constitutive crystals show no evidence of deformation or modification process;

2) breccias on an upper level in which the mineralogical properties are indeed affected but where crystals are still present as individual entities;

3) and rocks on top in which crystals have welded into a fusion glass.

This sequence is especially conspicuous on micrographic documents.

NEW RESULTS ON THE ORIGIN OF THE RIES CRATER

W.v.Engelhardt, Tübingen, Germany (FRG)

From July 1973 until January 1974 a new hole has been
drilled, 1206 m deep, within the central basin ot the
Ries crater. A complete series of cores has been ob-
tained of 324 m lake sediments and 882 m crater filling
breccias. Based on a first examination of these cores
and recent investigations on the petrography of crystal-
line Ries breccias a summarizing report will be given on
the structure of the crystalline basement before the Ries
event, the formation of the primary crater and its later
modification.

RIES CRATER BRECCIAS AND PLANETARY IMPACT FORMATIONS

D.Stöffler, Tübingen, Germany (FRG)

As the lunar Apollo missions revealed new evidence for the
existence of large and even global impact-produced ejecta
formations formed in the early lunar history, the study of
the geologic-petrologic properties and the origin of various
types of impact breccias at large terrestrial craters have
become more and more important for some basic problems of
the early geological evolution of the terrestrial planets.

At the Ries crater, Germany, which is the only major ter-
restrial impact structure where most of the ejecta blanket
is reserved and available for unlimited investigation (con-
trary to lunar and meteoritic breccias) two quite different
types of breccias are most conspicuous in the ejecta blanket:
a lower, weakly shocked, more or less continuous breccia unit
called Bunte Breccia which represents the upper 700 - 800 m
of the pre-crater section (predominantly Mesozoic sediments),
and a upper, highly shocked, discontinuous and much thinner
breccia unit called suevite which originates from a deeper
and more central part of the crater (predominantly crystalline
rocks). The following properties were measured on both brec-
cias: grain size distribution, petrographic modal composition,
degree of shock metamorphism of the constituent particles as
well as geological setting, distribution and volumetric prop-
erties with respect to the crater size and topography. These
properties and experimental and theoretical data from hyper-
velocity impact cratering suggest that Bunte Breccia was ejec-
ted continuously through ballistic trajectories during the
time of crater growth whereas suevite seems to be formed essen-
tially by a fallback mechanism of later high angle ejecta which
got mixed with vapourized rock material.

The possible analogy of these breccias and their mechanism of
formation to lunar surface metabreccias such as the Fra Mauro
formation will be discussed with respect to petrographic and
grain size data of Apollo 14, 15 and 16 breccia samples.

IN SITU X-RAY FLUORESCENCE ANALYSIS OF THE MARTIAN SURFACE FINES: THE U.S. 1975-76 VIKING MISSION

Benton C.Clark, K.Keil, A.K.Baird, H.J.Rose and P.Toulmin

Two spacecraft will be soft-landed on the surface of Mars as part of the Viking mission to explore this planet in 1976. These two landers plus the two orbiters which accompany them contain scientific payloads which are unprecedented in the U.S. planetary exploration program, both for the breadth of the investigations (life detection, organic chemistry, geochemistry, geomorphology, seismometry, meteorology, soil physical and magnetic properties, radio science, atmospheric water vapor distribution, and soil thermal properties and state) and the sophistication of the instruments which accomplish these measurements.

Although the primary mission is the search for life, sufficient instrumentation is included to allow a comprehensive analysis of the nature of regolith. Fines (<2mm) and bulk samples of coarse material (2-10mm) will be analyzed by an X-ray fluorescence spectrometer instrument employing radioisotope sources and energy-dispersive spectral measurements to identify major, minor and high-trace element components. In typical geological specimens, the elements detected are magnesium, aluminum, silicon, potassium, calcium, titanium, iron, rubidium, strontium, and zirconium. All other elements in the periodic table are also detectable if present in sufficient amounts (typically 50 to 1000 ppm), except the very light elements: hydrogen through sodium. In addition, the effects of particle size for inhomogenous specimens has received preliminary evaluation.

Conclusions of geologic significance will require the evaluation of these geochemical results in the context of the results of other experiments: imagery will provide spectral data in 3 visible and 3 infrared bands, with structural data down to a resolution of 1 mm; organic analysis will provide semiquantitative data on water content, carbonates, and other thermally-labile compounds; magnetic and physical properties studies will provide important bounds on the possible mineralogies; and orbital data on landing site, morphology and infrared spectrum will greatly aid in the definition of the geologic setting.

ELECTRON MICROPROBE EXAMINATION OF INHOMOGENEITIES IN TEKTITES

Stanley V.Margolis and Virgil E.Barnes, Austin, Texas, USA

Barnes pointed out at a Western Meeting of the American Geophysical Union that all exposed tektite surfaces have been etched and that the only original tektite surfaces remaining have been preserved where australite flanges have been tightly welded to the body of the tektite (Tr. AGU, 43, 466, 1962). Petrographic study of plates out from australites show that a thin zone at the surface of the body of tektites beneath flanges is composed of glass having a much wider range of refractive index than the body of the tektite as a whole. This thin inhomogeneous zone was dragged into flanges at the time australites were ablated and because of this flanges have a similar degree of inhomogeneity. Refractive index reflects composition; therefore, the wider the range of refractive index the wider will be the range in composition.

When the range of composition has been determined more will be known about the character of the fiery mist through which australites were propelled while they were still molten, and this in turn will give information about the impacted surface from which all of this material came. Inhomogeneity in the layered Muong Nong-type tektites is also being investigated; and an inventory is being made of detrital mineral inclusions and their melt products found in Libyan Desert glass.

RECENT RESULTS OF THE INVESTIGATION OF MOLDAVITES

Rudolf Rost, Prague, CSSR

The report is based on all significant papers of the author
and of other scientists dealing with the Czech and Moravian
moldavites which appeared in the last 5-10 years.

According to V.Bouška, J.Konta, K.Žebera etc. the earliest
sediments are Upper Miocene in age. A smaller part of tek-
tites occur in(or close to) the primary strewn field of their
fall from the atmosphere. The majority of other moldavites
were later redeposited by water. Two moldavites were found
on the northern margin of Prague in the terrace gravels of
the Vlatava river. One noteworthy double moldavite described
by V.Bouška and R.Rost has recently been found in the classic
area of moldavites S of České Budejovice. The surface of mol-
davites was also studied by scanning microscope. Since 1973
moldavites have been mined for jewellery purposes. An approxi-
mate calculation of the total amount of moldavites made in
1968 was confirmed as correct. According to J.A.Dolgov and
his co-workers (1969) small bubbles in moldavites enclose a
weak vacuum with the content of CO_2, H_2, N_2, noble gases etc.
(H_2S or SO_2).

Micromoldavites have so far not been found in Czechoslovakia.
The fragments of volcanic glasses encountered in Tortonian
sediments in Lipník and Bečvou (Moravia) cannot be identified
as micromoldavites or as glasses from the Bavarian molasse.

The Ries crater is regarded as a source of Czechoslovak molda-
vites by J.Konta and V.Bouška from the Charles University,
Prague. These two scientists along with W.Gentner, E.David etc.
assume that a part of rock material was transformed into gas
and thus separated from the glass of the Ries crater.

THE METEORITE OF UNTERMÄSSING

H.Strunz, West-Berlin, Germany

May I call the attention to a meteorite which was found in
1920 near Untermässing in Bavaria, 60 km ENE of the Ries,
in a straight direction Steinheim-Nördlingen-Untermässing-
Prague. This iron meteorite has the weight of 70 kg (Acta
Albertina Ratisbonensia 20, 1951/52); it is an octahedrite,
as mentioned by Heide, 1957 (Kleine Meteoritenkunde, p.129).

The meteorite belongs to the "Naturhistorischer Verein" in
Nürnberg, and after the museum was completely burned down
during World War II, we found it in the cellar in 1948 as
the only conserved object of the earlier collections. It
has the form of a rather exact rotation ellipsoid. It was
completely undamaged and we were allowed to saw off a 188
grams specimen. This specimen now is in "Staatliches For-
schungsinstitut für Angewandte Mineralogie" in Regensburg,
and some years ago we got from there a 1.96 grams sample to
Berlin for a polished section. According to E.Seeliger in
our institute in Berlin, it is a rather finegrained octa-
hedrite, with much more plessite than kamacite and taenite;
about 1.5 vol% are schreibersite. Also cohenite, graphite,
and chromite inclusions in the schreibersite have been ob-
served. A microprobe investigation is in progress.

At the present I only will express the opinion that this
meteorite may be a part (or a little brother) of the un-
known huge meteorite, responsible for the Ries impact.
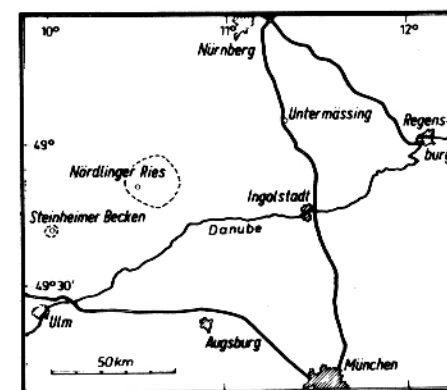
THE METEORITE "DOR EL GANI" (INCLUDING A CONTRIBUTION OF THE ORIGIN OF WIDMANSTÄTTEN STRUCTURE)

A.Mücke, E.Seeliger and E.Klitzsch, West-Berlin, Germany

The meteorite "Dor el Gani" was found in 1972 in the southern foreland Dor el Gani (16° 02 E; 26° 5730''N; Sahara).

The shape of the Fe- Ni- meteorite (weight 2575 g) points to a monotonous flight within the atmosphere of earth. This part of the meteorite which pointed towards the earth during the flight has been heated by friction of air, resulting in a heat shield which flow towards the back of the meteorite (heat shadow). By a bulge the heat shield is connected with the concave, scarred developed back part of the meteorite.

The chemical composition is 92.4 weight % Fe and 7.35 % Ni. Traces of Co, Cu and Zn are present. The structure is octahedric with wide kamacite lamellae.

Finally the origin of Widmanstätten structure will be discussed based on results from 1. Fe- Ni- melts and
                    2. Fe- Ni- alloys heated above
                       the Curie point.

1. and 2. were cooled under conditions of free fall.

CRYSTALLOGRAPHIC STUDIES OF A BRONZITE IN THE JOHNSTOWN ACHONDRITE

Masamichi Miyamoto, Hiroshi Takeda and Yukio Takano, Tokyo, Japan

X-ray studies of a bronzite in Steinbach, a stony-iron meteorite, show an exceptionally high degree of Mg-Fe ordering of the M1 and M2 sites, compatible with slow cooling that have been deduced for the development of Widmanstätten structure in the 700-500°C range[1]. This paper deals with an orthopyroxene (U.S.N.M. No.746) in Johnstown. The chemical and crystallographic data are:

$$(Mg_{1.47}Fe_{0.45}Ca_{0.05}Cr_{0.02}Mn_{0.01})(Si_{1.96}Al_{0.04})O_6$$
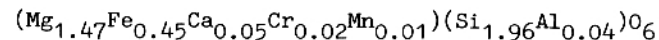
(analysis by A.M.Reid); $\underline{a}$ 18.276(7) $\underline{b}$ 8.861(4) $\underline{c}$ 5.201(3). The crystal structure has been refined in space group $\underline{Pbca}$ by the least-squares method using X-ray intensities measured by a diffractometer with MoKα radiation and graphite monochromator. The residual was 0.045 for 948 observable reflections. The determined site occupancies and the mean bond distances are:

$$M1(Mg\ 0.956 + Fe\ 0.044)\ 2.080Å;$$
$$M2(Mg\ 0.511 + Fe\ 0.435 + Ca\ 0.054)\ 2.185Å.$$
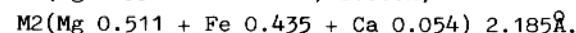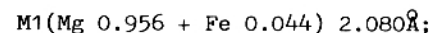
The distribution coefficient $k=(Fe/Mg)_{M1}/(Fe/Mg)_{M2}=0.054$, suggests that the hypersthene achondrite underwent slow cooling process similar to that of Steinbach.

The anisotropic temperature factors were not as large as those expected from the presence of weak diffuse streaks[2], which have been interpreted to have been produced by Ca-rich GP zones as was found in the Stillwater orthopyroxene by an electron microscope[3]. The fact is also compatible with slow cooling and may be useful in deducing the cooling rate of this group of meteorite.

1. Reid,A.M., Williams,R.J. and Takeda,H.(1973) Meteoritics $\underline{8}$,66.
   Takeda,H. (1973) Abstr.Annual meeting, Miner.Soc.Japan.
2. Takeda,H. (1972) Abstr.Geol.Soc.Amer. $\underline{4}$, 684, Minneapolis.
3. Chanmpness,P.E. and Lorimer,G.W. (1973) J.Meter.Sci.$\underline{8}$,467-474.

TAURUS-LITTROW TiO$_2$-RICH BASALTS: OPAQUE MINERALOGY AND
GEOCHEMISTRY

Ahmed El Goresy, Paul Ramdohr, Olaf Medenbach, and
Heinz-Jürgen Berhardt, Heidelberg, Germany (FRG)

Two distinct major rock types with different crystallization
pathes were recognized among the TiO$_2$-rich basalts of the
Taurus-Littrow site: a) Type I with the following crystalli-
zation sequence: Ulvöspinel + minor olivine $\longrightarrow$ armalcolite $\longrightarrow$
titanaugite + pigeonite $\longrightarrow$ ilmenite $\longrightarrow$ plagioclase + cristo-
balite. b) Type II with the following crystallization path:
Ulvöspinel + olivine $\longrightarrow$ armalcolite $\longrightarrow$ ilmenite $\longrightarrow$ titanaugite
$\longrightarrow$ plagioclase + tridymite. Of the studied basalts, samples
70035, 70017, 79155 and numerous lithic fragments in 74242 be-
long to type I, whereas samples 70215, 72015, 74275, 74243,
and the majority of lithic fragments in 74242 belong to type II.
Tan armalcolite was only encountered in type I rocks and gray
armalcolite is confined to type II rocks. Numerous electron
microprobe analyses of both armalcolite types indicate a compo-
sitional bimodality, whereby the gray variety shows higher MgO
and Cr$_2$O$_3$ contents than the tan armalcolite.

Secondary ilmenite rims around armalcolite are formed by one
or a combination of the following processes: a) reaction be-
tween basaltic liquid and armalcolite b) reaction between ar-
malcolite and ulvöspinel c) reaction between Fe^o and armalcol-
ite d) breakdown of armalcolite to ilmenite + rutile e) over-
growth of precipitating ilmenite around armalcolite. Reaction
b was not reported before from the lunar samples. Reactions a,
b, and c cause a strong partitioning of Mg and Cr between ar-
malcolite and ilmenite with preference of these elements to ar-
malcolite. From reaction b, a secondary titanian aluminian chro-
mite with a composition different from secondary chromites form-
ed by subsolidus reduction of ulvöspinel is also generated. The
majority of secondary ilmenites formed by reactions a and b
could be distinguished from coexisting primary ilmenites since
these secondary ilmenites show higher Cr$_2$O$_3$ concentrations. A
unique lithic fragment consisting of major metal + chromite +
minor silicates was encountered in sample 74242. This fragment
probably originated from a metal rich lense of a late differen-
tiate in the Apollo 17 landing site.

THERMODYNAMICS IN EXPERIMENTAL MINERALOGY AND PETROLOGY
S y m p o s i u m
Sponsored by the IUGS-Commission on Experimental Petrology

HIGH-TEMPERATURE SOLUTION CALORIMETRY WITH APPLICATION TO
PRESSURE-TEMPERATURE STABILITY RELATIONS IN REFRACTORY SYSTEMS

O.J.Kleppa and R.C.Newton, Chicago, USA

The methods of solution calorimetry yield heat of formation
data on minerals which make possible thermodynamic calcula-
tions of the temperature-pressure stabilities of minerals and
mineral assemblages. These data are valuable because they
provide checks on experimentally-determined P-T stability
curves of minerals. Moreover, in two classes of systems the
thermochemical method may be the only reliable means of de-
termining equilibrium relations. These are phase relations,
especially of hydrous minerals, at very low temperatures, as,
for instance, the blueschist assemblages, and phase relations
of anhydrous minerals at moderate temperatures which form in
the deep crust and upper mantle under conditions of very low
water pressure. In the first case, reaction kinetics in the
range below 400°C may be too slow to obtain reversal of equi-
libria in feasible laboratory times even in the presence of
an aqueous flux. In the second case a high pressure aqueous
flux may create micas, amphiboles or melt and so obscure the
desired anhydrous relations.

Newly developed methods of high temperature oxide melt solu-
tion calorimetry have provided thermochemical data pertaining
to the problem of anhydrous mineral stability at moderate and
high temperatures. In this method a calorimeter solvent of
molten lead borate is used at temperatures of 700° - 1100°C.
Many refractory minerals in the system CaO - MgO - Al$_2$O$_3$ -
SiO$_2$ dissolve readily in this melt. Some of these are quite
insoluble in HF, and so, have not yielded to low-temperature
aqueous calorimetric methods. Heats of formation for spinel,
aluminum silicates, and minerals in the system MgO - Al$_2$O$_3$ -
SiO$_2$ have been determined by the new technique. For some of
these minerals no previous reliable data existed. New heat
of formation data for several refractory phases are tabulated
below.

Subsolidus phase relations in the system MgO - Al$_2$O$_3$ - SiO$_2$ in the range 400°C - 1500°C and 0-30 kilobars have been compiled, making use of the new thermochemical data, along with available experimental work. Several principal conclusions have resulted:

1) The solution of Al$_2$O$_3$ in enstatite is very nearly accounted for thermochemically as ideal solution of the Mg-Tschermak's molecule. Many equilibria involving aluminous enstatite are strongly curved owing to the high entropy of Al$_2$O$_3$ mixing in enstatite.

2) The stability relations of sapphirine are highly variable from sample to sample. The disordered 2:2:1 form which may be prepared at high pressures has an absolute lower stability limit of about 700°C. The natural ordered 7:9:3 form has a much lower absolute stability temperature limit.

3) Cordierite, both synthetic and natural, has an upper pressure limit of about 8 kilobars.

4) The lower-pressure stability boundary of pyrope has a $\frac{dP}{dT}$ slope of 15-18 bars/°C over the range of conditions considered. Minimum stability pressure is about 14 kilobars.

PREDICTION OF PHASE DIAGRAMS WITH THERMOCHEMICAL DATA DEDUCED FROM LIMITED EXPERIMENTAL PHASE EQUILIBRIUM DATA

E.J.Essene, Ann Arbor, Michigan, USA

No abstract submitted

THE APPLICATION OF THERMODYNAMICS TO SUBSOLIDUS EQUILIBRIUM INVOLVING SOLID SOLUTIONS

Bernard J.Wood, Manchester, U.K.

Experimental data on either simple or complex systems cannot be directly applied to rocks without an understanding of the mixing properties of solid solutions. Many equilibria in systems involving complex solid solutions can be quantitatively calculated from experimental data on simple systems by using appropriate thermodynamic models of the solid solutions involved. The application of solution models to the subsolidus regions of a number of systems of petrological interest will be discussed. Examples will be drawn from the following:

(a) Systems involving Fe-Mg solid solutions

The effect of varying Fe/Mg ratio on reactions involving ferromagnesian silicates will be considered. The reactions:

$$(Fe,Mg)_2Si_2O_6 \rightleftharpoons (Fe,Mg)_2SiO_4 + SiO_2$$
orthopyroxene   olivine   quartz

and $3(Fe,Mg)_2Al_4Si_5O_{18} \rightleftharpoons 2(Fe,Mg)_3Al_2Si_3O_{12} + 4Al_2SiO_5 + 5SiO_2$
cordierite   garnet   sillimanite   quartz
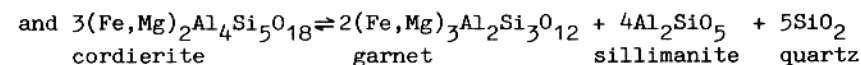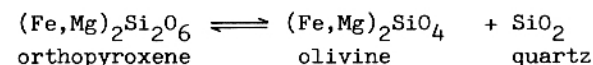
will be taken as examples.

The distribution of Fe^{2+} and Mg^{2+} between coexisting minerals and the dependence of partition coefficients on temperature, pressure and composition will also be discussed.

(b) Systems involving limited solid solutions

Examples to be considered will include

1. K AlSi$_2$O$_6$ - SiO$_2$ solid solutions
2. CaMgSi$_2$O$_6$ - Mg$_2$Si$_2$O$_6$ solid solutions
3. Experimental data on the reaction:

$$Mg_2Si_2O_6 + MgAl_2SiO_6 \rightleftharpoons Mg_3Al_2Si_3O_{12}$$
orthopyroxene   garnet
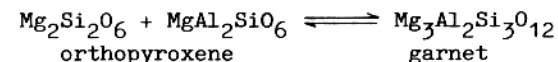
are consistent with a simple model of Mg-Al mixing in orthopyroxene. Experimental data on more complex orthopyroxene-garnet pairs are consistent with the data on the Mg-Al system and with simple models of Mg-Fe-Ca-Al orthopyroxenes and Ca-Mg-Fe garnet solutions.

THERMODYNAMICS OF ELEMENT DISTRIBUTION IN EXPERIMENTAL MAFIC
SILICATE-LIQUID SYSTEMS

P.L.Roeder, Kingston, Canada

Thermodynamic models used to describe the equilibrium between
crystalline phases and the basic or ultrabasic silicate liquids
found in nature have not been very successful because of the
chemical complexity of the phases. The major effort in this
field has been in developing empirical freezing point depress-
ion and chemical exchange equations from experimental and field
data. Freezing point depression equations are necessary in order
to predict the temperature of crystallization of a phase when
the amount of various species present in the liquid is known.
The chemical exchange equations are useful for predicting the
composition of crystalline phases as a function of temperature
and the ratio of species in the liquid. Equations describing
the equilibrium between crystals and liquid are considered for
olivine, plagioclase and spinel.

The equilibrium between olivine and basic liquid can be described
by empirical freezing point depression equations. These equations
are affected by changing liquid composition, for example increas-
ing alkalies in the liquid decreases the solubility of both mag-
nesium and ferrous iron relative to olivine. Because of the sim-
ilarity of the magnesium and ferrous iron species in the liquid
both are affected in a similar fashion. Thus the ratio of activi-
ty coefficients is essentially constant and the chemical exchange
equilibrium as expressed by the distribution coefficient is in-
sensitive to changes in temperature and liquid composition.

Chemical exchange equations have been written (Kudo and Weill and
Mathez) for the plagioclase-liquid equilibrium and these unlike
the olivine-liquid equilibrium have a fairly large temperature
coefficient and thus they are useful as a geothermometer. Pre-
sumably the large temperature coefficient is because of relative
differences in Al and Si polymerization in the liquid as a func-
tion of temperature.

Equations describing the spinel-liquid equilibrium have to take
into account the complex nature of the spinel solid solution.
This solution is far from ideal and thus the $Mg^{+2}:Fe^{+2}$ ratio in
the spinel is sensitive not only to this ratio in the liquid but
to the ratio of Fe^{+3}, Cr^{+3}, Al^{+3} and Ti^{+4} in the spinel structure.

THERMODYNAMICS OF EXPERIMENTAL SUB-SOLIDUS SILICATE SYSTEMS
INCLUDING MIXED VOLATILES

G.B.Skippen, Ottawa, Canada

The application of thermodynamic theory to mixed volatile
systems generally presumes that natural systems approach a
state of chemical equilibrium. Experimental data can then
be used to construct petrologic models that are based on
the equation.

$$\sum_i v_i \mu_i = 0$$

where v_i and μ_i are the stoichiometric coefficient and the
chemical potential of each component, i , in an equilibrium.
In many experimental studies where the phases involved con-
sist of a single component, it has been customary to make
no distinction between components and phases. In mixed vo-
latile systems, at least one of the phases, the fluid, con-
tains two or more components and it is necessary to recognize
that the energy balance in the above equation exists among
components rather than phases.

A convenient relationship for consideration of experimental
data can be derived from the above equation.

$$\frac{d \ln K}{d^{1}/T} = \frac{-\Delta H^{o}_{R}}{R}$$

The equilibrium constant, K, in this equation must be measured
experimentally for each independent equilibrium under con-
sideration. There exist four distinctly different methods for
measuring K in mixed volatile systems: (1) The calorimetric
method. (2) The extent of reaction method. (P.Metz) (3) The
gas analysis method. (H.Greenwood, W.Johannes) (4) The solid-
phase buffer method (H.Eugster). The consistency of results
obtained by each of the four methods can be demonstrated by
data for the equilibrium.

$$3\,MgCO_3 + 4\,SiO_2 + H_2O \rightleftharpoons Mg_3\,Si_4\,O_{10}(OH)_2 + 3CO_2$$
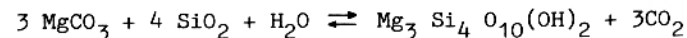
A review of additional experimental data for a typical mixed
volatile system, $CaO-MgO-SiO_2-CO_2-H_2O$, indicates sufficient
data to calculate a model for siliceous carbonate rocks. The
model expresses the stability field of common mineral assem-
blages as functions of temperature, total pressure, fluid com-
position, and carbonate phase composition.

THERMODYNAMICS OF MELTING IN EXPERIMENTAL SILICATE-VOLATILE SYSTEMS

C.Wayne Burnham, Pennsylvania, USA

The thermodynamics of melting in rock-forming silicate-volatile systems was first elucidated by Goranson (1938) using experimentally determined phase equilibria in the systems $NaAlSi_3O_8$-H_2O and $KAlSi_3O_8$-H_2O. In the ensueing 36 years, and especially in the past 17 years, several efforts have been made to deduce thermodynamic relations in these systems from experimental data on melting and solubility relationships. These efforts have met with only limited success due largely to lack of fundamental thermodynamic data on the pure phases and to rather large uncertainties on the slopes of experimentally determined phase boundaries. Within the last five years, however, the experimental and thermodynamic data necessary to calculate phase equilibrium relations in many rock-forming silicate-H_2O systems have become available. Unfortunately, data on volatiles other than H_2O are insufficient for a comparably rigorous thermodynamic analysis of their role in the melting of rock-forming silicates.

The system for which the most data are available is $NaAlSi_3O_8$-H_2O. Published thermodynamic data on H_2O and $NaAlSi_3O_8$ glass, combined with experimental H_2O solubility and P-$\bar{V}$-T data, provide the basis for calculation of the pressure, temperature and compositional dependence of the thermodynamic functions for both the H_2O and $NaAlSi_3O_8$ components in the melt phase. The chemical potential function for the H_2O and $NaAlSi_3O_8$ components, when combined with published thermodynamic properties of albite and H_2O, enable calculation of the phase relations in this system as a function of pressure, temperature and composition. The calculated and experimental phase relations agree within experimental error up to 10 kilobars for all H_2O-bearing compositions.

The fugacity (f_w^m) or activity (a_w^m) of H_2O in the melt phase has been found to vary linearly with the square of its mole fraction $(X_w^m)^2$ for values of $X_w^m \leqslant 0.5$, on the basis that one gram formula weight (GFW) of $NaAlSi_3O_8$ constitutes the effective mass of anhydrous melt that interacts with one GFW of H_2O. For $X_w^m > 0.5$, f_w^m varies exponentially with X_w^m; thus, Henry's law for a dissociated solute is obeyed for $X_w^m \leqslant 0.5$, but not at higher values of X_w^m.

These relationships, as well as other lines of evidence, are consistent with a solution model for H_2O in $NaAlSi_3O_8$ melts that involves two types of reaction. For the first GFW of H_2O, the solution reaction may be represented by $NaAlSi_3O_8 + H_2O = AlSi_3O_7(OH) + NaOH$; additional H_2O then enters the melt by the reaction, $AlSi_3O_7(OH) + nH_2O = AlSi_3O_{7-n}(OH)_{2n+1}$.

The extension of this simple solution model to aluminosilicate melts of more complex composition, such as igneous rock melts, requires proper definition of the mass of melt that is equivalent to one GFW of $NaAlSi_3O_8$ in its interaction with H_2O. This has been done for several rock compositions, ranging from tholeiitic basalt to Li-rich granite pegmatite, for which experimental data are available on the solubility of H_2O in these melts. These solubilities, when recast on a molal basis equivalent to $NaAlSi_3O_8$, are all identical within experimental error throughout the pressure range covered.

These results confirm the general validity of the proposed reaction model and establish the system $NaAlSi_3O_8$-H_2O as a quantitative thermodynamic model for hydrous magmas of widely different compositions. Thus, it is now possible to calculate the phase relations in many rock-forming silicate systems that would be difficult to determine experimentally.

MELTING RELATIONS IN SILICATE SYSTEMS WITH WATER AND
CHLORIDES

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1. The data on dissociation of alkali halides in supercritical
aqueous solutions and thermodynamic treatment of phase diagram
for the system $NaCl-H_2O$ show that both H_2O-rich vapour and
NaCl-rich liquids in this system are close to ideal solutions
(above ca. $500^{\circ}C$).

2. The miscibility gap between vapour and chloride-rich liquid
at relatively low pressures (below 1.5 kb at the temperatures
of granite solidus) is substituted at higher pressures by com-
positional range where the properties of fluid phase gradually
change from those of aqueous vapour to chloride melt with al-
most constant activities of components. This is corroborated
by the experimental data on chloride distribution between wa-
ter-chloride fluid and granitic melts at $800^{\circ}C$ and 2 kb.

3. Very low solubility of chlorides in acid silicate melts
(Kilinc, Burnham, 1972; Ryabchikov, Wall, Burnham, 1974) and
rock forming silicates in aqueous solutions together with the
discussed above properties of high temperature water-chloride
mixtures (exsolution at lower pressures and transitional range
at higher pressures) causes the solidus temperatures and solu-
bility of water in silicate melt in the systems rock forming
silicate - chloride - water to be nearly identical with those
in boundary system silicate - water up to very high concentra-
tions of chlorides in the bulk composition. This is demonstrated
by experimental data on the system granite - chlorides - water
(Ryabchikov, Hamilton, 1971).

STUDIES OF MINERAL REACTIONS BY HIGH TEMPERATURE SOLUTION
CALORIMETRY

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High temperature solution calorimetry, using molten oxide
solvents in a calvet-type twin microcalorimeter at $700-800^{\circ}C$,
has been applied to the study of a number of solid state
reactions in silicates and other oxides. This method has
the advantage of requiring quite small amounts of sample;
only 300-400 mg of a given phase usually are sufficient.
Data are presented on the enthalpy of the olivine-spinel
transition in nickel orthosilicate and on the enthalpies
associated with partial Al-Si disordering in sillimanite.
Development of calorimetry of iron and manganese minerals
under atmospheres of controlled low oxygen fugacity is
discussed.

THERMODYNAMIC AND CRYSTALLOGRAPHIC PROPERTIES RELATED TO Al-Si-Mg ORDERING IN $Ca_2MgSi_2O_7$—$Ca_2Al_2SiO_7$ MELILITE CRYSTALLINE SOLUTIONS

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Equations for the configurational entropy and homogeneous equilibria in $Ca_2MgSi_2O_7$—$Ca_2Al_2SiO_7$ melilites have been derived for two sets of constraints that do not permit Mg on the smaller T_2 sites: (1) When the T_2 sites are topologically equivalent one ordering parameter, $Z \equiv N_{Si(T_1)}$, and one composition parameter, $N \equiv 1-N_{Mg(T_1)}$, are required and the ordering is non-convergent. (2) When the T_2 sites are not equivalent an additional ordering parameter, $Y \equiv N_{Si(T_{2a})} - N_{Si(T_{2b})}$, is required and the additional ordering is convergent. For any given melilite, the configurational entropy decreases as Y increases. The structural formula for such a melilite is

$$Ca_2[Mg_{(1-N)}Al_{(N-Z)}Si_Z][Al_{(N+Z-Y)/2}Si_{(2-N-Z+Y)/2}][Al_{(N+Z+Y)/2}Si_{(2-N-Z-Y)/2}]O_7.$$
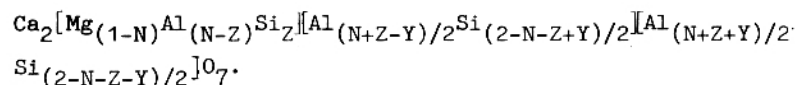
The first set of site constraints correspond to $P\bar{4}2_1m$ symmetry. Analysis of this (tetragonal) melilite structure shows that changes in the size of the T_1 and T_2 tetrahedra distort the structure causing changes in the cell parameters $\underline{a}$ and $\underline{c}$ (measured at room temperature), where differences between $\underline{a}$, $\underline{N}$, $\underline{Z}$, and $\underline{c}$ for any two melilites in N-Z space are given by:

$$\Delta \underline{a} = -0.162\Delta\underline{N} - 0.098\Delta\underline{Z} \tag{1}$$

and

$$\Delta \underline{c} = 0.055\Delta\underline{N} + 0.102\Delta\underline{Z} \tag{2}$$

Thus as the mol fraction of Si on T_1 increases, $\underline{c}$ increases and $\underline{a}$ decreases. In pure $Ca_2Al_2SiO_7$, this can be due only to Al-Si disordering from the configuration $Ca_2Al(Si_{0.5}Al_{0.5})_2O_7$ toward the configuration $Ca_2SiAl_2O_7$. Cell parameters of quenched synthetic $Ca_2Al_2SiO_7$ gehlenites annealed between 600 and 1530°C vary with annealing temperature such that $\underline{a}$ decreases and $\underline{c}$ increases with temperature. These obersvations are consistent with the effects of Al-Si disordering predicted by the structure analysis. A maximum value of 0.04 ± 0.01 for Z at 1590°C (melting point of gehlenite) is inferred from the data. Assuming the vibrational entropy to be independent of degree of order, we obtain:
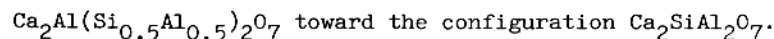
$$T(^{o}C) = 5300 \left[\ln \frac{(1-Z)}{Z} - 2 \text{ arctanh } Z \right]^{-1} - 273.15 \tag{3}$$

which relates degree of order - and thus change in cell dimension - with equilibration temperature. These results confirm that at least 2.755 and possibly as much as 3.08 cal $mol^{-1}K^{-1}$ must be added to the currently accepted entropy data for gehlenite. Annealing studies such as the above can be used as a simple method for self-calibration of any natural iron-free melilite as a single-phase geological thermometer. This method requires extremely high precision and accuracy in determining cell parameters.

THERMODYNAMICS OF THE NEPHELINE-FELDSPAR EQUILIBRIUM

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As a result of the experimental study, the K and Na distribution between nepheline (Ne) and high and low alkali feldspars (Fsp) at high temperatures (T) has been defined. Systems of the type mineral - aquous solution of the alkali chlorides $(K,Na)Cl^{aq}$ were studied at 1000 kg/cm^2 pressure, while to study the systems mineral - alkali chloride melts $(K,Na)Cl^m$ sealed quartz tubes and saturated vapor pressure were used (Table).

Experimental work undertaken to study the distribution of K and Na between the equilibrium phases at high temperatures ($^\circ$C)

	Fsp_{ss}^l	Fsp_{ss}^h	$(K,Na)Cl^{aq}$	$(K,Na)Cl^m$
Ne_{ss}	400-1000°	500-1100°	400-500°	800-1100°
Fsp_{ss}^l		500-1000°	400-500°	800-1000°
Fsp_{ss}^h			500-700°	800-1100°

The isotherms of alkali distribution between all the phases of the systems under study were determined. Based on the thermodynamic interpretation of the experimental data, energy of mixing for each phase was estimated and diagrams of the phase relations, Ne-Fsp^h and Ne-Fsp^l (mineralogical thermometers) were constructed. They proved to be effective but in the sodic region of compositions for both intrusive and subvolcanic and volcanic rocks.

TEMPERATURE-DEPENDENT Mg-Fe DISTRIBUTIONS IN PIGEONITES

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The Mg(2+), Fe(2+) distribution over the M1 and M2 positions in pigeonite depends on the thermal history of the mineral. Until this time, the crystal structures of pigeonites from four lunar basalts and one terrestrial andesite have been refined using x-ray diffraction. In addition, the average Fe(2+) site occupancies obtained from Mössbauer spectra of pigeonite separates from six lunar basalts have been reported. The pigeonites studied so far have wollastonite components of 5-11 percent and, with one exception, ferrosilite components of 25-36 percent. The terrestrial pigeonite (Isle of Mull) is more ironrich: Fe=52 percent. This consistent body of data allows the following conclusions:

(1) The natural Mg,Fe distribution coefficients k_n vary between 0.045 and 0.14, most frequent values being between 0.08 and 0.11.

(2) The equilibrium temperatures T_n of the observed natural distributions are between 520 and 840°C, the differences being indicative of significantly different cooling histories. The temperatures generally correspond to T_n values of orthopyroxenes from basaltic lava flows.

(3) The standard Gibbs free-energy difference $G_E^\circ(1000^\circ C)$ for the Mg,Fe exchange reaction (4-6 kcal/formula unit) is distinctly higher than the corresponding value of orthopyroxene. However, a significant correlation with the wollastonite component cannot be noted in the data. The nature of the apparently large scatter in the G_E° values is not yet understood.

(4) In contrast to the orthopyroxene series there is no evidence yet that the Mg,Fe distribution in pigeonites with a constant wollastonite component can be interpreted in terms of the ideal solution model. For this, the range in chemical composition studied is too small. The peculiarly low value k_n=0.045 of the Mull pigeonite may possibly point to a strong deviation from ideality.

(5) For semi-quantitative analysis of the cooling history in terms of heat-flow models the rate constants for the exchange reaction at various temperatures are needed. Preliminary studies show the same order of magnitude as for those of orthopyroxene.

DISTRIBUTION OF IRON AND MAGNESIUM BETWEEN BIOTITE AND A SALT SOLUTION

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The equilibrium distribution of magnesium and iron between synthetic biotites and coexisting (Mg,Fe)-chloride solutions have been studied in the temperature range from 400° - $700^{\circ}C$ under water pressures of 200 - 2000 bars. The experiments were carried out with experimental technique described by HINRICHSEN (1967, 1968). The distribution coefficients and the distribution isotherms, represented in ROOZEBOOM-diagrams have been calculated by using the ideal solution models in a least square refinement. In the temperature range from 700° - $500^{\circ}C$, the distribution isotherms have a hyberbolic shape, which accords with the ideal distribution of iron and magnesium between biotite and salt solution.

Computation of the equilibrium constant K for the ion exchange reaction

$$KMg_3AlSi_3O_{10}(OH)_2 + 3\ FeCl_2 \xrightleftharpoons{2m\ KCl} KFe_3Al\ O_{10}(OH)_2 + 3\ MgCl_2$$

gives values of 0.055 at $700^{\circ}C$ to 0.126 at $500^{\circ}C$, respectively. The plot of ln K against 1/T shows a curve with constant slope between 600° and $700^{\circ}C$. In this temperature range, the heat of reaction ΔH can be calculated by using the van't HOFF equation

$$\frac{d\ln k}{dt} = \frac{\Delta H}{RT^2}$$

ΔH has a value of -8,3 kcal/mole between 600° and $700^{\circ}C$. At 550° and $500^{\circ}C$ the temperature dependence curve begins to deviate from linearity.

In some ion exchange experiments the biotite was partly transformed to chlorite. This chloritization of the biotites increases with incrasing water pressure and decreasing temperature and decreasing potassium content of the salt solutions.

THE THERMODYNAMIC AND EXPERIMENTAL INVESTIGATIONS OF THE OPEN MINERAL SYSTEMS

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Natural mineral systems are well known as the open systems with perfectly mobile components: Experimental and theoretical studies of (natural) mineral equilibria, the geological interpretation of the data have to be based on the major peculiarities of these systems which involve the intensive parameters being independent equilibrium factors for the perfectly mobile components.

A combined program is the best way to investigate these systems. Such a program should consist of:

a) prognostic topological study of the systems;

b) experimental key data acquisition;

c) thermodynamic calculations of the general diagram of the system;

d) design of the possible petrogenetic models.

The stated above is illustrated by the results of the experimental study performed by the authors on the alumosilicate systems, characterized by the perfectly mobile regime of water, carbon dioxide, alkali and pH.

THE ENERGETIC THEORY OF MISCIBILITY GAPS IN MINERAL SOLID SOLUTION

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The theory of regular solutions established the following simple relations between mixing enthalpie ΔH_m and mixing energy Q

$$\Delta H_m = x_1 x_2 Q \tag{1}$$

(x_1 and x_2 - molar fractions of components 1 and 2 accordingly) and between Q and critical temperature of mixing $T_{c\tau}$

$$T_{c\tau} = \frac{Q}{2R} \tag{2}$$

(R - universal gas constant). These relations are the basis for the estimation of miscibility gaps of solid solutions.

We have developed the energetic theory of ΔH_m and Q using the following general equation:

$$\Delta H_m = E_{s.s.} - x_1 E_1 - x_2 E_2 \tag{3}$$

where E - lattice energy (only for pure ionic solids) or atomisation energy (for majority of minerals) of solid solution ($E_{s.s.}$) and pure components (E_1 and E_2). The simple crystal chemical model of solid solution based on two additivity rules: the additivity of interatomic distances (Vegard's rule) and effective atomic charges. With these approximations we obtain from (3) and (1) the next main expression:

$$Q = a(\Delta\epsilon)^2 + b\left(\frac{\Delta r}{r_1 + r_2 + r}\right)^2 \tag{4}$$

where $\Delta\epsilon$ is the difference of ionicity degrees of pure components, $\Delta r = r_1 - r_2$ is the difference of radii of substituent ions (atoms), r is the radia of common structural unit for both of components, a and b are semiempirical parameters.

The greater Q the less the limits of isomorphous substitution in according to equation (2). Therefore we conclude from (4): isomorphous limits at given T the less, the more the ionicity difference (electronegativity difference) and the size difference for the isomorphic atomic pair. The other conclusions from (4) deal with the polarity (asymmetry) of substitutions and the influence of size of common structural unit, r in (4): the larger r, the more extensive the miscibility of the same isomorphic pair of elements.

If the bonding characters of components are similar ($\Delta\epsilon \leqslant 0.05$) the equation (4) approximately becames:

$$Q = b\left(\frac{\Delta r}{r_1 + r_2 + 2}\right)^2 \tag{5}$$

Parameter b in (5) can be estimated by allowing for some crystal data (molar volume, compressibility and so on).
Then we obtain the way for determination of miscibility gaps in many mineral systems (oxides, sulfides, carbonates, silicates and etc.) in good agreement with experimental data. The energetic theory allows to predict the influence of the other components in multicomponent systems and the role of polymorphous transitions.

REGULAR SOLUTION MODEL FOR THE $Fe_{1-x}S$ - $Ni_{1-x}S$(mss) SOLID SOLUTION

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The monosulfide solid solution (mss) of the FeS-NiS-S system extends continuously from the FeS-NiS binary join to more S-rich compositions over a wide temperature range. FeS activities (a_{FeS}) were determined at $930^\circ C$ for mss by analyzing with an electron microprobe the FeS content of sphalerites which had been equilibrated with the mss in standard evacuated silica tube experiments. Studies on the Zn-Fe-S system have previously shown that between 225° and $1100^\circ C$ the FeS content of sphalerite is a function only of a_{FeS} and this relation is not affected by other elements in sphalerite such as Cu, Cd, Mn or Ni. The sphalerite products contained progressively decreasing amounts of FeS indicating decreasing a_{FeS} in the mss passing from stoichiometric FeS (std. state, $a_{FeS}=1$) to NiS ($a_{FeS}=0$) and from the FeS-NiS join to more S-rich $(Fe,Ni)_{1-x}S$ compositions. Conversely, the Ni content of sphalerite increased systematically across the mss field reaching a maximum of 3.8 mole % NiS on the NiS-S join.

The variation of a_{FeS} with mss composition fits a regular solution model in which end-member components $Fe_{1-x}S$ and $Ni_{1-x}S$ mix ideally for a given mole % S. The relationship between a_{FeS} and mole fraction of FeS in mss (X_{FeS}^{mss}) is described by $a_{FeS} = \gamma X_{FeS}^{mss}$ where γ is a function of mole % S in mss as follows: 1.0 at 0 % S, i.e. the solution obeys Raoult's Law on the FeS-NiS join; 0.93 at 5 % S; 0.81 at 10 % S; 0.63 at 13 % S. Variation of γ with temperature is under investigation.

The small range in Ni content of sphalerite at $930^\circ C$ makes it unlikely that a_{NiS} can be precisely determined in like manner to a_{FeS}. However, we have in progress measurements of S_2 fugacity ($= a_{S_2}$) which combined with our a_{FeS} data in the Gibbs-Duhem relation will permit calculation of a_{NiS}.

THE ORIGIN OF THE ASSEMBLAGE: QUARTZ + Al-SILICATE + RUTILE + Al-PHOSPHATE

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Large bodies of quartz-kyanite or quartz-andalusite occur in several, widely separated localities in the United States and Sweden. These bodies are large enough to be of economic importance, and are characterized by the minerals quartz, Al-silicate (andalusite, kyanite, pyrophyllite), rutile, and Al-phosphate (lazulite, augelite, svanbergite). All the deposits have in common features that are difficult to explain by regional or thermal metamorphism of a sedimentary rock. Some of these features are: massive volumes of rock composed mostly of quartz + kyanite or andalusite with large concentrations of the Al-silicate, pervasive occurrence of rutile as inclusions in all other minerals, rare Al-phosphate minerals in local concentrations, and less common, but persistent tourmaline, topaz, and pyrite.

All of the features of two California occurrences, White Mountains and Cargo Muchacho Mountains, can be explained by an extension of the thermal, ionic equilibria in aluminosilicate assemblages, developed by Eugster (1970, Fortschr.Min.), and H^+ ion metasomatism, as proposed by Hemley (1964, Econ.Geol.). For example, considering the reaction

$$2KAlSi_3O_8 + 2H^+ = Al_2SiO_5 + 5SiO_2 + 2K^+ + H_2O$$

the equilibrium constant, $K(P,T) = a_{K^+}^2 \cdot f_{H_2O}/a_{H^+}^2$
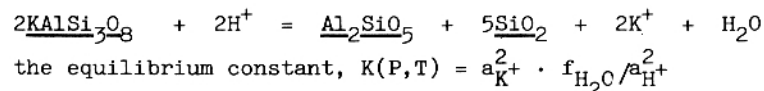
can be calculated from available thermodynamic data (Eugster, 1970). Decreases in f_{H_2O} or increases in a_{H^+} substantially reduce the stability field of K-feldspar. If one hypothesizes pervasive permeation of H^+ enriched fluids through a quartz-feldspar meta-volcanic rock, a final assemblage of quartz + Al-silicate can result. If the temperature is above $425^\circ C$, andalusite will develop at low pressures and kyanite, at high pressures. Pyrophyllite will form at temperatures below $425^\circ C$ and in later stages commonly replaces the higher temperature assemblages. The acidic fluid would allow movement of aluminum to form the massive concentrations of Al-silicate, and permit recrystallization of all minerals to large sizes.

In the California occurrences, if rutile forms from ilmenite by a reaction like

$$\underline{FeTiO_3} + H^+ = \underline{TiO_2} + FeOH^+,$$
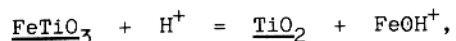
the pervasive nature is most easily explained. The early fluids apparently contained sufficient other components to provide fluorine for topaz, boron and fluorine for tourmaline, and sulfur for pyrite.

Later fluids were richer in phosphate and sulfate ions, because Al-phosphate minerals (lazulite, augelite, and trolleite) partially replace Al-silicate along fissures and even later woodhouseite- and alunite-group minerals fill fractures and other cavities.

EXPERIMENTAL STUDY OF $T-X_{CO_2}$ LIMITS OF THE ZEOLITE FACIES

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Laumontite and prehnite stabilities are controlled by temperature and chemical potential of CO_2 in the fluid, as is shown by topologic analysis of the low-temperature mineral equilibria in the system $CaO-Al_2O_3-SiO_2-H_2O-CO_2$. The upper temperature limit of the zeolite facies is fixed by decomposition of laumontite into prehnite + montmorillonite + quartz. The replacement of laumontite by the association of calcite + montmorillonite + quartz and kaolinite + calcite + quartz represents the low temperature limit.

Experimental study of the reaction laumontite = prehnite + montmorillonite + quartz at $P_s = P_{H_2O} = 1000$ bars has shown the equilibrium to be established at T = 260 $\mp$ 10°C. Equilibrium of reaction laumontite = montmorillonite + calcite + quartz depends on both temperature and CO_2 content in the solution, its coordinates being T = 220$^\pm$ 10°C at X_{CO_2} = 0, and T = 390$\mp$ 10°C at X_{CO_2} = 0,1. Coordinates of the singular reaction prehnite = calcite + montmorillonite, which represents the lower boundary of prehnite stability field, are X_{CO_2} = 0, T = 240$\mp$ 10°C; X_{CO_2} = 0,15, T = 390$\mp$ 10°C.

Increase P_{CO_2} results contraction of the prehnite and laumontite stability fields and their replacement by clay minerals + carbonate association. These experimental data define the limits of the zeolite facies metamorphism of metabasites at the temperature range 220- 260$\mp$ 10°C and very low CO_2 content in the fluid (P_{CO_2} : P_{H_2O} <0,02). With higher CO_2 content, substantially non-metamorphosed rocks have been found to transfer directly into the greenschist facies of metamorphism.

EXPERIMENTAL CHECKING OF THERMODYNAMIC DIAGRAMS OF STABILITY
OF W, Mo AND Bi MINERALS IN HYDROTHERMAL CONDITIONS

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1. The authors calculated the stability conditions of some
principal minerals, such as W, Mo and Bi, and made an ex-
perimental attempt to test them as some main elements of
these diagrams, in particular, to test the pH effect on the
mineral stability.

2. It has been found for tungsten that with increase of alka-
linity in sulfide solutions, ferberite is replaced by pyrite
with simultaneous entering of tungsten in solution. The spe-
cific pH-value for a given equilibrium is mainly determined
by the activity of hydrogen sulfide and tungsten ratio. The
activity of tungsten in solutions equilibrated with ferberite
and pyrite was calculated by the thermodynamic equilibrium con-
stant of corresponding reaction for the given experimental
pH and hydrogen sulfide. The calculated values were found to
be in good agreement with those for tungsten concentrations
chemically determined in the solutions after completion of
the experiments.

3. It has been found for molybdenum minerals that intense re-
placement of powellite by molybdenite in sulfur hydrogen so-
lutions occurs at $300^{\circ}C$ at pH $\leqslant 7$, which satisfactorily fits
the results of thermodynamic calculations. In these experi-
ments the indicator of sulfur and oxygen volatility was pyrrho-
tite; this permitted one to plot the experimental conditions
on the diagram lg f_{O_2}-pH.

4. It was experimentally found that at $250^{\circ}C$ in solutions with
H_2S concentration of about 0.05 M bismuthinite was more stable
at pH $<$ 8 whereas metallic bismuth was more stable in alkaline
conditions. This is also confirmed by the field positions of
the phases on the plotted diagram.

MÖSSBAUER STUDY OF IRON IN NATURAL AND SYNTHETIC BIOTITES

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Mössbauer spectra are described for chemically complex natural
and synthetic trioctrahedral micas. The Mössbauer parameters
at roomtemperature (see table 1) can clearly distinguish be-
tween Fe^{2+} and Fe^{3+} in the different lattice positions in mi-
cas. In spite of the large chemical variations of natural mi-
cas the Mössbauer parameters, quadrupole splitting and isomer
shift, show small variations.

While natural biotites show no pronounced ordering of Fe^{2+}
into the two types of octahedral sites. M1 and M2, synthetic
Fe-Mg-biotites show a temperature dependece of the ordering
of ferrous iron into the different octahedral sites. This
feature is discussed in view of the complex crystal-chemistry
of micas.

Table 1. Mössbauer parameters of micas in mm/s.

Sample	Site	Coordination	ISOMER*) SHIFT	QUADRUPOLE SPLITTING
Natural biotite	Fe^{2+}M1	octahedral	1.03	2.10
	M2	"	1.06	2.56
	Fe^{3+}M1	"	0.40	1.20
	M2	"	0.43	0.62
Ferriphlogopite	Fe^{3+}Si	tetrahedral	0.17	0.50

*) Relative to iron metal.

RADIATION INDUCED EFFECTS IN SYNTHETIC α-QUARTZ
DOPED WITH Co(II)

F.Hassan and A.Sacroug, Cairo, Egypt

The optical absorption spectrum of a synthetic α-quartz single crystal doped with traces of Co(II) ions was measured at liquid nitrogen and at room temperatures. Upon X-irradiation at liquid nitrogen temperature several bands developed. Electronic transitions between the $^1A_{1g}$ ground state of the octahedrally coordinated Co(III) ion and the $^1T_{2g}$ and $^1T_{1g}$ states were identified. These induced absorption bands were found to be unstable and completely disappeared at room temperature.

The results obtained from optical absorption measurements were compared to those obtained using ESR technique.

The possibility of the photo-oxidation of Co(II) to Co(III) at liquid nitrogen temperature in the α-quartz structure will be discussed.

The following reaction is proposed:

$$Co(II) \quad \xrightarrow[\text{room temperature}]{\text{X-Rays (Liquid nitrogen)}} \quad Co(III) + e$$
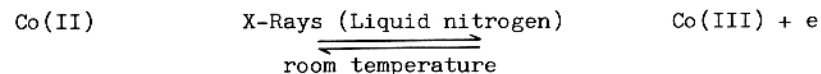
RADIATION CENTRES IN ANHYDRITE

A.S.Marfunin, L.V.Bershov, A.V.Speranskii, Moscow, USSR

Electron paramagnetic resonance (EPR) and luminescence studies of anhydrites from ore deposits of Middle Asia, Norilsk and other regions show that isomorphism and interstitial impurities, vacancies and electron-hole centres in these crystals are the most important features of the anhydrites from different localities.

It is possible to distinguish the radiation (or spectroscopic) varieties of anhydrites.

1) The yttrium-containing anhydrites with centres Y^{2+}, YO_2, $O_2^{3-} - Y^{3+}$.

2) The rare earth anhydrites with $TR^{2+} = TR^{3+} + e^-$.

3) The boron-containing anhydrites with free radicals BO_2^o.

4) The phosphorus-containing anhydrite with free radicals PO_m^{n-}.

5) The ozonide (O_3^-) and peroxide (O_2^-)-ion containing anhydrites.

6) The thiosulfate anhydrite with SSO_3^-.

7) The anhydrites with oxygen vacancies and radicals SO_3^-, SO_2^-.

8) The hydrogen-containing anhydrites with the centres involving hydrogen as compensator.

9) The alkali anhydrites with $O_2^{3-} - K^+$, $O_2^{3-} - Na^+$.

These varieties correlate with geochemical environment and regional distribution of anhydrites and reflect the thermal and radiation history of the minerals.

MÖSSBAUER STUDY OF IRON IN SINGLE CRYSTALS OF FAYALITE
AND FORSTERITE AT ELEVATED TEMPERATURES

D.L.Warburton and S.S.Hafner, Marburg, Germany (FRG)

Two single crystals have been selected for a study of the
Mössbauer effect of ^{57}Fe at the M1 and M2 positions: (1) a
natural fayalite (Fa97) from Rockport and (2) a synthetic
forsterite (Fa01) with iron enriched to 90 percent ^{57}Fe.
Crystal sections with a thickness of 100 μm have been pre-
pared parallel to (100), (010), and (001). They have been
studied at 300, 450, and 600°C.

The quadrupole-split ^{57}Fe-doublets reveal information about
the electric field gradient tensors at the M1 and M2 posi-
tions. The tensors generally consist of five independent
parameters: the maximum value V_{zz}, the asymmetry parameter
η , and three angles, α, β, γ, which describe the orientation
of the tensors relative to the crystallographic axes. The
splittings of the doublets depend on V_{zz} and η; the inten-
sity ratios of the two peaks of the doublets depend on η
and α, β, γ. For M1 α, β, γ, are arbitrary angles. For M2 two of
the three angles are 0 or 90°.

The M1 and M2 doublets of fayalite are sufficiently resolved
so that assignment and analysis of the M2 tensor are possible.
In the spectrum of forsterite the low-energy peaks of the
doublets overlap so that the intensity ratios cannot be deter-
mined completely. However, the analysis is facilitated using
two arguments. First, in high-energy peaks of the doublets
do not cross over in the olivine solid solution series. Se-
cond, the tensors in fayalite and forsterite are not signi-
ficantly different. The latter argument has been confirmed
by lattice summations using the point charge model based on
fifteen crystal structure refinements of olivines.

ABSORPTION AND LUMINESCENCE OF SPESSARTINES. $Mn_3Al_2Si_3O_{12}$

K.Recker and R.Leckebusch, Bonn, Germany (FRG)

Impurity free spessartines are yellow. Natural spessartines
always contain impurities in variable amounts and therefore
exhibit different colour shades (yellowish, reddish, brownish),
which until now have not been explained entirely.

To correlate absorption and luminescence with chemical com-
position a number of spessartines were investigated by spec-
trochemical analyses, absorption spectra (350 - 3500 nm), and
luminescence spectra (400 - 800 nm). With respect to the re-
sults of the chemical analyses the spectra have been discussed
under aspects of the crystal field theory.

According to the chemical analyses Mn and Fe are the only ab-
sorbing cations in the investigated spessartines. The absorp-
tion maxima could be attached correspondingly to Mn^{++} and
Fe^{++}ions (8-fold coordination) and to Fe^{+++}ions (6-fold coor-
dination). The different colours of the spessartines are caused
by different transparencies and intensities of absorption max-
ima due to variable Fe^{2+}/Fe^{3+} contents.

The investigated spessartines do not exhibit any luminescence
at room temperature, but yellowish crystals, in contrast to
brownish ones, luminesce more or less brightly at 77°K under
uv radiation. The luminescence spectra show a maximum at 602 nm,
which causes a red luminescence colour, and some other maxima
in the region between 450 to 500 nm. The maximum at 602 nm is
due to Mn^{++}ions, the origin of the short wave maxima could not
yet be explained. According to experience the absence of lumi-
nescence at room temperature is caused by interactions of Mn^{++}-
ions (concentration quenching). The luminescence of the spes-
sartines certainly is suppressed by the relative high iron con-
tent (killer effect). At a Mn/Fe rate of about 30:1 the killer
effect does not impede luminescence completely, while it does
so totally at about 10:1.

PVT EQUATIONS OF STATE FROM ULTRASONIC MEASUREMENTS AT
VERY HIGH HYDROSTATIC PRESSURES

R.J.O'Connell, Cambridge, Mass., USA

Ultrasonic techniques can provide very precise measurement
of the elastic properties of minerals as a function of tem-
perature and pressure. The accuracy is limited by possible
systematic errors. Recent developments of technique have
permitted one major source of error to be eliminated, name-
ly the effect of bonding an ultrasonic transducer to the
specimen. A complete thermodynamic equation of state may
be obtained from ultrasonic measurements as a function of
temperature and pressure, and thermal expansion and heat
capacity at zero pressure. This permits detailed evaluation
of theoretical or empirical equations of state. Current
measurements to pressures of 40 kilobars in a hydrostatic
pressure medium will provide detailed tests of high pres-
sure equations of state and permit refinement of the meas-
urement of high pressure.

MODIFIED GLADSTONE AND DALE CALCULATIONS FOR CARBONATES

A.Pabst, Berkeley, California, USA

The rule of Gladstone and Dale or similar rules are generally
used only to calculate mean refractive indices from molar re-
fractivities of components, usually those of the constituent
oxides. Bragg (1924) calculated discrete values for ε and ω
of calcite and for α,β and γ of aragonite from atomic refracti-
vities by taking into account the influence of neighboring di-
poles. Such calculations are complicated and have been little
used.

In connection with work on eitelite, $Na_2Mg(CO_3)_2$, a simple
method was devised for calculating expected values of ε and
ω for double or multiple carbonates. Molar refractivities are
calculated for both the ε and ω rays of the constituent carbon-
ates which are optically negative and either uniaxial or bi-
axial with small optic angle. If these values are then used in
accordance with the rule of Gladstone and Dale, or a comparable
relation, to calculate ε and ω of a complex carbonate it is im-
plicitly assumed that the CO_3 groups in this carbonate are in
parallel alignment with their planes normal to the optic axis
or acute bisectrix as in the constituent carbonates from which
the input data were taken.

The method can be used for predictions in several ways:

(1) If the calculated indices are close to the observed indices
the assumption mentioned is correct.

(2) If the results of calculation and observation do not agree,
especially if the observed birefringence is markedly less than
that calculated, it may be concluded that the assumption is not
applicable and that the CO_3 groups in the material are not in
parallel alignment.

(3) The calculations may be used to predict the as yet unknown
refractive indices of certain carbonates of known structure.

Examples of each of these types of prediction will be given.

OPTICAL PROPERTIES OF MINERALS DERIVED FROM ATOMIC PROPERTIES

Orson L.Anderson, Los Angeles, California, USA

The variation of the ambient index of refraction, n of minerals, with their ambient density, ρ_o, is derived from the equations of motion appropriate to visible optics in a dielectric material. Special consideration is given to the case where oxygen is the main anion.

A number of useful equations relating n and ρ_o are derived where the controlling parameters are identified as mass, spring constant, valence, and anion polarizability. For mineral sequences where the mean atomic weight is nearly constant, the relationships between index of refraction and velocity of sound are derived. It is shown that laws controlling the index of refraction are similar to those controlling the velocity of sound systematics in minerals.

Petrology II
　　　Tuesday, September 17, 1974
　　　　　　Chairmen: E. Niggli
　　　　　　　　　　H.G. Huckenholz

Joint Session IMA-DMG:
Technical Mineralogy and Applied Crystallography
　　　Wednesday, September 18, 1974
　　　　　　Chairman: K.H. Wedepohl

GEOCHRONOLOGY OF A POLYMETAMORPHIC AND ANATECTIC GNEISS
REGION: THE MOLDANUBICUM OF THE AREA LAM - DEGGENDORF,
EASTERN BAVARIA

B.Grauert, R.Hänny, G.Soptrajanova, Zürich, Switzerland

Rb-Sr isotopic analyses of whole-rocks and biotite and U-Th-Pb
analyses of zircon and monazite reveal regional metamorphic
events for the Ordovician (Caledonian metamorphism) and the
Carboniferous (Variscan orogeny), both accompanied by anatexis.
The extent of the Caledonian and Variscan anatexis, however,
cannot be evaluated so far because the field petrographic cri-
teria are not sufficient to distinguish clearly between early
and late Paleozoic anatexites. Evidence for a Precambrian meta-
morphism has not been found. Rb-Sr whole-rock isochrons obtained
on leucosomes and melanosomes of partially molten paragneisses
are interpreted as a minimum age of the second, early Variscan
anatexis. Concordant and nearly concordant zircon ages (318-335
m.y.) of coarse-grained granites and diatexites are regarded as
evidence for an intensive early Variscan granitization and pa-
lin-genesis. Concordant zircon ages of diorite dykes, crosscutt-
ing the anatexites, establish a lower time limit of 309-312 m.y.
for the Variscan anatexis. Rb-Sr ages of biotite (310-290 m.y.)
indicate the end of the Variscan metamorphism.

Estimates of the time of sedimentation or diagenesis based on
Rb-Sr whole-rock analyses for some metasediment series in the
north of the area yield maximum ages of 550 m.y., provided that
Rb and Sr migration did not exceed substantially the extent of
the outcrops (30-500 m) between the time of diagenesis and the
Ordovician metamorphism. Otherwise, an upper limit of 2.0-2.3
b.y., which is the "primary" age of detrital zircons, can be
established.

U-Pb SYSTEMATICS OF ZIRCONS DURING THE ANATEXIS OF A
MOLDANUBIAN PARAGNEISS

D.Gebauer, M.Grünenfelder, Zürich, Switzerland

U-Pb data are reported from zircon suites separated from
the following rocks: 1) a biotite plagioclase gneiss,
2) completely molten derivatives of this gneiss (diatexi-
tes) and 3) a non - molten calcsilicate gneiss boudin with-
in a nebulitic part of the biotite plagioclase gneiss. All
samples were taken within about 30 m of a small quarry in
the moldanubian basement of Eastern Bavaria.

The detrital, heterogenous zircons from the small calcsili-
cate gneiss boudin which contains a waterfree mineral assem-
blage do not show any new crystal growth after their depo-
sition in contrast to the zircons of the biotite plagioclase
gneisses. This fact is explained with the differing water
contents of the two host rocks. Nevertheless the zircons
from the calcsilicate gneiss suffered a great loss of radio-
genic lead during the time of anatexis, about 460 m.y. ago.
The zircons of the biotite plagioclase gneiss, however, have
again been — in addition to the migmatization 460 m.y. ago —
open systems during the following Hercynian metamorphism.

Zircons from the anatectic end-product of the biotite plagio-
clase gneisses (diatexit) still contain a great amount of in-
herited, detrital zircons. However, refaceting, overgrowth
and new growth of zircon is much more abundant in this rock-
type which crystalized from an anatectic melt. The age of
these zircons points to the 460 m.y. event which is further
supported by Rb-Sr data.

ECLOGITES OF THE BOHEMIAN MOLDANUBICUM

Arnost Dudek and Eva Fediukova, Prague, CSSR

Moldanubian eclogites occurring in connection with
peridotites, gneisses and migmatites are distinguished
into three main groups on the basis of the chemical
composition of coexisting garnet-clinopyroxene pairs,
mode of occurrence and petrographical character of the
eclogite bodies. According to Fe and Mg partitioning
between both minerals, conditions of mineral equilibrium
giving rise to individual groups of eclogites are dis-
cussed.

ON EQUILIBRATION CONDITIONS OF THE SUDETIC ECLOGITES, POLAND

Nonna Bakun-Czubarow, Warzawa, Poland

Gneisses of the Eastern part of the Polish Sudetes include common, plagioclase-free eclogites and transitional oligoclase-bearing rocks, represented by two series: carinthine-eclogite and granulite-eclogite.

Equilibration temperature of the common Sudetes eclogites has been determined by means of geothermometers based on partitioning of elements between coexisting minerals, e.i. by means of Fe^{2+}-Mg garnet-clinopyroxene and garnet-amphibole geothermometers, as well as by means of newly calibrated Mn-Mg garnet-clinopyroxene one. The equilibration temperature of the common eclogites ranges from 440 to $620^{o}C$.

Load pressure estimated on the basis of the omphacite composition ranges from 7 to 11.7 kb.

The following trace transition elements: Sc, V, Cr, Mn and Ni, which participate in exchange reactions of great sensitivity to the p/t condition changes, have been used as indices of blastesis conditions of eclogites. The concentration of the above mentioned elements together with REE have been applied in searching for primary material of the eclogites.

The results of investigation of the sudetic transitional eclogitic rocks have been used for a tentative elucidation of the discrepancy among the experimentally obtained eclogitization process boundaries.

OPTICAL AND ELECTRON MICROPROBE INVESTIGATIONS OF CHROMITE AND OTHER OPAQUE MINERALS IN YUGOSLAVIAN OPHIOLITIC ROCKS

Stanko Grafenauer, West Lafayette, USA

In Yugoslavia there are numerous ophiolitic diapiric or intrusive complexes which on well exposed localities display the entire sequence of these rocks from dunites to pillow lavas. Geographically these rock display increasing Mg enrichment along a traverse running from NW to SE. This enrichment is associated with increase of accessory chromite and with chromite and with chromium ore deposits of considerable magnitude. The enrichment leading to formation of Alpine-type deposits took place at depth mostly as a result of static differentiation. The final position and form was effected through kinetic differentiation during the movement of ophiolites caused by continental drift in Mediterranean.

Primary textures and mineral associations in the chromite ore have been studied and will be discussed. Some cumulate features preserved in Alpine type chromite deposits include certain textures found in stratiform complexes in addition to nodular and orbicular textures. Some of the textures indicate partial melting at depth. In addition to transition textures the rocks also display features that provide new evidence of the crystallization mechanisms of chromite and olivine. This study records micrographically myrmekitic and emulsion textures observed for the first time in Yugoslavian rocks. As far as the author can verify this study also reports the first occurrence of sideronitic textures in any chromite deposit. In some rocks enriched on titanium ilmenite and rutile exsolutions were observed in chromite. Awaruite, maucherite and heazlewoodite were identified for the first time from Yugoslavian localities. The chromite grains often display interior areas containing magnetite and "ferritchromit" which is harder and brighter than regular chromite. Chromite often has been replaced hydrothermally by uvarovite, kaemmererite and Cr-diopside. Because of their positions, mineral associations and textures displayed by ores and rocks these Yugoslavian deposits are morphologically and genetically classified as podiform.

THE OPAQUE MINERALS OF SOME PELITIC METAMORPHIC ROCKS OF
SCOTLAND AND THE RELATIONSHIP TO METAMORPHISM AND GEOCHEMISTRY

Peter J.Hill, *Hersham, U.K.*

The opaque minerals described are from the Lower Psammitic
Group and the Pelitic and Upper Psammitic Groups of the
Lower and Upper Dalradian of Scotland. *They include pyrite,*
pyrrhotite, chalcopyrite, pentlandite, magnetite, hematite,
ilmenite and rutile. The rocks come from the chlorite, bio-
tite and garnet zones of Barrovian metamorphism. The most
common assemblages are:

> ilmenite $\pm$ rutile $\pm$ pyrrhotite,
> rutile $\pm$ pyrrhotite,
> pyrite   + chalcopyrite,
> ilmenite + magnetite $\pm$ pyrite,
> ilmeno-hematite + magnetite.

Chalcopyrite is a common accessory mineral in sulphide bear-
ing assemblages and pentlandite is found as exsolution fiammi
in pyrrhotite. The Lower Psammitic Group contains rutile $\pm$
pyrrhotite in chlorite and lower biotite zones and ilmenite $\pm$
rutile $\pm$ pyrrhotite in the upper biotite and garnet zones.
The Pelitic and Upper Psammitic Groups of the chlorite and
biotite zones contain all of the assemblages mentioned. The
magnetite bearing rocks (with ilmenite or ilmeno-hematite)
are albite schists, a rock type which is not found in the
garnet zone. The stratigraphic equivalents in the garnet zone
contain ilmenite + rutile $\pm$ pyrrhotite. The geochemistry re-
flects the variation in opaque mineral assemblages between
the two stratigraphic divisions. The oxidation ratio ($2Fe_2O_3$ x
$100/2Fe_2O_3$ + FeO molar) is used to compare the two divisions.
The Lower Psammitic Group is relatively reduced and homogeneous
whereas the Pelitic and Upper Psammitic Groups are hetero-
geneous. *Also the garnet zone rocks of the Lower Psammitic*
Group are significantly more reduced than the rocks of chlorite
and biotite zones. Several explanations are presented to ac-
count for this observation.

ROCKS AND ROCK FORMATION IN AN EXAMPLE OF FRICTIONAL
FUSION ON A THRUST PLANE IN THE LANGTANG HIMAL, NEPAL

Ludwig Masch and E.Preuss, München, Germany (FRG)

A hyalomylonite in the Langtang Himal, north of Kathmandu,
Nepal, was described by Scott and Drever (1953) as an ex-
ample of fusion on a thrust plane.

The authors of this paper recently revisited this locality,
collected new sample material and obtained more detailed
information on field relations.

The hyalomylonite is developed as a sheet-like body of a
uniform thickness of one to three centimeters on a thrust
plane extending over several hundred meters. Of all the
conjugate fault planes associated with the thrust, only
one was seen to contain hyalomylonite. Diapyre-like pockets
rise up to sixty centimeters above the main hyalomylonite
sheet. These pockets are created by an upward movement of
the melt, and are filled with a hyalomylonite which in some
instances becomes pumice like.

Dikelets of tuff-like appearance, composed of comminuted
brecciated and glassy material sprout out of these pockets.

The cataclastic rocks on the oposing sides of the thrust
plane exhibit different textures. The rocks of the footwall
are coherently cataclastic, showing a phyllonitic texture-
sand mylonitic banding whereas the rocks of the hanging wall
have been strongly fractured and brecciated.

The formation of this rock assemblage and its relation to
pseudotachylites and the pumice like rock in the landslide
area of Köfels in the Ötztal, Austria, is discussed.

SYNTHESIS OF MANGANESE-BEARING KYANITE AND ANDALUSITE, $(Al,Mn^{3+})_2SiO_5$, AND SOME ADDITIONAL RESULTS IN THE SYSTEM $Al_2O_3-SiO_2-MnO-MnO_2$

Irmgard Abs-Wurmbach and K.Langer, Bochum, Germany (FRG)

High pressure experiments on the join Al_2SiO_5-"Mn_2SiO_5" of the system $Al_2O_3-SiO_2-MnO-MnO_2$ were performed in a piston-cylinder-apparatus using an external MnO_2/Mn_2O_3-oxygen buffer. Gem quality andalusite (0.40 wt% Fe_2O_3, 0.01 wt% Mn_2O_3), Mn_2O_3, and high purity SiO_2 served as starting materials in the inner Pd- or Au-capsules. Traces of water were added to promote crystal growth. An excess of 10 % SiO_2 was added to overcome SiO_2-leaching.

At 20 kb/1000°C, kyanite mixed crystals, $(Al_{2-x}Mn^{3+}_x)SiO_5$, were obtained as slightly yellow-orange crystals with a length of up to 70 nm. The colour is the same as that of natural Mn^{3+}-bearing kyanite from Mautia Hill/Tanzania. The range of kyanite solid solubility at 20 kb/1000°C is limited to about 3.5 mole% "Mn_2SiO_5" (x=0.07). Within this range, the lattice constants a, b, c, and V increase with Mn^{3+}-contents by 0.12 %, 0.11 %, 0.22 %, and 0.44 %, resp., if compared with pure Al_2SiO_5-kyanite. The small range of solid solubility in the present system disproves the assumption that higher amounts of $Al^{[6]}$ in the kyanite matrix might be substituted by Mn^{3+} than by other trivalent 3d-ions of comparable size because of the Jahn-Teller-effect (Langer and Frentrup 1973). In Mn^{3+}-rich compositions of the join studied, kyanite$_{ss}$ coexists with braunite, $Mn^{2+}Mn^{3+}_6[O_8|SiO_4]$, pyrolusite, MnO_2, and a SiO_2-rich liquid. The stable coexistence of pyrolusite with the Mn^{2+}-bearing phase braunite at oxygen fugacities of the MnO_2/Mn_2O_3-buffer was confirmed by experiments with a mixture $7Mn_2O_3\cdot 2SiO_2$.

In runs with 25 mole% "Mn_2SiO_5" at 15 kb/900°C, i.e. within the stability field of kyanite in the pure Al_2SiO_5-system (Richardson et al. 1969), andalusite$_{ss}$ was formed as deep green, strongly pleochroitic crystals (viridine) containing up to 19 mole% "Mn_2SiO_5". In long runs (30 and 63 hrs), besides andalusite$_{ss}$ minor amounts of braunite, corundum$_{ss}$ and glass and also traces of kyanite$_{ss}$ were found. These results may indicate, that Mn^{3+}-substitutions stabilize the andalusite structure type appreciably towards higher pressures and temperatures, and may be of importance for estimations of p-T-f$_{O_2}$-conditions in nature.

Joint Session IMA - DMG:
TECHNICAL MINERALOGY AND APPLIED CRYSTALLOGRAPHY

SILICON NITRIDE CERAMIC, A POTENTIAL MATERIAL FOR HIGH TEMPERATURE APPLICATION

E.Gugel, Rödental, Germany (FRG)

The majority of ceramic materials such as earthenware, stoneware, porcelain is still based on natural clay or kaolin. Natural or synthetic oxide-powders are the basis of refractory bricks, electro-ceramic products and the pure oxide ceramics.

The group of oxide-free compounds with boron, silicon, carbon and nitrogen is of interest of high temperatures. Some of these are also resistant in oxidizing atmosphere up to high temperatures, because they form a protective silica-layer. For various reasons silicon nitride is particularly promising. Its structure, the chemical and physical characteristics as well as its production methods and the possible use in gas turbines will be discussed.

CRYSTALLOGRAPHIC ASPECTS OF ELECTRONIC MATERIALS

H.v.Philipsborn, Regensburg, Germany (FRG)

Mineral names such as zinc blende, spinel, perovskite, garnet, scheelite are found these days more often in physical and technical publications than in mineralogical ones. Under discussion are not natural minerals, though, but synthetic single crystals of the same structure type, which display interesting electrical, magnetic, optical, acoustical (in short: electronic) properties.

The use of these crystals relies on crystal chemical knowledge of the relationships between chemical composition and crystal structure on the one hand, and between crystal structure and physical properties on the other hand. Added are successful synthesis of single crystals and insight in the relationships between physical-chemical conditions of crystal growth, the details of crystal structure and defects, and the physical properties mentioned before.

Though a lot of the early research in the field has been done by mineralogists and crystallographers at German universities, the main advances later on were made by chemists, metallurgists, and physicists in American industrial research and development laboratories. Unfortunately there seems to be insufficient communication between these different groups to make full use of the results of one group to the other.

The talk will cover various electronic materials (by crystal structure type), their single crystal synthesis, and physical properties. In all cases reference will be made to corresponding mineral objects, methods, and results. Bridging the gap is of particular importance for the group of silicates, well studied as natural minerals, but hardly tapped as synthetic single crystals for electronic materials.

SIMULATION OF TWO DIMENSIONAL CRYSTAL STRUCTURES, OF DEFECTS AND OF LATTICE VIBRATIONS BY FLOATING MAGNETS

G.Brunner, Zürich, Switzerland

The "behaviour of atoms" is being simulated by means of magnets which float without friction on water or on an air cushion. The structures form themselves, and diffusion, thermal vibrations, ideal structures and defects may be studied.

The magnetisation of the magnets i perpendicular to the plane in which they move. Parallel oriented and similarly magnetised magnets repel each other and form closest packings (resembling Mg and Cu), since the neighbours have largest separations (Acta Cryst. A 27 (1971) 388-390). For structures of two kinds of atoms, by reversing polarity and by mounting each kind at a different height above the plane in which they move, a good approximation to a real force field with an equilibrium position is obtained: at large distances, the difference in height has little influence and the two kinds attract due to the reversed polarity; at short distances they repel due to the neighbourhood of poles of the same sign. Interpenetrations of closest packings with various coordination numbers resemble the structures of $NaCl$ and of ZnS, and also an analogue of $CsCl$ is formed with a transition from the $NaCl$ type to the $CsCl$ type when the "pressure" is increased.

ORTHORHOMBIC NaAlGe$_3$O$_8$: A NEW TETRAHEDRAL FRAMEWORK STRUCTURE

H.Kroll, J.Löns, H.Pentinghaus, Münster, Germany (FRG)

During a systematic investigation of substituted feldspars[1]
a new framework structure has been found, an orthorhombic
modification of NaAlGe$_3$O$_8$, which has $\underline{a}$ = 8.428, $\underline{b}$ = 8.907,
$\underline{c}$ = 4.955 Å, $\alpha = \beta = \gamma = 90°$, and space group $\underline{P}$ $\underline{m2_1n}$. The
distribution of Al and Ge within the framework is random.
Neglecting the slight distortions within the framework, the
topologic symmetry is $\underline{I}$ 4/$\underline{mmm}$, as can be seen in the figure.
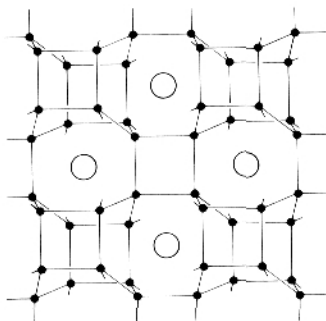
The prominent feature of the
structure is the occurrence
of six-membered tetrahedral
rings, the apices of which
point up, up, down, up, up,
down. By virtue of a mirror
plane normal to the $\underline{a}$ axis
cages are formed which are
bounded by four six-membered
rings. The cages are related
by a pseudo-body centering
vector. This structure type was first predicted by Wells
(1954) as a topologically possible framework structure.

The orthorhombic NaAlGe$_3$O$_8$ compound is stable below 550°C,
1 Kb P$_{H_2O}$. It transforms to the corresponding disordered
feldspar when heated at about 800°C under dry conditions. The
orthorhombic polymorph of CaAl$_2$Si$_2$O$_8$ displays cell parame-
ters and a powder diffrection pattern strikingly similar to
this new compound.

1) BRUNO and PENTINGHAUS: Research on types of Feldspars. -
   Proc. of the NATO Advanced Studies Inst. on Feldspars,
   University of Manchester Press (in press).

ADSORPTIVE PROPERTIES OF CLAY MINERALS COVERED WITH HEAVY METALS

W. Dosch and E. Memapuri, Mainz, Germany (FRG)

Highly effective and selective adsorbers were prepared by cover-
ing external surfaces of montmorillonites with heavy metals. The
specific adsorptive properties of such samples was tested for
poisonous or badly odorous substances such as insecticide phos-
phoric ester, organic sulfur compounds (1) or substances used
militarily (2). Possible uses of the new adsorbers are decon-
tamination of gases and liquids, including water purification
and carriers for pesticides. The adsorption of phosphoric ester
was tested for different adsorbers. Montmorillonites covered
with heavy metals, in particular a hectorite covered with 5 wt.%
Ag, showed the best properties regarding the amount and the
rate of adsorption. The capacity of this adsorber for different
esters amounts to 20 to 40 wt.%. The decay of poisonous residues
with time in presence of an inert liquid was measured by gas
chromatography. In addition adsorption isotherms were determined.
X-ray work and scanning electron microscopy reveal the adsorbed
substances to be fixed mainly on external surfaces of the ab-
sorber. The internal structural swelling of the clay plays only
a minor role. Besides silver, a number of other heavy metals are
effective in montmorillonite as carrier, though in a less pro-
nounced way. The adsorbed substances can be washed out with
pyridine by displacement adsorption. Solvants influence the ad-
sorption independently of their dielectric constant, polarity or
dipole moment. Adsorption proceeds easily in n-hexane, methanol,
chlorine carbon hydrogen, less in acetone, and water, little in
acetonitrile, toluene, furane, dioxane. No adsorption takes
place when pyridine, which is adsorbed preferentially, is present
as a solvant. The optimum of heavy metal coverage is about 4-5
weight %. In experiments with water (25 ml) contaminated with
phosphoric ester (100 mg), 99 % of the poison was adsorbed by
2 g hectorite (with 4 % Ag).

(1) W.Dosch, H.Keller, T.Poles: Studies on the absorption of
    phosphoric esters, sulfur compounds and other poisons,
    unpublished.
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MORPHOLOGY, CHEMISTRY, AND PHASE ANALYSIS OF GAS DUST FROM
REFUSE INCINERATORS

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For pollution control it is of great importance to know the
chemical bulk composition of dusty emissions as well as the
special form in which harmful elements are present. Gas dusts
of a series of home and industrial refuse incinerators were
analysed chemically for the elements Be, Sr, Ba, Cu, Ni, Mn,
Cd, Zn, Pb, Ti, Cr, Cl, F, and P.

Transmission- and scanning electron microscopy were used to
determine the morphology of dusts in view of their effects
on the lung. Phase analysis of the special "form" of the ele-
ments present was done by small-area diffraction on the
transmission electron microscope combined with energy-disper-
sive chemical analysis.

Chemical analysis of the dusts has shown that the concentra-
tions of harmful materials are below the officially tolerated
limits. Phase analysis indicates that the major part of harmful
elements is bound in such a way (as compounds slow to dissolve
or insoluble under atmospheric conditions) that harmful effects
on the invironment are not to be expected.

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(underlined page = speaker)