SELECTED AUTHORS' ABSTRACTS

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THALENITE IN THE WHITE CLOUD PEGMATITE, SOUTH PLATTE DISTRICT, JEFFERSON COUNTY, COLORADO

John W. Adams & William N. Sharp, *U.S. Geological Survey, Denver, Colorado*

Thalenite, together with allanite and fluorite, occurs in veinlets interstitial to insular yttrofluorite masses at the White Cloud pegmatite. The thalenite is believed to have formed by metasomatic replacement of yttrofluorite during a late episode in the development of the pegmatite. Thalenite has been reported from only two other localities in the United States.

THE CRYSTAL STRUCTURE OF THE GOLD TELLURIDE, MONTBRAYITE

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Montbrayite from Robb-Montbray mine, Quebec, has the formula : $(Au_{1.880}, Ag_{0.023}, Sb_{0.085}, Pb_{0.036})_{2.024}(Te_{2.830}, Bi_{0.170})_{3.000}$ as determined by electron microprobe. An *x*-ray investigation of the analyzed material was undertaken by the precession method using Zr-filtered Mo radiation. About 2000 reflections were collected with $\sin \theta/\lambda < 0.80$. The mineral is triclinic with space group *P*1. Its crystallographic data are : $a = 12.106$Å ; $b = 13.442$Å ; $c = 10.796$Å ; $\alpha = 104°23'$; $\beta = 97°30'$; $\gamma = 107°56'$; $V = 1577.39$Å ; $Z = 12$ $d_{obs} = 9.94$ g/cc ; $d_{calc} = 9.89$.

The structure was determined by trial and error. The diffraction effects suggested that the mineral could have a similar structure to a closely related group of gold-silver tellurides, calaverite, krennerite and sylvanite. This kind of structure, may give rise to a cubic reciprocal superlattice, which could be found in the diffraction pattern of montbrayite. Hence the basic structure of the mineral could be postulated. Assuming a center of symmetry and an average form factor for Au and Te, the structure refined from *R* values of 70%-65% to 30% by least squares methods. Without the symmetry restriction and after refinement of site occupancy, the *R* values improved to a limit of 23%. The structure consists of rows of atoms in the sequence : Au-Te-Au-Te-Te-Au having bond lengths : 3.03, 3.03, 2.80, 3.10, 2.80 Å respectively.

MOSSBAUER SPECTRA OF LUNAR MATERIALS

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Mossbauer spectra have been used to identify the iron-bearing minerals ilmenite, pyroxene, olivine, iron, and troilite, in fines and crushed rocks of types A, B and C. In

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describing the assignment of the peaks, particular attention is given to the search for magnetite, for this mineral has been unsuccessfully sought by other workers and other techniques. Computer-fitted areas are used to semi-quantitatively estimate the relative proportions of these minerals in the various samples. One distinct trend shows that the iron metal content increases on breakdown of the crystalline rocks.

The ferrous site populations in light and heavy fractions of pyroxenes from a type B rock have been determined. The potential importance of these site populations in interpreting the thermal history of these rocks is discussed.

EUDIALYTE FROM THE KIPAWA LAKE AREA, QUEBEC

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Eudialyte occurs as spectacular pink coloured aggregates in syenitic rocks of Grenville age near Kipawa Lake, Temiscamingue Co., Quebec. The host rocks are rich in aegirine augite and an amphibole probably of the eckermanite-arfvedsonite variety. Eudialyte constitutes up to 10% of the rock and thorite up to 5%. Many other unusual minerals are also present.

Chemical analysis indicates the Kipawa eudialyte is low in Fe_2O_3 and MnO in comparison to other eudialytes. Other oxides are within the ranges given for eudialytes from Kola and elsewhere.

Cell parameters determined by *x*-ray powder methods show the Kipawa sample has $a_0 = 13.95 \pm 0.02$Å, $c_0 = 30.10 \pm 0.02$Å based on a hexagonal cell.

The Kipawa Lake eudialyte is similar in composition and associated peralkaline environment to that of Kola, U.S.S.R., Ilimaussaq, Greenland and elsewhere.

THE QUANTITATIVE DETERMINATION OF SOME CARBONATE MINERALS IN META-VOLCANIC ROCKS OF THE GREENSCHIST FACIES BY X-RAY POWDER DIFFRACTION

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The identification of carbonate minerals in low grade metamorphosed volcanic rocks by optical means poses time consuming difficulties. Using *x*-ray powder methods for quantitative determination of minerals of a crystalline mixture, internal standard graphs were plotted for calcite, dolomite, ferroan dolomite (ankerite) and magnesite in a mixture of minerals common to meta-volcanic rocks in the greenschist facies. Two separate internal standard materials were used, NaCl and powdered metallic Mo. The internal standard graphs for each of these materials are straight lines relating the ratios of peak heights of reference diffractions for selected carbonate minerals and the peak heights of the internal standard reference diffractions to concentration of carbonate minerals in the greenschist facies mineral mixtures. Reproducibility and accuracy are comparable to those obtained by optical methods.

MINERALOGY AND PARAGENESIS OF AMBLYGONITE-MONTEBRASITES FROM THE TANCO (CHEMALLOY) PEGMATITE, BERNIC LAKE, MANITOBA

Ivanka Černá, P. Černý & R.B. Ferguson, *Department of Earth Sciences, University of Manitoba, Winnipeg*

In the Tanco pegmatite, amblygonite-montebrasite has been found in three successively younger zones: (1) as rare grains in the medium-grained albitic wall zone where it occurs in coarser-grained nests of K-feldspar, quartz, beryl, and mica; (2) in subordinate amounts in the coarse-grained K-feldspar — spodumene + quartz — albite — amblygonite zone, as large crystals and irregular masses; (3) as the main concentration in the coarse-grained quartz — spodumene + quartz - amblygonite — (± K-feldspar and pollucite) zone, where it forms crystals and aggregates up to 3 metres in diameter, embedded in quartz.

The F contents of 140 specimens have been determined by an x-ray powder diffraction method developed from the data of Moss *et al.* (1969), and they are shown to vary from about 1.4 to about 7.1 wt. %. These results indicate that the F contents of the amblygonite-montebrasites differ in different zones of the pegmatite, and within individual crystals in a single zone; the latter variation results from either primary zoning or secondary alteration. The following colours and compositions (in approx. wt.%) characterize the primary amblygonite-montebrasites in the three above-mentioned parent assemblages: (1) white with about 4% F; (2) pink cores with 5.6-6.8% F overgrown by white with 5.0-6.6% F and rimmed by yellow with 4.0-5.6% F; (3) mostly white with F content of 5.4-7.1%, but in the upper part of the zone (near the pollucite body) the white material carrying only 5.0-6.4% F is rimmed by yellow containing 4.5-5.1% F. Secondary montebrasite in all zones occurs as brownish or gray veinlets in primary amblygonite-montebrasite containing from 1.4-4.8% F, usually 2-3.5%; this montebrasite is in some cases accompanied by micas and fluorapatite.

In the course of crystallization of the pegmatite, amblygonite-montebrasites of the early wall zone seem to be F-poor (4%); the F content increases to 4.0-6.8 in zone (2), and to 5.4-7.1% in zone (3), but decreases within the upper quartz-rich parts of this zone to 4.5-6.4%. Within each individual zone, zoned crystals show a decrease in F during their growth. Secondary montebrasite contains much less F than its parent phase, and mostly less than any primary phase within its parent zone.

PETROLOGY OF GRAPHIC INTERGROWTHS OF FELDSPARS AND QUARTZ IN PEGMATITES

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Three examples of different genetic types of graphic pegmatite zones are demonstrated. The necessity of detailed textural examination and careful sampling and of obtaining extensive information about the composition of the graphic intergrowths, their feldspar hosts, and feldspars in other pegmatite zones is stressed.

In a series of Czechoslovak pegmatites, intimately mixed intergrowths of Kf + qtz and plg + qtz compose a zone intermediate between fine-grained margins and central blocky zones and cores. The normative Or-Plg-Q of the graphic intergrowths and Or-Ab-An of their feldspars show very restricted variation within a single pegmatite. From the margins to the innermost graphic pegmatites, the compositional changes in the coexisting feldspar pairs follow the course of the feldspar solidus-solvus intersection as known in the Or-Ab-An-Q-H_2O system; the blocky feldspars deviate from these paths. The graphic intergrowths are thus interpreted as last products of fractional magmatic crystallization; the positively correlated Ab and qtz contents in potassic intergrowths seem to be indicative of the relative pressure during their crystallization. Preliminary results obtained recently on the Greer Lake, S. E. Manitoba pegmatites suggest the same character of their graphic zones.

Very coarse Kf + qtz intergrowths with low qtz content are imbedded in a fine-grained albitic aplite, and frequetly accumulated along the hanging-wall contact, in many pegmatites of South Dakota, California, and New Mexico (Orville 1960, Jahns & Tuttle 1963). The latter authors concluded from compositional, textural, and experimental evidence that the Kf + qtz intergrowths originated by selective leaching of potassium from a cooling, volatile-saturated pegmatite magma into a coexisting supercritical gas.

A group of pegmatites from Karelia, U.S.S.R. (Shurkin *et al.* 1962) contains separated outer plg + qtz and inner Kf +qtz zones, intermediate between granular borders and blocky cores. The Kf and plg contents of these pegmatites, and the qtz content of their graphic zones, vary widely. From the margins to the centre of the pegmatite bodies, An and Or in plg and An, Ab in Kf decrease. This suggests a subsolidus crystallization of the whole pegmatite bodies from supercritical fluids.

PETALITE AND SPODUMENE RELATIONS IN THE TANCO (CHEMALLOY) PEGMATITE, BERNIC LAKE, MANITOBA

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Gray-to-white crystals of petalite up to 2 metres in length occur in the quartz — petalite — amblygonite (± pollucite) zone adjacent to the pollucite body in the upper parts of the pegmatite. Petalite is ferquently penetrated by fine-grained vermicular intergrowths of spodumene and quartz, which pass in some cases into coarser aggregates of parallel spodumene fibers embedded in quartz. Euhedral tabular masses of these fibrous spodumene + quartz intergrowths also occur abundantly in the K-feldspar — spodumene + quartz — albite — quartz — amblygonite zone.

Chemical analyses, densities, and quantitative *x-ray* powder diffractometer determinations show that the bulk composition of the spodumene + quartz intergrowths is close to that of petalite. The spodumene/quartz ratio agrees within ± 12% with the required value of 64.5 : 35.5 (wt.%). This compositional and textural evidence shows that the spodumene + quartz intergrowths originated by the breakdown of petalite. Stewart's (1963) study suggests that low pressure and relatively high temperature favour petalite crystallization, and that temperature decrease could be the major cause of its breakdown to spodumene + quartz. The coarseness of the aggregates, the considerable volume decrease during the reaction, and consequent local migration of silica explain the deviations of the compositions of the spodumene + quartz aggregates from the theoretical petalite composition.

The only primary spodumene in the pegmatite seems to be that occurring in the K-feldspar — quartz — albite — beryl (— wodginite — muscovite) zone, intergrown with quartz in the interstices of feldspars. Its iron and sodium contents are slightly higher than those of spodumene after petalite.

Infrequent albitization was the earliest alteration of petalite, in some places accompanied by spodumene and/or quartz. This was followed by the breakdown to spodumene + quartz. After this reaction, the relics of petalite were commonly penetrated by calcite and cookeite, and sometimes by adularia-type potassium feldspar. Secondary spodumene is frequently veined by albite + quartz. Later alteration of both primary and secondary spodumene produced cookeite, Cs-beryl, Cs-analcime, calcite, quartz, adularia, apatite, and montmorillonite-illite.

ELECTRICAL PROPERTIES OF APOLLO 11 AND 12 ROCK SAMPLES

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Two samples (breccia and fines) from Appolo 11 and three samples (crystalline rocks and fines) from Apollo 12 were measured for dielectric conductivity, relative permittivity and loss tangent in the frequency range of 10^3 to 10^7 Hz. Contact electrode method of the capacitance type was used on the samples maintained in a dry nitrogen atmosphere at room temperature. Due to the absence of moisture, the samples behave as dielectric material. The investigations revealed the following general characteristics: (1) The dielectric conductivity increases from below 10^{-7} mhos/m for all samples at 10^3 Hz to almost 10^{-4} mhos/m for the rocks and to 10^{-5} mhos/m for the fines at 10^7 Hz, (2) the relative permittivity is 7.3 ± 5% and 8.1 ± 5% for Apollo 11 breccia and Apollo 12 crystalline rocks respectively at the higher frequencies, with an increase of 10 to 20% for the lower frequencies aid is 3.8 for Apollo 11 fines and approximately 3.0 for the Apollo 12 fines, (3) the loss tangent ranges from 0.14 to 0.02 for the breccia and from 0.05 to 0.01 for the crystalline rocks decreasing most rapdily above 10^6 Hz and from 0.13 to 0.005 for the fines decreasing gradually over the frequency range.

THE IDENTITY OF "GREEN ENARGITE"

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"Green enargite" from Tsumeb, S.W. Africa was identified as tennantite by Moritz[1], mainly on the basis of its colour as a powder. A new occurrence of "green enargite" from Murgtal, St. Gallen, Switzerland proved to be anisotropic (Bayer, Bächtiger & Corlett[2]), throwing doubt on the identity of this mineral. Moreover, the high Hg-content of this occurrence of "green enargite" — higher, for instance, than any tetrahedrite-tennantite studied by Springer[3] — has made a detailed chemical investigation of this and other occurrences necessary. "Green enargite" from Butte, Montana; El salvador, Chile; and La Guanaca, Chile also is anisotropic. Electron probe microanalyses from all these localities, however, confirm the tennantite chemical composition for this phase: $(Cu,Fe,Hg)_{12}(As,Sb)_4S_{13}$. It is suggested that a slight displacement of atomic positions, particularly those occupied by the Cu-group, may result in a lowering of the symmetry to a non-isometric system.

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[1] Moritz, *Jb. Min., Beil.-Bd.,* **61,** 118, (1933).

[2] Bayer, Bächtiger and Corlett, *Schw. Min. Petr. Mitt.,* **48,** 832, (1968).

[3] Springer, *N. Jb. Min. Mh.* 24, (1969).

DEFORMATION IN APOLLO SAMPLES

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Samples returned from the Apollo 11 and 12 missions have been examined to determine the nature and extent of deformation in crystalline rocks, breccias and fines. Strain features observed are classified as:

1. Strain of crystallization, common in strongly zoned clinopyroxenes in the ilmenite bearing rocks considered to be indigenous to the lunar mare sites.
2. Shock deformation, ranging from weak fracturing seen in most rocks, to planar features and isotropic states in silicates, seen in a small proportion of the rock and mineral fragments in the breccias and fines. Glasses observed in the same material are notable for their variation in shape, composition and internal textures, and are considered to be the product of melting at extreme shock pressures from meteorite impact.
3. Crushing and kinking, suggesting slow strain rate deformation, seen in a small number of fragments which lack ilmenite and which are probably derived from the lunar highlands.

The main events in lunar history indicated by these studies are early differentiation of a feldspar-rich crust, subsequent anorogenic volcanism filling the mare basins with low viscosity basaltic flows, and a later history dominated by meteorite bombardment.

REFINEMENT OF THE CRYSTAL STRUCTURE OF CUBANITE

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The crystal structure of cubanite has been refined using crystal *x*-ray intensity data from material from the Strathcona Mine, Sudbury District, Ontario. A value of the conventional residual index of 0.11 for refinement of positional scale and isotropic thermal parameters was obtained. The structural peculiarity of cubanite, in which the Fe atoms are opposed across shared tetrahedral co-ordination edges, suggests some degree of σ bond formation between the metal *e* orbitals, although consideration of the distortion observed in the structure is not entirely in accord with this model. Some observations are made on the origin of the weak ferromagnetism in the light of the new data and modern magnetic theory. Experiments on the stability of cubanite show that at low pressure it inverts to the cubic form at less than 220° C. A structural investigation of the cubic modification, based on *x*-ray powder intensity data demonstrates that it has the sphalerite structure.

THE GRAPHICAL REPRESENTATION OF SULPHIDE-SILICATE PHASE EQUILIBRIA

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The oxidation and sulphidation of a particular (Fe, Mg) silicate mineral is most completely represented by composition contours on a log f_{O_2} — log f_{S_2} diagram. A part of these phase relations may be expressed in the form of ternary phase diagrams subject to certain stipulated restrictions, *e.g.* a constant f_{O_2} or the presence of magnetite. It is possible to combine phase diagrams of several (Fe, Mg) silicates in order to display phase relations between the minerals and the iron sulphides in a tetrahedron representing a four-component system. And since sulphur is not a constituent of the silicate minerals, phase relations may be adequately shown on one side of the tetrahedron thus achieving a planar representation.

SOME OBSERVATIONS ON WELOGANITE

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Weloganite was described first in 1968 by Sabina, Jambor & Plant. Their study indicated that weloganite is trigonal (space group $P3_1$ or $P3_2$). Our study, on material collected in July, 1969, revealed the existence of a monoclinic polytype (space group *C2/c* or *Cc*) ; the *x*-ray powder patterns of the two polytypes are indistinguishable from each other, Sabina *et al.* (1968) describe zoned crystals across which no chemical difference could be detected. An electron probe traverse, courtesy of Dr. D.C. Harris, across a crystal containing zones of both polytypes, showed no chemical differences. Dr. Harris, however, did detect a significant amount of Na in our crystal. In selecting material for a new chemical analysis, no attempt was made to separate trigonal from monoclinic material. The results of that analysis are: SrO 34.5, CaO 1.49, Na_2O 8.23, K_2O 0.04, ZrO_2 13.78, CO_2 30.5 and H_2O 9.66 wt.%. The ideal proportions derived from this analysis are: $(Sr_{1.36},Na_{1.08},Zr_{0.45},Ca_{0.11})_{3.00}(CO_3)_{3.00} \cdot 2H_2O$. This formula requires that $Z = 6$ for the trigonal cell.

The following are the measured cell parameters of monoclinic weloganite: $a = 8.95$, $b = 15.54$, $c = 37.09$, Å, $\beta = 103°45'$. *D* meas. = 3.20. *D* calc. = 3.22 for $Z = 24$. That the monoclinic (*M*) and trigonal (*T*) polytypes are intimately related is evidenced from the following: $a_M = a_T$, $b_M = 2a_T \sin 60°$, $c_M = 2c_T$ cosec $(180-\beta)$. Upper level precession photographs of the a^*c^*-planes of both polytypes show pronounced "streaking" of the reflections in the c^*-direction. This can be interpreted as stacking disorder in the *c*-axis direction and it suggests that other polytypes may be possible.

Because the trigonal and monoclinic weloganite both have the same chemical compositions, and because their cell dimensions are closely related, they are considered as polytypes.

Weloganite exhibits strong triboluminescence, giving bluish-white flashes when crushed.

CHEMICAL VARIATION AMONG THE NON-CARBONATE MINERALS OF THE CARGILL LAKE CARBONATITE, ONTARIO

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The amphiboles and phlogopites in a suite of carbonatite rocks from Cargill Lake have been analysed by electron microprobe.

The amphiboles, which belong to the richterite series, show chemical variations both within single grains and between different samples. Within a single grain the zoning is manifest by Ca, Mg, and K increasing to the centre of the grain and by Fe and Na increasing towards the edge. The zoning can be both sharp and gradual.

The phlogopite also has variable composition with Fe increasing from the centre to the edge coupled with a corresponding decrease of Mg and Al. All the phlogopites possess reverse pleochroism as is commonly found in this type of association. The explanation given for this phenomenon, Fe^{+3} substituting for Al in tetrahedral sites, is confirmed by the probe analyses.

Minerals of the humite group occur sporadically in the body, but no systematic chemical variation has been detected. Fluorapatites, which are abundant, exhibit no special chemical features.

CORRELATION IN EARLY PRECAMBRIAN BASINS OF THE CANADIAN SHIELD

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Rb-Sr isochrons of suites of metasedimentary extrusive and intrusive igneous rocks from the Rice Lake, Rainy Lake, and Saganaga-Northern Light Lakes areas, together with published data from these and other Archean basins of the Canadian Shield, give an age pattern in the range from 2,750 to 2,550 m.y. ago. The 2,700 m.y. isochrons include suites of metasedimentary, extrusive and intrusive rocks and indicate a major orogenic event. The 2,550 m.y. isochrons reflect low-grade metamorphism and, locally, igneous activity.

A number of isochrons fall in the range from 2,650 and 2,600 m.y. ago, but the analytical precision is generally inadequate to resolve between these ages and older or younger events, except in individual basins where use can be made of geological information. Although precise isochrons are relatively few in number, the data now available warrant the conclusion that the Archean basins were developed at approximately the same time, and this must be considered in any hypothesis of crustal development of the Canadian Shield.

MINERALOGY AND PARAGENESIS OF WODGINITE, TANTALITE, AND PSEUDO-IXIOLITE FROM THE TANCO (CHEMALLOY) PEGMATITE, BERNIC LAKE, MANITOBA

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Wodginite $(Ta,Nb,Mn,Fe,Sn,Ti)_2O_4$, manganotantalite $(Mn,Fe)\ (Ta,Nb,Ti,Sn)_2O_6$ and pseudo-ixiolite $(Ta,Nb,Mn,Fe,Sn,Ti)_2O_4$ are the three major Ta-oxides occurring at Bernic Lake, wodginite being by far the most abundant. Microlite $(Na,Ca)_2Ta_2O_6(O,OH,F)$ and tapiolite $(Fe,Mn)\ (Ta,Nb)_2O_6$ occur in minor amounts. In general all of these Ta-minerals are primary with no mutual inter-reactions.

Wodginite occurs mainly in the K-feldspar-muscovite-quartz-beryl zone immediately below the quartz core. Pseudo-ixiolite occurs in the quartz-plagioclase-K-feldspar-spodumene-muscovite zone just outside the wodginite-bearing zone. Wodginite and tantalite are concentrated in the bluish albitic aplite which occurs mainly towards the base of the pegmatite and in small patches in other parts of the pegmatite.

The wodginites are not homogenous, with the contents of Ta_2O_5 showing variations of ± 5% within one crystal. In general they have lower Mn and higher Fe,Sn, and Ti contents, and higher Ta/Nb ratios than either tantalite or pseudo-ixiolite. The chemical distinctions between tantalites and pseudo-ixiolites are less marked. Both have low Fe and high Mn, and five out of six tantalites have lower Sn and Ti contents and higher Ta/Nb ratios than the pseudo-ixiolites.

The occurrence in separate zones within the pegmatite of the wodginite and pseudo-ixiolite might be attributed to wodginite having crystallized later at a higher f_{O_2} than the pseudo-ixiolite. The bluish albitic aplite appears to have a Ta mineralogy that is distinctive from the other zones. It contains both tantalite and wodginite, indicating an f_{O_2} compatible with the crystallization of either of these minerals. The slightly higher Ta/Nb ratios of tantalites over pseudo-ixiolites is consistent with the ideas of Fersman (1940) and Kornetova (1961), whereby the first tantalites to crystallize in Ta-rich pegmatites have higher Ta/Nb ratios. This is assuming that the bluish albitic aplite is a primary zone, formed early in the sequence of pegmatite crystallization as suggested by Jahns & Burnham (1969).

MINERALOGY OF THE EVANS-LOU PEGMATITE, PORTLAND-WEST TOWNSHIP, QUEBEC

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The Evans-Lou pegmatite intrudes Precambrian calc-silicate rocks and quartz diorite. This pegmatite exhibits a normal but asymmetric sequence of zones. About 60 minerals are found, 9 of which are unidentified. There is a complex assemblage of Y, Nb, Bi, V, Th, U compounds. Most of the rare-element minerals are from the quartz core close to its contact with the giant perthite zone. In the primary minerals, yttrium occurs in garnet, fergusonite, allanite, uranothorite, sphene, apatite and hellandite. Secondary yttrium minerals are silicates and carbonates and, more rarely, phosphates and vanadates. Bismuth occurs as native bismuth, now largely altered to bismutite, No primary vanadium mineral has been recognized and a concentration of vanadium of 100 to 1 is necessary to form wakefieldite (YVO_4) from hellandite. A period of brecciation and recementation by quartz separates the primary mineralization from the formation of a host of secondary products.

CRYSTALLIZATION HISTORY OF THE DUFFS GRANOPHYRE, HOLYROOD COMPLEX, NEWFOUNDLAND

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

VEIN AND AMYGDULE MINERALS OF THE METCHOSIN BASALT, SOUTHERN VANCOUVER ISLAND

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Veins and amygdules in the Metchosin Basalt east of the Sooke River contain epidote, pumpellyite, prehnite, laumontite, chabazite, stilbite, analcite, quartz and calcite. Plagioclase, chlorite and amphibole were also identified and are probably vein-amygdule phases. Doubling of lines in an *x*-ray diffraction pattern similar to that of analcite probably represents non-cubic analcite although wairakite is possible.

The minerals listed probably were not simultaneously in equilibrium. Aspects, however, resemble zeolite or zeolite-greenschist transitional grades of metamorphism. Assuming reasonably normal geothermal gradients, burial of the area under one to several kilometers of overlaying Metchosin Basalt or post-Metchosin sediments is suggested.

No regional zoning of vein and amygdule minerals could be recognized in this reconnaissance study.

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THE CHEMICAL COMPOSITION OF SOME APOLLO LUNAR SAMPLES

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Major, minor and trace element determinations have been made on rocks and fine surficial material from the Apollo 11 and 12 missions by a combination of chemical, atomic absorption and optical emission spectroscopic procedures. Signicant differences are observed between the chemical composition of lunar material and terrestrial rocks of a similar nature, particularly in the high Ti content of the Apollo 11 samples, and in the general absence of Fe(III) and of volatile constituents such as water, carbon dioxide and fluorine. Compositional differences are also found between samples from the two landing sites.

EFFECT OF PREIRRADIATION ANNEALING ON THE THERMOLUMINESCENCE OF QUARTZ

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The application of the thermoluminescence of natural and artificial quartz to investigations of geological, mineralogical, archeological, solid state, and radiation dosimetry problems is complicated by several factors. These include : polymorphic transitions ; trace amounts of elements (such as Al, Ti, Fe) ; the valency state of some trace elements ; and the presence of other types of lattice imperfections. Many of these complicating factors can be related on the one hand to the pressure-temperature conditions during and following formation of the crystal, and, on the other, to the natural or artificial radiation history.

Samples of quartz which had been systematically annealed at several temperatures below and above the low quartz-high quartz transition point, and then excited with increasing *x*-ray doses, generally showed a maximum thermoluminescence at 400°C (denoting a maximum radiation sensibility at this annealing temperature), followed by an abrupt decrease in sensitivity after being heated above the α-β transition temperature. Preliminary results suggest that the radiation sensitivity of quartz, as measured by thermoluminescence, can possibly be used as a geothermometer.

ROMARCHITE AND HYDROROMARCHITE, TWO NEW STANNOUS MINERALS

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Tin pannikins lost from the overturned canoe of a voyageur between 1801 and 1821, were recovered 15 feet below the surface of the water at Boundary Falls, Winnipeg River, Ontario. Some of the surfaces of the pannikins have a thin crust of alteration products consisting of white crystals and black crystals.

The black crystals give *x*-ray powder diffraction data practically identical to those given for SnO by Swanson *et al.* (1955). Strongest spacings (in Å for $CuK\alpha$) are: 2.98(10), 1.601(9), 1.799(7), 2.679(6) and 1.491(6 broad). Space group is *P4/nmm* with $a = 3.79$Å and $c = 4.83$Å. X-ray spectrographic scans detected only tin and a trace of iron. The mineral is named romarchite (*R*oyal *O*ntario *M*useum *Arch*aeology).

The white crystals have an *x*-ray powder pattern which matches that of stannous oxide hydrate ($5SnO.2H_2O$). The strongest spacings (in Å for $CuK\alpha$) are: 3.50(10), 2.773(9), 2.961(8), 1.924(7), and 1.906(7). Donaldson (1961) found that synthetic $5SnO.2H_2O$ was triclinic with $a = 11.5$, $b = 6.03$, $c = 19.8$ (all in Å),$\alpha = 99°$, $\beta = 60°30'$, $\gamma = 88°30'$. X-ray spectrographic scans detected only tin. The mineral is name hydroromarchite in allusion to its relationship to romarchite.

The minerals and names have been approved by the Commission on New Minerals and Mineral Names, I.M.A.

PETROLOGY OF THE AXELGOLD LAYERED ANORTHOSITE

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The Axelgold intrusion was formed from a single pulse of gabbroic anorthosite magma which was emplaced into steeply dipping rocks of the Cache Creek formation in central British Columbia. The body is oval-shaped, 7 mi. by 3 mi., with its long axis parallel to the regional northwest trend. Its age has been suggested as Jurassic, but it could be much younger.

The body consists of a layered series ranging in composition from anorthosite to anorthositic gabbro and ferrodiorite, capped by a massive quartz diorite to granodiorite. The layered series is divided into seven zones on the basis of cumulus mineralogy, texture, and structure. Plagioclase and olivine are cumulus minerals in all zones, clinopyroxene is cumulus in some zones, and orthopyroxene is cumulus in ferrodiorite. Ilmenite and sulfides occur in all zones, but are much more abundant in some than in others. Sulfides are pyrrhotite, minor chalcopyrite, and rare pentlandite; they form scattered rounded blebs which probably once were immiscible sulfide droplets in a silicate magma. Accumulations of sulfides, ilmenite, and/or mafic silicates up to a few feet thick occur in parts of the intrusion.

Chemical fractionation consists of strong enrichment of Fe, Mn, and Ti in the upper ferrodiorite at the expense of Al and Si; and strong enrichment of K and Si in the cap rock at the expense of Ca and Mg.

Except for its much smaller size, the Axelgold intrusion is grossly similar to the Kiglapait intrusion of Labrador.

MINERALOGY AND PETROLOGY OF SOME LUNAR SAMPLES

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The major minerals of the Apollo 11 and 12 rocks can be assigned to common terrestrial rock-forming mineral groups, but show compositional variations and textural relationships which lie outside previous petrographic experience. The compositional variation in clinopyroxene and the presence of the new mineral, pyroxferroite, are illustrations of the unusual mineral assemblages that can crystallize under extremely low partial pressures of oxygen and water. The crystalline rocks and fragments of similar composition in the breccias are interpreted as products of dry, highly reduced melts generated by internal magmatic processes rather than by impact. Low oxygen fugacity and low rates of diffusion in the melts led to unusual iron enrichment with the production and the preservation of metastable phases and a final residuum of granitic composition.

ABSORPTION AND RETENTIVITY OF ABSORBED AND RADIOGENIC ARGON IN HEATED MICAS

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Chemically analyzed phlogopite, biotite, muscovite, lepidolite and fine-grained micaceous alteration products were heated in air, in argon and at reduced pressure to temperatures selected from their DTA and TGA data. Argon isotopes, H_2O, F, FeO and Fe_2O_3 were determined after heating and losses of argon were correlated with degree of oxidation and dehydration of the micas. Results indicate that loss of radiogenic argon and absorption of atmospheric argon vary with chemical composition, grain-size and morphology of the mica. By comparing results obtained on specimens of similar grain size it is shown that the retentivity of radiogenic argon in heated micas decreases in the order phlogopite — biotite — muscovite in direct proportion to their thermal stabilities. With increasing time heated muscovite loses proportionately more argon and water and becomes heterogenous, consisting of unaltered patches enclosed in a dehydrated host. When heated in Ar at 1 atm. pressure, all micas adsorb argon. Coarse-grained muscovite adsorbs less argon than biotite of similar grain size, whereas a fine-grained muscovite-like alteration product adsorbs three times as much atmospheric argon as the coarse-grained muscovite. After reheating in air, phlogopite loses about 10 per cent and biotite about 50 per cent of the adsorbed argon. Partly dehydrated and oxidized micas are stable up to 1200°C. Differential loss and adsorption of argon in coexisting micas, and the capacity of fine-grained micaceous alteration products to adsorb large quantities of argon may account for some discrepancies in K-Ar ages.

CRYSTALLOGRAPHY AND CHEMISTRY OF Li-Rb-Cs-BEARING MICAS FROM THE TANCO (CHEMALLOY) PEGMATITE, BERNIC LAKE, MANITOBA

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Twelve Li-Rb-Cs-rich micas from the TANCO pegmatite, Bernic Lake, Manitoba and two from other localities, have been examined in detail by *x*-ray diffraction, optical and chemical methods. The *x*-ray study revealed the presence in three of the specimens of the structure type $1M$ together with the $2M_1$, one is entirely $1M$, and all the others are $2M_1$ only. X-ray powder reflections that distinguish the two structure types are described. The following correlation between structure type and chemical composition was observed: micas with the $2M_1$ structure were found to contain up to 3.42 wt.% Li_2O; from 3.50% to 4.28% Li_2O both structure types appear with progressively greater amount of $1M$; and above about 4.5% Li_2O $1M$ alone is likely to occur. The contents of Rb_2O (up to 5.1 wt.%) and Cs_2O (up to 0.8 wt.%) increase roughly with an increase in Li_2O, but they do not seem to affect the change in structure because two of the specimens with highest Rb + Cs have the $2M_1$ structure, and the $1M$ type was found in micas containing lower Rb + Cs but higher Li percentages. Li, Rb and Cs have a little influence on the unit cell dimensions, generally increasing the *a* and *b* dimensions and cell volume, and decreasing β with increasing amounts. The variation of the two refractive indices in the plane of the cleavage, derived by the immersion method in monochromatic (Na) light, showed them to decrease with increasing Li_2O. The $2M_1$ micas display the highest indices ($\gamma = 1.599$-1.573), the $1M$ types show the lowest values ($\gamma' = 1.566$-1.561). All the x-ray chemical and optical data indicate that the $2M_1$ micas from the TANCO pegmatite belong to muscovite and lithian muscovite, and that the $1M$ structure type is characteristic of lepidolite at this locality.

LATE TECTONIC MINERALIZED STRUCTURES IN SOUTHWESTERN NEW BRUNSWICK

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Mineral deposits of economic interest occur in rocks ranging in age from late Precambrian to Carboniferous in southwestern New Brunswick. The area has undergone intense polyphase deformation and emplacement of a large batholith, composed mainly of granite and related plutonic rocks, during Middle Devonian. Most of the early tectonic mineral deposits occupy dilatent structures along the contacts of these intrusive rocks.

Block faulting characterized the next period of major tectonic activity, which occurred during the Carboniferous. Volcanism was locally active and numerous small intrusions were emplaced along major fault zones during this period. Recent K/Ar analyses at Carleton University on samples from four of these intrusions indicate that they were emplaced between 320 ± 18 and 338 ± 18 m.y. ago. Although Carboniferous rocks are generally weakly deformed, rocks mapped as Mississippian, along the Bay of Fundy, 20 miles east of St. John, contain stretched pebbles and a penetrative schistosity, indicating intense strain.

All of the late tectonic mineral deposits are associated with prominent Carboniferous fault zones. The largest known deposit occurs at Mount Pleasant, in a narrow northwest trending fault block, where copper, zinc, lead, tungsten, molybdenum and bismuth minerals occur in intensely fractured and altered Carboniferous volcanic rocks. Three successive phases of silicic volcanic rocks are present and the mineral deposits occur in fractures and breccia zones along the contacts of the intensely silicified late phase volcanic rocks.

Several types of late tectonic mineral deposits occur in the St. John region. Porphyry copper-type of deposits occur along a major, late Paleozoic fault northwest of the city. At Musquash, lead-zinc-silver deposits are associated with northeast trending fault zones that are locally intruded by granite dykes dated at 334 ± 18 m.y. Silver base-metal and copper-molybdenum minerals are present in fractures which post-date a granite intrusion yielding a K/Ar age of 364 ± 20 m.y., near Evandale.

GRENVILLE METAVOLCANIC ROCKS IN THE BISHOP CORNERS — DONALDSON AREA, EASTERN ONTARIO

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A calc-alkalic succession at least 5500 metres thick varies from potassium-poor olivine tholeiite flows in the lowest part exposed, through andesite flows and pyroclastic rocks, to rhyodacite pyroclastics at the top. Analyses of 57 core samples demonstrate a single extrusive cycle. Associated rocks are metagraywacke and dolomitic marble, and a younger metasedimentary suite including metaconglomerate and pelite.

The rocks are metamorphosed in the almandine amphibolite facies. In a strike length of 33 km, isograds divide the metavolcanic rocks into five mineral zones : chlorite, biotite, blue hornblende, green hornblende, and diopside. Equivalent zones in the pelites are : chloritoid-staurolite, kyanite-staurolite, and sillimanite-muscovite.

Fe in epidote, Ca in plagioclase, K and Na in hornblende, and ferric/ferrous ratio in rock, biotite, and hornblende increase with metamorphic grade. In biotite and hornblende, octahedral Al decreases with increasing grade, whereas other chemical variables depend mainly on host-rock composition. Element distribution between biotite and hornblende shows no sensitivity to grade.

WAGNERITE FROM SANTA FE MOUNTAIN, COLORADO: A NEW OCCURRENCE

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Wagnerite, a magnesium fluophosphate, occurs in a layer of sillimanite-plagioclase gneiss of Precambrian age at Santa Fe Mountain, near Idaho Springs in the Colorado Front Range. Here wagnerite is a minor constituent of the gneiss, which also contains varying amounts of quartz, biotite, rutile, apatite, corundum, monazite, andalusite, and tourmaline. This is the first reported occurrence of wagnerite in the United States.

The Colorado wagnerite generally is anhedral and fine-grained, yellow to yellowish brown in color. Luster is vitreous to resinous. Cleavage (100) is very poor. In transmitted light, grains are colorless and non-pleochroic; the refractive indices and $2V$ show a range in values: $\alpha = 1.565 - 1.571$, $\beta = 1.567 - 1.572$, $\gamma = 1.578 - 1.585$ (all ± 0.002); $(+)2V = 28\frac{1}{2}° - 33°$; $Z \Lambda c \sim 23°$; $r > v$.

Single-crystal *x*-ray diffraction studies show that wagnerite from Colorado is monoclinic, space group $P2_1/a$ with $a = 11.929 \pm 0.005$Å, $b = 12.698 \pm 0.008$Å, $c = 9.633 \pm 0.004$Å, $\beta = 108°12' \pm 03'$, vol. 1386Å; *Dm* 3.13 gm/cc, *Dx* 3.12 gm/cc for $16\{Mg_2(PO_4)F\}$. A strong monoclinic pseudocell, space group $I2/a$, with $a_p = a$, $b_p = b/2$, $c_p = c$, $\beta = 108°12' \pm 03'$, is present. The *x*-ray diffraction powder pattern has the following strong lines (*hkl, d, I*): $\bar{1}41$, 2.969Å (100); $\bar{4}02$, 2.837Å (71); 202, 3.113Å (60); 122, 3.286Å (50); 023, 2.747Å (25); $\bar{4}21$, 2.694Å (18).

Comparison of precession photographs of wagnerite with those of ferroan wagnerite, $(Mg,Fe,Mn)_2(PO_4)(F,OH)$, (formerly talktriplite) and magniotriplite, $(Mg,Fe,Mn)_2(PO_4)F$ indicated that all three have strong monoclinic pseudocells with space group $I\ 2/a$; the true cell of ferroan wagnerite is identical with that of magniotriplite but differs from that of wagnerite.

Wagnerite has been more recently identified at a second locality in the United States near Quartzite, Arizona, where it occurs in rutile-bearing kyanite gneiss. It is probable that additional occurrences will be found by study of other calcium-poor aluminous metamorphic rocks.

RARE-EARTH — FLUORINE PEGMATITES OF THE SOUTH PLATTE DISTRICT, JEFFERSON COUNTY, COLORADO

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The rare-earth fluorine-rich pegmatites of the South Platte district, Jefferson County, Colorado, constitute a distinctive and well-defined province. The district, which contains over 50 centrally clustered pegmatites and 10 outlying deposits, is underlain chiefly by granitic rocks of the Pikes Peak batholith. Unlike other pegmatite districts in Colorado genetically affiliated with this granite, the South Platte pegmatites occur well within the pluton rather than marginal or exterior to it. The central group of pegmatites is restricted to elevations between 6800-7800 feet within the granite, forming a clearly defined pegmatite niveau.

In shape and external structure, two end-member types are distinguishable: (1) vertical pipes essentially circular in plan, and (2) vertical to steeply dipping, thick, ellipsoidal lenses. Internal zonal structure is conspicuously developed, consisting of the following generalized, idealized sequence:

1. very poorly developed thin border zone, usually absent;
2. wall zone of graphic granite-biotite rock;
3. intermediate zone of feldspar;
4. core margin zone of green fluorite;
5. large core of quartz, in places with microcline.

Notable is the absence of essential muscovite as a zonal species.

Superimposed on the zonal pattern in over 95 percent of the pegmatites are subordinate hydrothermal core-margin and fracture-controlled replacement units, characterized by either an albite-fluorite — rare-earth assemblage or a hematite-iron silicate assemblage.

Fluorite appears in several generations, and geological, geochemical, and fluid-inclusion data are being employed to determine its paragenesis. Fluorite of apparent primary magmatic origin contains inclusions partially filled with liquid CO_2. Younger fluorites are characterized by rare-earth element contents.

Pikes Peak pegmatites throughout Colorado are noted for their boron and beryllium species. This province is a typical one in having essentially no tourmaline and very little beryl and high contents of rare-earth and iron minerals. Minor beryllium is represented chiefly by gadolinite. Preliminary data indicate that the host granite is also anomalously enriched in rare-earth elements in the form of accessory bastnaesite and allanite.

MAGNETIC STUDIES OF MOON SAMPLES

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Preliminary studies of the magnetic properties of lunar samples have revealed the following properties. Definite remanent magnetization is present and it seems likely that this was acquired on the lunar surface. One possible explanation is that it is of thermal origin acquired when the moon had a liquid core and its own magnetic field or when the moon was near the earth and in the influence of the earth's magnetic field. It is also possible that some other poorly understood phenomenon involving the solar wind or shock impacts have had an influence. The magnetic studies reveal the presence of several mineral phases: (a) pure iron (igneous); (b) iron-nickel (5-7% Ni meteoritic); (c) iron-nickel (30% Ni, meteoritic). The magnetic measurements suggest that the soil contains less than ½ percent of iron-nickel meteorite so that the soil is mainly of lunar origin.

AGE DETERMINATIONS AND ISOTOPIC ABUNDANCE MEASUREMENTS ON LUNAR SAMPLES (APOLLO XI)

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Three samples of crystalline rock yield K-Ar whole-rock ages of 2270, 2875 and 3370 m.y., while Rb-Sr results are compatible with a 4600 m.y. reference isochron having an initial Sr^{87}/Sr^{86} ratio of 0.6989. The Pb^{207}/Pb^{206} age determined for a sample of type D fines is 4670 m.y. The K/Rb ratios do not differ greatly from those found in chondritic meteorites and certain types of terrestrial basic rocks. The primordial Ar^{36} content of two samples of type A crystalline rock are similar to the concentrations found for carbonaceous chondrites.

Isotopic compositions of Li, K, Rb, Sr, U and Th agree with terrestrial and meteoritic values.

PETROLOGY AND U-Nb MINERALIZATION OF THE ALKALIC ROCK-CARBONATITE COMPLEX AT PRAIRIE LAKE, ONTARIO

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The Prairie Lake complex is composed dominantly of rocks of the ijolite series and carbonatite. The ijolite series consists of rocks with highly variable nepheline to pyroxene ratios; nepheline-rich rocks contain melanite, pyroxene and wollastonite with minor interstitial calcite, alkali feldspar and feldspar-nepheline intergrowths, whereas the pyroxene-rich rocks are characterized by magnetite, melanite, biotite, calcite and minor nepheline. Carbonatites are generally calcite-rich but some are dolomitic and there are late breccias with groundmass-dolomite. The common carbonatite minerals are calcite, biotite, apatite, olivine, pyroxene, magnetite, pyrrhotite, and pyrochlore. The U_3O_8 and Nb_2O_5 contents of pyrochlore vary inversely in the ranges 1-30% and 65-25% respectively. Carbonatites are mainly located around the margin of the circular intrusion and ijolitic rocks occur toward the central region. Biotite-rich zones often occur between the pyroxenitic and carbonatitic rocks as bands in the carbonatite. Olivine-magnetite-apatite segregations also occur in carbonatite. The country-rock granitic gneisses are slightly fenitized. The complex is interpreted to have formed by intrusions of magmas generated by strong differentiation of a carbonated, nephelinitic parent. The U-Nb mineralization is the result of precipitation from carbonatite magma.

STUDIES ON THE MINERALOGY OF SERPENTINE TEXTURES

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The application of a Norelco microbeam (50 micron diameter) *x*-ray diffraction camera to the study of the serpentine textures has provided a means of identifying the minerals in situ in thin section,and has allowed the relationship between the observed optical properties of a textural unit and the crystallographic axes of the constituent mineral to be determined directly.

During the normal course of serpentinization, olivine alters the most readily, followed by orthopyroxene, talc, clinopyroxene and/or amphibole (amphibole, chlorite, and talc generally occur in ultramafic rocks as the result of high temperature alterations prior to serpentinization and are not produced as part of the serpentinization process). Olivine usually alters to mesh textures with rims of "α-serpentine" (length-fast fibers) and centers of "α-serpentine", "γ-serpentine" (length-slow fibers) or "serpophite" (isotropic serpentine), and less frequently alters to "α-serpentine" hourglass textures. Pyroxenes, amphiboles and talc alter to a variety of serpentine pseudomorphs, usually referred to as bastites. However, in all cases, regardless of the host mineral, the microbeam *x*-ray camera study indicates that lizardite is the only serpentine mineral produced although in some cases brucite is intimately associated with the lizardite on a submicroscopic scale.

Following the development of primary lizardite, fine late-stage veins usually are formed. These are composed of either chrysotile; mixtures of chrysotile and lizardite; lizardite; or 6-layer serpentine, and display a wide range of textures.

In some cases, serpentinization may continue and form secondary serpentine textures composed of antigorite, 6-layer serpentine, lizardite and/or chrysotile. These secondary textures are characterized by interlocking grains or interpenetrating blades, and usually develop by the replacement of primary lizardite textures or, in the case of some antigorites, by the replacement of primary anhydrous minerals. Antigorite secondary textures are the most common ; 6-layer serpentine secondary textures occur less frequently and usually are associated with late-stage 6-layer serpentine veins ; lizardite and/or chrysotile secondary textures are rare. Serrated veins of antigorite or chrysotile often develop as secondary textures and, in special cases, can form "γ-serpentine" hourglass or "γ-serpentine" mesh textures. Many of these secondary serpentine textures are found in chrysotile asbestos deposits and indicate that these deposits undergo a more complex development than that which occurs during normal serpentinization.