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JOINT MEETING WITH THE AMERICAN CRYSTALLOGRAPHIC ASSOCIATION

(For the outline of the Program, see, *Am. Mineral.* **49**, 1507, 1964)

DEERITE, HOWIEITE AND ZUSSMANITE, THREE NEW MINERALS FROM THE FRANCISCAN OF THE LAYTONVILLE DISTRICT, MENDOCINO CO., CALIFORNIA

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Deerite, howieite and zussmanite are essential minerals in some of the metamorphosed shales, siliceous ironstones and impure limestones of the Franciscan formation.

These minerals occur in various associations with ferro- and ferri-stilpnomelane, spessartine-rich garnet, riebeckite, crocidolite, quartz, aegirine, grunerite, aragonite, oligonite and ferroan-kutnahorite.

Deerite occurs in black acicular crystals, amphibolelike in cross section, just transparent on thin edges. Cleavage (110) good. $\gamma = c$, α 1.840 ± .01, γ 1.870 ± .01, pleochroism slight: α dark brown, $\beta\gamma$ dark brown black. G 3.837. Monoclinic, cell dimensions a 10.755 Å ± .002 Å, b 18.87 Å ± .006 Å, c 9.568 Å ± .002 Å (fiber axis), pseudo $c \sim 3.2$ Å. β 107.12° ± .04°, space group $P2_{1/a}$, twin [001] submicroscopic. Deerite a, b, c approximately equals clinoamphibole $2c$, b, a.

One-half unit cell contents for $0 = 55$.

$$(\mathrm{Mg_{.09}Mn_{.95}\overset{2+}{Fe}_{11.99}})_{13.03}(\mathrm{\overset{3+}{Fe}_{6.48}Al_{.42}})_{6.9}\mathrm{Si_{13.04}O_{43.94}(OH)_{11.06}}$$

Howieite occurs in dark green to black bladed crystals. Cleavage (010) good, (100) fair, (2$\bar{1}$0) weak. α 1.701, β 1.720, γ 1.734, biaxial—2V 65°, dispersion strong $v > r$, pleochroism marked: α pale golden yellow, β dark lilac gray, γ dull green. G 3.378. Triclinic, cell dimensions a 10.17 Å, b 9.72 Å, c 9.56 Å (all ± .05 Å), α 91.3°, β 70.7°, γ 109°. Unit cell contents for $0 = 44$.

$$(\mathrm{Na_{1.03}Ca_{.02}})_{1.05}(\mathrm{Mg_{.45}Mn_{2.98}\overset{2+}{Fe}_{6.41}})_{9.84}(\mathrm{\overset{3+}{Fe}_{1.57}Al_{.62}})_{2.19}(\mathrm{Si_{11.96}Ti_{.40}})_{12.00}\mathrm{O_{31.3}(OH)_{12.69}}$$

Zussmanite occurs in pale green tabular crystals. Cleavage (0001) perfect. ω 1.643, ϵ 1.623, uniaxial—, pleochroism weak: ω pale green, ϵ colorless. G 3.146. Rhombohedral lattice. Hexagonal cell dimensions a 11.66 Å ± .02 Å, c 28.69 Å ± .02 Å. Rhombohedral cell dimensions 11.69 Å, α 59.8°. Laue group $\bar{3}$, space group $R3$ or $R\bar{3}$. Rhombohedral unit cell contents for $0 = 56$.

$$(\mathrm{Na_{.07}K_{.92}})_{.99}(\mathrm{Mg_{1.33}Mn_{.46}\overset{2+}{Fe}_{10.85}\overset{3+}{Fe}_{.11}Al_{.34}Ti_{.01}})_{13.10}(\mathrm{Si_{16.6}Al_{1.4}})_{18}\mathrm{O_{42.2}(OH)_{13.8}}$$

SEVEN NEW BARIUM MINERALS FROM EASTERN FRESNO COUNTY, CALIFORNIA

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Seven new barium-bearing silicate minerals have been found in eastern Fresno County, California. The minerals occur in sanbornite-bearing metamorphic rocks which crop out in a narrow zone $2\frac{1}{2}$ miles long near a granodiorite contact.

Macdonaldite [$BaCa_4Si_{15}O_{35}\cdot 11H_2O$] is biaxial (− or +), $2V=90°$, $\alpha=1.518$, $\beta=1.524$, $\gamma=1.530$, colorless, $X=c$, $Y=b$, $Z=a$, G(meas.) = 2.27. It is orthorhombic, $Bmmb$ or $Bm2_1b$, $a=14.06$, $b=23.52$, $c=13.08$, $Z=4$.

Krauskopfite [$BaSi_2O_5\cdot 3H_2O$] is biaxial (−), $2V=88°$, $\alpha=1.574$, $\beta=1.587$, $\gamma=1.599$, colorless, $X=b$, $Y\wedge a=6°$, $Z\wedge c=10\frac{1}{2}°$, $a\wedge c=94°\ 32'$, G(meas.) = 3.14. It is monoclinic, $P2_1/a$, $a=8.460$, $b=10.622$, $c=7.837$, $\beta=94°\ 32'$, $Z=4$.

Walstromite [$BaCa_2Si_3O_9$] is biaxial (−), $2V=30°$, $\alpha=1.668$, $\beta=1.684$, $\gamma=1.685$, colorless, G(meas.) = 3.60. It is triclinic, $P\bar{1}$ or $P1$, $a=6.743$, $b=9.607$, $c=6.687$, $\alpha=69°\ 51'$, $\beta=102°\ 14'$, $\gamma=97°\ 6\frac{1}{2}'$, $Z=2$.

Fresnoite [$Ba_2TiSi_2O_8$] is uniaxial (−), $\omega=1.775$, $\epsilon=1.765$, O = colorless, E = yellow, G(meas.) = 4.23. It is tetragonal, $P4/mbm$, $P4bm$, or $P\bar{4}b2$, $a=8.52$, $c=5.210$, $Z=2$.

Verplanckite [$Ba_2MnSi_2O_6(OH)_2$] is uniaxial (−), $\omega=1.683$, $\epsilon=1.672$, O = orange-yellow, E = colorless, G(meas.) = 3.62. It is hexagonal, $P6/mmm$, $P\bar{6}2m$, $P\bar{6}m2$, $P6mm$, or $P622$, $a=16.35$, $c=7.17$, $Z=7$.

Muirite [$Ba_5CaTiSi_5O_{15}(OH)_6$] is uniaxial (+), $\omega=1.697$, $\epsilon=1.704$, O = orange, E = colorless, G(meas.) = 3.86. It is tetragonal, $P4/mmm$, $P4mm$, $P422$ or $P\bar{4}2m$, $a=13.942$, $c=5.590$, $Z=2$.

Traskite [$Ba_5FeTiSi_6O_{18}(OH)_4$] is uniaxial (−), $\omega=1.714$, $\epsilon=1.702$, O = brownish-red, E = colorless, G(meas.) = 3.71. It is hexagonal, $P6/mmm$, $P\bar{6}2m$, $P\bar{6}m2$, $P6mm$, or $P622$, $a=17.88$, $c=12.30$, $Z=6$.

ZEOLITE TYPE X EQUILIBRIA WITH TRIVALENT CERIUM AND YTTRIUM CATIONS[1]

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Cerium equilibria were determined with several natural and synthetic zeolites including Linde 4A, 13X, AW-400, AW-500, Norton Zeolon, and natural erionite, phillipsite and clinoptilolite. Only Type X (Linde 13X) showed favorable mass action quotients at relatively high fractions of cerium on the zeolite. Further, only with Type X was the cerium capacity the same as the strontium or sodium capacity, 3.6 meq/g. The exchange data for Type X is given in the table. K is a rational thermodynamic equilibrium constant and $\Delta G°$ is a standard Gibbs free-energy change for the reaction given.

Reaction	K, 25° C.	$\Delta G°$, 25° C., cal/mole
$3Na_z \rightarrow Ce_z$	45.6	−2300
$2Na_z \rightarrow Sr_z$	19.9	−1800
$3Sr_z \rightarrow 2Ce_z$	0.759	+ 200
$3Na_z \rightarrow Y_z$	6.61	−1100

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[1] Read by title.

PYROXENE RELATIONS IN EXPERIMENTALLY CRYSTALLIZED 1887 MAUNA LOA BASALT

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Experimental investigation of the kinetics of crystallization of the 1887 Mauna Loa, Hawaii basalt reveals significant time-dependent phase relations of a similar nature as those found in natural basalts and andesites which are conventionally interpreted as resulting through changes in temperature and composition of the crystallizing magma. The experimental method employs a stack of two large quench furnaces and, to minimize oxidation of Fe, 8 g charges contained in very thin platinum foil tubes and heated in an atmosphere of argon. Runs of several days duration starting with powdered basalt (with all phases present as potential seeds) show that augite, hypersthene, and plagioclase all crystallize stably between 1170° C. and 1090° C. In other runs where the charge is first completely liquefied at about 1200° C. and then quickly introduced into the other furnace at a lower constant temperature no self-nucleating hypersthene forms at any temperature. Augite self-nucleates at temperatures less than 1140° C. Pigeonite (OP$\|$(010); 2V_z 20°) nucleates from 1170° C. to at least 1135° C.; as these crystals become larger with time at any particular constant temperature the optic angle appears to increase, greater inhomogeneity is evident, and finally, after about four days, each grain clearly becomes composite, consisting of exsolved hypersthene and augite. The latter commonly forms irregular jackets and patchy cores or, rarely, thin (100) lamellae in the host hypersthene.

SKARNS OF THE PRECAMBRIAN, DENVER MOUNTAIN PARKS AREA, COLORADO

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Skarns developed by polymetamorphism of 3 closely folded calcite-rock, calc-silicate and quartzitic members of the Idaho Springs sequence, crop out in separate, subparallel, well-defined belts within a wide northwest–southeast trending arc of metasedimentaries that border an antiform of at least 4 generations of Precambrian granites at the southwest.

Regional dynamothermal metamorphism of calcareous and associated sedimentary strata was followed by multiple granite contact metamorphism. Retrograde metamorphism imposed additional modifications, especially of the calc-silicate minerals. Field investigations located minor endomorphic (autometasomatic) and contact skarns in the outer marble-marmorite belt. The light colored skarn with white quartz bodies developed where the calcite-rich strata are intensely crumpled and dislocated by faulting. The marble relics of the intermediate belt are enveloped by massive skarn, calc-silicate gneiss and black silexite. The mantle is a half to a mile wide. Discrete pods and strike-aligned lenses of marble and continuous calcite-rich layers are confined to the heart of the calc-silicate envelop. Skarn and marble-marmorite bodies do not merge.

Contact and endomorphic skarns of the intermediate and inner belts, produced by dynamothermal metamorphism, are invaded by mirocline-rich pegmatite and black silexite bodies loaded with innumerable pyrite grains of probable granite contact origin. Retrograde metamorphism has modified all the calc-silicate minerals of the inner and intermediate belts but has had little effect on the outer one, and the mineralogy of the outer belt is well preserved. Exceptions are marble relics in fault and shear belts, where magnesia-rich and hydrothermal minerals occur.

THE ORIGIN OF SOME NATIVE LEAD-PYROCHROITE PARAGENESES

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Systems containing PbS, Mn_3O_4, $CaCO_3$ and $BaCO_3$ in various quantities are discussed. It is found that under certain conditions minerals like native lead, pyrochroite, and hydrocerussite can be formed by redox processes in these systems. The models are compared with native lead-pyrochroite occurrences at Långban, Sweden, and Franklin, New Jersey.

THE ORIGIN OF TINCALCONITE AT SEARLES LAKE, CALIFORNIA

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Tincalconite ($Na_2B_4O_7 \cdot 10H_2O$) occurs at Searles Lake as coarse-crystalline, commonly euhedral, crystals within the salts of both the upper and lower salt structures. Textural relations indicate it has grown as a reaction product directly from the saturated lake brine. Lake brine temperatures range from 20 to 25° C. The occurrence is unusual inasmuch as tincalconite is generally formed as a dehydration product of borax when exposed to the air.

In pure $Na_2B_4O_8$-water solutions the borax-tincalconite transition temperature is at 60.8° C., however it is lowered by addition of other salts to the solution. Borax converts to tincalconite at 39.6° C. in saturated NaCl-$Na_2B_4O_8$ solutions. Van't Hoff determined a transition temperature of 35.5° C. in solutions saturated with halite, sylvite, and aphthitalite. Teeple determined solubilities in salt systems which approximate the composition of Searles Lake brines over temperatures ranging from 20°–35° C. Borax was apparently the stable sodium borate phase in all these experiments.

On the basis of existing experimental solubility determinations, it is concluded that the tincalconite at Searles Lake did not form under present brine temperature conditions, except possibly the tincalconite that occurs near the salt flat surface, but that it must have formed earlier under warmer brine conditions. Apparently the tincalconite is kept from hydrating to borax by a surrounding permeability seal of either fine-grained trona or clay.

Data from the system $Na_2B_4O_8$-NaCl-H_2O suggest that tincalconite is a metastable phase at Searles Lake. Had equilibrium been maintained only borax and kernite should have formed.

THE SHAPE OF MISORIENTED RECIPROCAL LATTICE PLANES AS RECORDED BY PRECESSION PHOTOGRAPHY

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The shape of reciprocal-lattice planes in precession photographs is a function of the orientation of these planes relative to the precessing axis. The exact equation of the perimeter of central planes is derived in terms of the lengths of the reciprocal lattice vectors, *i.e.*, $\xi = f(\bar{\mu}, \tau, \epsilon)$ in the usual notation. Qualitatively one may say that the shape passes from a circle to a curtate cardioid, to a cardioid and finally to a prolate cardioid as the error $\epsilon = 0$, $\epsilon < \bar{\mu}$, $\epsilon = \bar{\mu}$, and $\epsilon > \bar{\mu}$ respectively.

The precession orientation methods presently in use are shown to be special cases or approximations of the general equation. In addition other methods of orientation, which extend and complement the present methods are suggested by the general equation.

The perimeter of the recorded region may also be characterized by an angular measurement, *viz.* the angle between the radius vector and the tangent to the perimeter. The relation of the orientation error to this angle is given by an equation which is directly soluble for the error in contrast to the most generally used method which requires graphical solution. Furthermore this method is unlimited in allowing an error of any size to be evaluated as long as the reciprocal lattice plane in question can be discerned.

TEMPERATURE PARAMETERS OF SILICATE CRYSTAL STRUCTURES

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Analysis of experimentally determined temperature factors for ten refined silicate crystal structures with R values less than .06 affords a meaningful comparison of thermal models for oxygen, silicon, and aluminum atoms. Vibration ellipsoids for these atoms in varying structural environments provide guides to temperature factors expected in other silicates, and demonstrate that structural disordering furnishes significant nonthermal contributions that lead to abnormally high thermal parameters.

The rms displacements of 29 three- and four-coordinated oxygen atoms associated with pure Si and Al tetrahedra range from .065 Å to .084 Å; the mean is .075 Å, corresponding to an isotropic temperature factor, B, of .44. When oxygen is only two-coordinated, rms displacements normal to the cation-anion vectors increase to .11–.15 Å. In disordered tetrahedra containing mixtures of Si and Al, the rms displacements of oxygen atoms toward the cations increase to .10–.12 Å. These increases parallel to bonds represent superposition of positional disordering effects, directly related to cation substitutional disordering, onto the true oxygen thermal vibrations.

Eleven Si and Al atoms have rms displacements ranging from .05 Å to .07 Å; the mean value is .06 Å, corresponding to $B = .31$. For Si plus Al in six disordered tetrahedra, rms displacements increase to .08–.09 Å, representing an increase of mean B to .60.

Other structural factors, such as the existence of defect sites or substitutional disorder in octahedral coordination polyhedra, will also induce anomalously high temperature factors. These non-vibrational contributions, when recognized in detailed anisotropic refinements, may provide crystal-chemical information not available from interatomic distance comparisons.

MINERALOGY OF THE KALKAR QUARRY, SANTA CRUZ, CALIFORNIA

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A suite of more than 50 minerals has been found in the Kalkar quarry of the Pacific Limestone Products Company, near Santa Cruz, California. Represented are sulfides, sulfosalts, oxides, carbonates, sulfates, phosphates, antimonates and silicates. Sulfide and sulfosalt mineralization is adjacent to faults and occurs in irregular patches within fine-grained, recrystallized magnesian limestone. Interbeds of siliceous and pelitic limestone contain sulfides whereas the sulfosalts are confined principally to the purer limestones. Silicate minerals are developed in the siliceous and pelitic limestones. All secondary minerals are the result of near-surface alteration of the metallic minerals.

Paragenetic studies indicate an overlapping sequence of deposition in the sulfide and sulfosalts with molybdenite, loellingite and gersdorffite forming earliest and at temperatures possibly above 600° C., followed by arsenopyrite, pyrrhotite, pyrite and sphalerite, perhaps below 550° C. The sulfosalts formed last at temperatures below 400° C. The mineralization appears to be related to the intrusion of coarse-grained Mesozoic granite into interbedded magnesian limestone and siliceous and pelitic limestones of the Sur Series (pre-Cretaceous).

THE CRYSTAL STRUCTURE OF TURQUOIS, $CuAl_6(PO_4)_4(OH)_8 \cdot 4H_2O$

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Turquois is triclinic, space group $P\bar{1}$, with cell dimensions $a = 7.424$ Å, $b = 7.629$ Å, $c = 9.910$ Å, $\alpha = 68.61°$, $\beta = 69.71°$, $\gamma = 65.08°$. This cell contains one formula of

$$CuAl_6(PO_4)_4(OH)_8 \cdot 4H_2O,$$

so that the Cu atom is fixed in an inversion center. Three-dimensional intensity data were collected on a single-crystal diffractometer using a proportional counter as detector, and were corrected for Lorentz-polarization factors and absorption. The interpretation of a three-dimensional Patterson function and of a three-dimensional electron-density function based on signs due to the Cu contribution only, gave a trial structure that was refined by Fourier methods and then by least-squares methods to $= 7\%$.

The structure can be described in terms of planes of approximately close-packed oxygen atoms oriented parallel to (001). Planes containing the Al in octahedral coordination and planes containing the Cu in a 4+2 octahedral coordination alternate between oxygen layers. The octahedral groups of anions around the aluminum are single and double; two phosphorus tetrahedra link each double group to its translational equivalent, forming a tetrahedra-octahedra chain parallel to the *b* axis. The PO_4 tetrahedra together with the single aluminum octahedra constitute a zig-zag chain in the direction of the *c* axis. The water content has been determined to be four molecules per cell.

CRYSTAL STRUCTURE OF THE SODIUM CALCIUM BORATE, ULEXITE

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Ulexite, $NaCaB_5O_9 \cdot 8H_2O$, is triclinic $P\bar{1}$, $a = 8.809 \pm 0.02$, $b = 12.86 \pm 0.04$, $c = 6.678 \pm 0.002$ Å, $\alpha = 90°15 \pm 05$, $\beta = 109°10 \pm 05$, $\gamma = 105°25 \pm 05$, cell volume 687.0 Å, density (calc.) 1.959, (obs.) 1.955 ± 0.001 g cm^{-3} (data from Clark and Christ, *Am. Mineral.* **44,** 712, 1959). The crystal structure was solved by standard three-dimensional Patterson and Fourier methods. Visually estimated three-dimensional data have been used in least-squares refinement of coordinates and individual isotropic temperature factors for the 24 atoms of the asymmetric unit, reducing the residual from an initial value of 0.52 to a present value of 0.16.

The structure contains the isolated borate polyanion $[B_5O_6(OH)_6]^{3-}$ predicted by Christ (*Am. Mineral.* **45,** 334, 1960), consisting of the pentaborate polyanion originally found by Zachariasen (*Zeit. Krist.* **98,** 266, 1937) modified by addition of one hydroxyl group to each of two opposite B-O triangles. The ulexite polyanion is thus composed of three tetrahedra and two triangles, linked at corners to produce two six-membered alternating B-O rings in approximately perpendicular planes. The polyanions are hydrogen-bonded into sheets that are cross-linked by bonds to Na and Ca cations. Each Ca is coordinated by two water molecules and six polyanion oxygen atoms and hydroxyls. Each Na is surrounded by an octahedron of four water molecules and two hydroxyls; these octahedra share edges to form chains along the *c* direction. Polymerization of the ulexite polyanions, according to Christ's fourth rule, produces the $[B_5O_7(OH)_4]^{3-}$ chains found in probertite, $NaCaB_5O_9 \cdot 5H_2O$, by Kurbanov *et al.* (*Doklady Akad. Nauk SSSR* **152,** 1100, 1963). The structural formula of ulexite is $NaCaB_5O_6(OH)_6 \cdot 5H_2O$.

A NEW, BARINGER HILL-TYPE, RARE-EARTH PEGMATITE FROM THE CENTRAL MINERAL REGION, TEXAS

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The discovery of a new rare-earth pegmatite, the Rode Ranch pegmatite, in the Central Mineral Region of Texas has made possible the detailed study of an occurrence quite similar to the famous Baringer Hill pegmatite, now flooded by the waters of Buchanan Lake.

The dominant mass of the Rode Ranch pegmatite consists of bodies of milky quartz and large masses and crystals of microcline perthite. The primary rare-earth minerals have been found in three general associations. Allanite and fergusonite are found along a quartz-albite contact but, generally, within the albite. The albite is a soft, red feldspar apparently similar to the "red rock" of the Baringer Hill pegmatite. Cyrtolite and fergusonite occur disseminated in the massive microcline perthite. Cyrtolite, fergusonite and gadolinite occur interlaminated with large sheets of biotite along a microcline perthite-quartz contact.

Metamictization is complete in the allanite, fergusonite, and gadolinite and partial in the cyrtolite. Heating causes recrystallization of fergusonite and cyrtolite but dissociation occurs in the allanite and gadolinite before recrystallization.

Thus far, the following minerals, including many alteration products, have been identified from the pegmatite; quartz, albite, microcline, biotite, allanite, fergusonite, gadolinite, cyrtolite, bastnäsite, thorogummite, nontronite, sericite, magnetite, hematite, pyrite, garnet, beta beryllium hydroxide, and hyaline opal.

THE CRYSTAL STRUCTURE OF THE DECAVANADATE, $K_2Zn_2V_{10}O_{28}\cdot 16H_2O$, THE CHEMICAL ANALOG OF HUMMERITE AND PASCOITE

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When vanadium oxide ores of the Colorado Plateau are leached with ground waters, rather acid (pH 4–6) orange solutions are formed containing the isopoly complex decavanadate ion $V_{10}O_{28}^{6-}$. Bright orange crystals of pascoite, $Ca_3V_{10}O_{28}\cdot 16H_2O$ and hummerite, $K_2Mg_2V_{10}O_{28}\cdot 16H_2O$ are often deposited by these solutions in cracks or on exposed surfaces. The complex has been well-established chemically to be a 10-nucleate molecular group, but its structure is now revealed for the first time in the crystal structure analysis of the isostructural zinc analog of hummerite, $K_2Zn_2V_{10}O_{28}\cdot 16H_2O$.

The crystals are triclinic, space group $P\bar{1}$, with $a=10.778\pm3$ Å, $b=11.146\pm3$ Å, $c=8.774\pm3$ Å, $\alpha=104°\ 57\pm1'$, $\beta=109°\ 32\pm2'$ and $\gamma=65°\ 2\pm2'$ (Z=1), as determined by least squares analysis of x-ray powder data. 5,143 intensity data for all reflections with $(\sin\theta)/\lambda<0.7$ were collected by the Weissenberg, multiple-film method, using MoKα radiation. The structure was solved from the three-dimensional, sharpened Patterson map in which the Zn–V vectors gave a clear image of the 10 vanadium atoms in the $V_{10}O_{28}^{6-}$ group. Structure factors for the six atoms, Zn+5V, gave the phases for 2,959 terms for the first electron density map. This map revealed all 29 non-equivalent atoms as well-shaped peaks of proper height, with no extra or spurious detail above ordinary background irregularities.

The decavanadate group consists of a cluster of 10 condensed VO_6 octahedra: 6 are arranged in a 2×3 rectangle by sharing horizontal edges, and 2 pairs of octahedra are inserted above and below the rectangle by sharing sloping edges. The complex group, which may be thought of as a portion of a rocksalt type of structure, has orthorhombic *mmm* symmetry, and is completely isolated from other groups by the intervening cations and water molecules. The zinc ion is coordinated in a regular octahedron to 6 water molecules, and the potassium ion is in contact with 10 oxygen atoms: 3 water molecules from 2 $Zn(H_2O)_6^{2+}$ groups, 5 oxygen atoms from 3 neighboring $V_{10}O_{28}^{6-}$ groups, and 2 further H_2O molecules that fill the remaining space in the crystal.

AN OCCURRENCE OF ABUNDANT CHIASTOLITE, SAWTOOTH MOUNTAIN, ALASKA

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The occurrence of classically developed chiastolite porphyroblasts in a thermally metamorphosed slate in Alaska yields information on reaction rim formation and possibly information on unusual distortion of foliation in slate and of rotation of porphyroblasts. Regionally metamorphosed sedimentary rocks on Sawtooth Mountain, approximately 35 miles southwest of Livengood, Alaska, have been intruded by a stock. Near the igneous metamorphic contact, slates contain thinly armored chiastolite porphyroblasts which formed at the expense of the slate and apparently without initially distorting the foliation during their growth.

Drag of foliation occurs across many chiastolite prism faces which are nearly normal to the foliation. However, relict foliation within the porphyroblasts shows no effect of this sort of disturbance. Foliation is bulged adjacent to chiastolite prism faces which are nearly parallel to the foliation. The drag and the bulge of foliation are interpreted to have resulted during the latter part of porphyroblastic growth. These occurred when the growing crystals pushed out graphitic and minor phyllosilicate impurities which accumulated unevenly before the advancing crystal faces. The stress thus caused is believed to have rotated the porphyroblasts.

The thin armor on the porphyroblasts is interpreted to have been caused by marginal replacement of chiastolitic andalusite by the removed phyllosilicates which were more stable under the existing stress-temperature conditions than was the chiastolitic andalusite.

A UNIQUE OCCURRENCE OF URANIUM MINERALS, MARSHALL PASS, SAGUACHE COUNTY, COLORADO

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In 1956 several unusual uranium deposits were uncovered in the Marshall Pass district, Saguache County, Colorado. Two of the ore bodies occurred in alluvium at about 10,000 feet elevation. The largest of these, on the Lookout No. 22 claim, produced about five tons of "high grade" uranium ore.

The bedrock at the deposit is a quartz-biotite-feldspar schist which has been altered adjacent to a fault zone. Small areas of the schist have been completely replaced by uranium and sulfide minerals producing "rich" ore bodies that have been found *in situ* in the alluvium above the fault.

Ore specimens are tabular to rounded yellow masses measuring from a few inches in diameter to large slabs 2′×1′×8″ thick and weighing as much as 140 pounds. All samples contained a yellow oxidized coating rimming a black interior of uraninite and sulfides.

Geochemical sampling of soils surrounding the deposit indicated that the uranium migrated less than 100 feet downslope from the ore body.

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[1] Read by title.

Radioactive minerals of the deposit included uraninite, schoepite, epiianthinite, becquerelite, soddyite, boltwoodite, uranophane, zeunerite, metazeunerite, and a hydrated autunite. Other minerals were tetrahedrite, chalcopyrite, sphalerite, chalcocite, covellite, galena, pyrite, and marcasite.

Uraninite occurs in concentric banded and colloform masses showing fractures and microfaults that have been rehealed by later uraninite. Secondary uranium minerals and sulfides transect the uraninite and occur interstitially between banded masses.

The uranium deposit is probably mesothermal and of late Cretaceous to early Tertiary age.

MINERALOGY OF THE BUTTE DISTRICT, MONTANA

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Continuing intensive study of the geologic environments integral to the Butte ore deposits has confirmed the occurrence of over 130 minerals, many previously unreported from Butte. Grouped according to environment, the mineral suites are found to support, refine, and extend existing theories concerning chronology of the district geology and zonation of the hydrothermal mineralization. Environments mineralogically described are: the Tertiary Boulder Batholith Butte quartz monzonite host rock, including its pegmatite-aplite segregations and quartz porphyry dikes; the late-magmatic—pre-Main Stage hydrothermal phases of quartz-molybdenite veinlets and Early Dark Micaceous alteration-mineralization; the Main Stage hypogene mineralization and its contemporaneous wall rock alteration; post-ore rhyolite dike intrusion and ore metamorphism; and supergene alteration of ore minerals and wall rock in both pyrite-rich and pyrite-poor assemblages. The list of verified minerals at present includes 3 native metals, 19 sulfides, 14 sulfosalts, 18 oxides, 2 halides, 12 carbonates, 15 sulfates, 15 phosphate-arsenate-tungstates, and 35 silicates. A few reliably reported but unverified species are described, new occurrences, habits, and assemblages are cited, and minerals ascribed to Butte in the literature but found to be of unlikely or restricted occurrence are noted. Of particular interest to mineralogists is the reporting of the minerals aikinite, wittichenite, and djurleite in the Butte ores. Of general interest are preliminary descriptions of a pyrophyllite-topaz-zunyite alteration assemblage; of the pre-Main Stage, feldspar-destructive, sericite-biotite early Dark Micaceous alteration-mineralization; and of a recently defined Deep Level Zone of Main Stage sulfide mineralization.

ORIGIN OF THE TERM *NUÉE ARDENTE*

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Nuée ardente, the term in use to designate the glowing, gaseous, ash-laden, avalanching cloud characteristic of certain volcanic eruptions, has long been assumed to have originated with A. Lacroix in his writings on the 1902 eruption of Mt. Pelée on the island of Martinique. In actual fact, it was introduced into the geologic literature in 1873 in an article by F. Fouqué describing the volcanic eruptions in 1580 and 1808 on the island of San Jorge in the Azores. Fouqué derived it from the Portuguese *nuvem ardente* which was used in early Azorean accounts to describe the fiery-cloud phenomenon accompanying the eruptions. In his first on-the-spot reports from Martinique, Lacroix, believing that the clouds he observed were a phenomenon as yet undescribed, designated them as *nuages denses*. In later reports and in his full, final report, convinced that the clouds were similar to those that had occurred on San Jorge, he decided to adopt the name given in the old Azorean records and translated by Fouqué as *nuées ardentes*. Since that time, the term, retained in its French form, has become well established in volcanologic terminology, in part from general usage but more particularly, perhaps, from its use by F. Perret in a vivid description and a discerning analysis of the 1929–1932 eruption of Mt. Pelée.

ZEOLITE ZONING IN VOLCANIC ROCKS AT THE NEVADA TEST SITE, NYE COUNTY, NEVADA

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Chabazite, clinoptilolite, mordenite and analcime form progressively deeper, but overlapping zones in rhyolitic rocks of Tertiary age at the Nevada Test Site in southern Nevada. More than 500 samples from 15 drill holes have been analyzed by *x*-ray diffraction methods. The zeolitization extends over a stratigraphic interval of more than 12,000 feet, but the maximum thickness at one locality is 64000 feet. The zeolites are largely the products of devitrification of glass that took place long after deposition.

The decrease in water of hydration and the increase in density, assuming ideal formulas, with depth indicates some control by temperature and pressure. Parallelism of the top of the zeolitized interval and an old topographic surface, cross-cutting relationships between the zones and stratigraphy and the present water table, original rock composition, and variations in rock chemistry with depth indicate that the zoning is largely controlled by ground water chemistry. The occurrence of zeolites at anomalous depths with respect to zoning and abundant clay minerals in tuffs just above highly permeable Paleozoic rocks indicates that permeability may control zoning locally. Restriction of mordenite to the western part of the area studied is probably due to small differences in ground water chemistry that cannot be interpreted at the present time.

A SLIDE-RULE FOR UPPER-LEVEL SETTINGS FOR THE PRECESSION CAMERA

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By changing the equation $S = r_s \text{ Cot Cos}^{-1} (\text{Cos } \bar{u} - d^*)$ to $\text{Cos } \bar{u} = d^* + \text{Cos Cot}^{-1} S/r_s$ a circular slide-rule for determining upper-level settings for the precession camera can be constructed. It is possible with this slide-rule to achieve the twin objectives of maximizing the precession angle and remaining within the physical limitations imposed by the motion of the camera. The slide-rule permits one to choose between a number of possible settings, and/or to vary the settings quite rapidly. The slide-rule has been constructed with a 60mm film-to-crystal distance in mind, so that $Fd^* = 60\ d^*$; however, other slide-rules of the same type can easily be constructed for any film-to-crystal distance.

d^*, from cone-axis photographs, can also be quickly determined on this slide-rule.

SOLUBILITY AND GROWTH OF SPHALERITE UNDER HYDROTHERMAL CONDITIONS

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The solubility of sphalerite (cubic ZnS) was studied between 300° and 450° C., between 270 and 1360 bars, in a variety of mineralizer solutions. In particular, 0.5–10.0 N KOH was found to have a large effect on solubility and solubilities as high as 10 wgt. % were obtained. The temperature dependence of solubility is shown to follow the Van't Hoff equation, and the dependence of solubility upon $(OH)^-$ concentration leads to information concerning the species present. The solubility was found to be nearly independent of pressure. The results are compared with previous solubility studies of quartz, sapphire and zincite under similar conditions.

The solubility data were used to find suitable conditions for the hydrothermal crystallization of ZnS. Growth rates as high as 15 mil/da were obtained in ⟨110⟩ in 10 molar KOH at 550 bars when the crystallization temperature was in the neighborhood of 350° and the temperature difference between dissolving and growth zones was 10–20°. The effect of growth conditions on rate is discussed as is the optical quality of the crystals.

NEW SPECIFIC REFRACTIVE ENERGY VALUES FOR CuO AND Sc_2O_3

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Large deviations between calculated and experimental mean indices of refraction (n), obtained when the Gladstone and Dale relation ($n-1/d=K$) was applied to several copper-bearing minerals under investigation, led to the determination of a new specific refractive energy value (k) for CuO, using the chemical, optical, and density data of dioptase, $CuSiO_3 \cdot H_2O$. The newly derived k_{CuO}, 0.173, replaces the previously accepted k_{CuO} value 0.191. Using the new k_{CuO} value, the rule of Gladstone and Dale was applied to 49 minerals in which copper is an essential constituent. Of these, 23 were found to have deviations within 0.010 between mean calculated n and mean measured n. Those for which the deviation calculated is greater than 0.010 are believed to contain inaccuracies in the data for their chemical or optical properties.

On the basis of new optical determinations, specific gravity measurements, and spectrographic and chemical analyses of kolbeckite and sterrettite, both of which are now known to have the composition $ScPO_4 \cdot 2H_2O$ (Mrose, Meyrowitz, and Wappner, unpubl. data, 1964), the specific refractive energy for Sc_2O_3 has been determined to be 0.264, replacing the value 0.248 previously derived from thortveitite, $(Sc, Y)_2Si_2O_7$. The new k for Sc_2O_3 (0.264) is considered more reliable because of the simplicity of the analytical results and the close agreement of the optical and specific gravity measurements obtained on kolbeckite and sterrettite (=kolbeckite) from two localities. Analyses of thortveitite from Iveland, Norway, show such variation in the scandium and rare-earth oxide contents that the homogeneity of the analyzed samples as well as the analytical procedures used in determining those constituents are suspect. Use of thortveitite to determine the specific refractive energy value for Sc_2O_3 is complicated by the fact that the specific refractive energies for the rare-earth oxides have not been rigorously established.

OBSERVATIONS ON THE CRYSTAL CHEMISTRY OF FOSSIL BONE AND THE CARBONATE APATITES[1]

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The crystal chemistry of the carbonate apatites is being reviewed in the light of new x-ray diffraction, chemical, infrared, and thermal analyses of apatites and fossil bones. Infrared spectra give more critical information on the role of carbon in the apatite structure than any other method employed to date. The spectra indicate that carbon is present as CO_3^{2-} and is substituted in essentially the same manner for all apatites regardless of surface area, CO_2 or H_2O+ content. The presence of tridentate peaks in the v_3 region for CO_3^{2-} in fossil bone and some apatites suggests that there are non-identical carbonate sites. Infrared spectra of heated and analyzed samples confirm the two site structure as one group of peaks in the v_3 region is reduced in intensity before the other. Structural calculations by the method of McConnell on a typical analysis (sum 100.40%) of fossil bone produces a formula

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[1] Read by title.

$$(Ca_{8.79}Mg_{0.32}Na_{0.68}K_{0.12}C_{0.28})(P_{4.75}C_{0.57}H_{40.68})O_{24}(F_{1.68}OH_{0.38})$$

but with 3.57 excess H. Calculations on 7 other fossil bones and 2 phosphorites lead to the same problem of excess H if C is assigned preferentially. The failure of proposed structures to accommodate all components in these francolites which are high in F, CO_2 and H_2O+ indicates that present models for the carbonate apatite should be altered to allow some CO_2 or H_2O+ to be assigned to sites not recognized in the fluor-apatite structure or to a tightly adsorbed pseudo-molecular position.

GROUND-WATER LEACHING OF SODIUM FROM QUICKLY COOLED VOLCANIC ROCKS

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Quickly cooled silicic volcanic rocks are highly susceptible to ground-water leaching of Na_2O. Various workers have previously recognized that natural glasses, if hydrated, are particularly susceptible to leaching. Rocks with vitric groundmasses, particularly highly porous tuffs, may lose as much as 3 per cent Na_2O.

In addition, analytical data obtained during recent work on rocks from southern Nevada show that 0.5 to 1 per cent Na_2O has been leached from both porous and densely welded ash-flow tuffs that have devitrified during cooling (primary devitrification) and from quickly chilled devitrified lavas. These rocks appear fresh and unaltered in both hand specimen and thin section. Cristobalite is the dominant groundmass silica mineral in the leached rocks. More slowly cooled lavas and tuffs having primary quartz instead of cristobalite in the groundmass are not leached; they have the same sodium content as rocks from the same stratigraphic unit which have groundmasses of nonhydrated glass.

It is known (Buerger, 1935; 1954) that the composition of natural cristobalite and tridymite typically departs appreciably from pure SiO_2. In particular, Al^{3+} replaces Si^{4+}, the charge balance being maintained by the incorporation of alkali and alkaline-earth ions in interstitial positions. A high degree of such replacement can be expected in cristobalite formed at the relatively high temperatures of primary devitrification. Tuffs with groundmass cristobalite typically contain 0.3 to 0.7 per cent H_2O plus. It is inferred that H_3O^+ very slowly replaces Na^+ ions in the "stuffed" cristobalite and tridymite by ion exchange with ground-water. In addition, it appears that in some cases soda is also lost during secondary low-temperature recrystallization of primary cristobalite to quartz.

K_2O usually is not leached, possibly because of the large size of the potassium ion.

A. N. WINCHELL'S OBSERVATIONS ON PLAGIOCLASE, 1900; AN HISTORICAL NOTE

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A. N. Winchell's doctor's dissertation (Paris, 1900), "Étude minéralogique et petrographique des roches gabbroiques de l'État de Minnesota, États-Unis, et plus spécialement des anorthosites," was soon republished in English (*American Geologist* **26,** 151–188, 197–245, 261–306 and 348–388, 1900). A chemical analysis and detailed observations on a labradorite from Carlton Peak were reported and a difference of about 6° noted in the optic angle from that of similar labradorite studied by Fouqué. Winchell wrote: "Since his (Fouqué's) measures were all made on feldspars from the volcanic rocks, it seems probable that the optic angle is distinctly greater in labradorite of the deep-seated rocks than in the corresponding labradorite of the volcanic rocks. It will be interesting to examine this question further as the measures of the optical on material of known composition increase in number." Winchell was fully aware of the significance of these relations for he recurred to them thrice in the same chapter and again in his conclusions. Unfortunately he did not "examine this question further" and 40 years passed before others took it up.

If the indices and optic angles of Winchell and Fouqué are interpreted from the best modern data (J. R. Smith, 1958), compositions more anorthitic by 6 to 8% than those shown by their analyses are indicated. However, Winchell was correct in stating that the differences in indices and birefringence are negligible, whereas those of optic angle are significant, for in the range An 58–70 the optic angle of low plagioclases is larger by 5 to 7 degrees.

THE CRYSTAL STRUCTURE OF A MARIALITE SCAPOLITE

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The crystal structure of an 80.6% marialite scapolite, with $a=12.060$ Å ± .003, $c=7.572$ Å ± .003, and space group $I4/m$ was determined and refined. Three-dimensional intensities were collected with an equi-inclination, single-crystal diffractometer from a spherical crystal of scapolite from Gooderham, Ontario.

After several unsuccessful attempts at refining the model proposed by Pauling (1930) and Schiebold and Seumel (1932), the three-dimensional Patterson function was computed and solved for an approximation of the structure with the minimum function method. This model was completed and refined by Fourier and least squares methods. The refined structure is similar to that of Pauling, Schiebold and Seumel; however, most of the atomic coordinates have been shifted substantially:

	x	y	z	B
(Na, Ca, K)	.1340 ± .0003	.2113 ± .0002	0	2.65
Si-1	.3388 ± .0001	.4104 ± .0001	0	.82
(Si, Al)-2	.3374 ± .0001	.0851 ± .0001	.2060 ± .0002	.76
O-1	.4587 ± .0005	.3483 ± .0004	0	1.60
O-2	.3066 ± .0006	.1206 ± .0004	0	2.14
O-3	.0517 ± .0003	.3500 ± .0002	.2148 ± .0006	1.55
O-4	.2293 ± .0003	.1289 ± .0002	.3281 ± .0006	1.37
Cl	0	0	0	

The average T-O distances are 1.608 Å in the first and 1.665 Å in the second tetrahedron. Comparison with known Si, Al-O distances indicates that Al must be restricted to the second tetrahedral position.

LAYER STRUCTURES IN SECONDARY COPPER MINERALS

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Strong lines with spacings near 7.2 and 3.6 Å appear in the powder patterns of several seondary copper minerals having a single perfect cleavage. The minerals contain hydroxyl ion and tetrahedrally coordinated anions. The patterns bear a resemblance to that of kaolinite and suggest possible analogous structures.

Copper can be accommodated in modified trioctahedral layers by distortion of the cation coordination. Sites on trigonal axes are forbidden to copper but may have cations such as aluminum or be voids. Hypothetical trigonal layers are proposed as follows: (1) seven sites, one having trigonal symmetry; (2) nine sites, three trigonal; (3) twelve sites, three trigonal. Layers involving no trigonal sites may be of trigonal or lower symmetry. Layers with less than seven sites require that all or none be trigonal. Layers with more than twelve sites are possible.

Two seven-site layers normal to the 14.34 Å hexagonal axis are established by partial determination of the spangolite structure. The cation composition is Cu_6Al per layer. The nine-site layer is suggested for an undescribed, rhombohedral copper silicate having three layers, possibly Cu_6Al_2 (one site vacant), normal to the 21.27 Å trigonal axis. The twelve-site layer, with composition Cu_9Al (two sites vacant), is suggested for chalcophyllite. Six layers normal to the 57.4 Å trigonal axis require a different linkage to anions than that in spangolite.

Devillite may have layers of eight non-trigonal sites. Clinoclase has a 7.12 Å spacing but requires more sites than a single layer can accommodate. Antlerite has ribbon-like units related to sheet structures.

POLYTYPISM IN BIOTITES

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Single-crystal studies, by means of the Buerger precession camera, of 42 individual crystals of an oxybiotite from the brecciated margin of a rhyodacite lava flow at Ruiz Peak, N. M. show that the specimen contains approximately one-third 1M, one-third $2M_1$, and one-third more complex polytypes. Among the complex forms, 4- and 20-layer monoclinic, 8- and 14-layer triclinic, a probable 10-layer monoclinic, and probable 3-, 23-, and 25-layer triclinic polytypes were found. Three of the multilayer types are excellent examples of structures with a periodic stacking fault. These structures are based on a 1M sub-cell with probably every n-th layer ($n=8$, 14, and 25) faulted. Biotite samples from Idaho, Alaska, Canada, and N. Ireland, of both igneous and metamorphic occurrence, show a similar mixture of polytypes. A well-crystallized 3-layer triclinic form was found in the specimen from Newcastle Co., N. Ireland. The apparent continuous or semi-continuous streaking parallel to c^* which appears in the precession photographs of some of the biotite crystals can be explained by the presence of a number of periodic stacking faults or by a stacking fault having a very large repeat distance. These studies suggest that, in general, biotite specimens may be composed of more than one polytype or a complex mixture of many polytypes. The identification of biotite polytypes by x-ray powder techniques may thus be invalid. Crystal structure analyses of the 1M, $2M_1$, and 4M oxybiotite polytypes are in progress as well as interpretation of probable stacking sequences and twinning relationships of the more complex forms.

HYPABYSSAL ALKALINE BODIES AND STRUCTURE OF PART OF THE NORTHWESTERN CRAZY MOUNTAINS, MONTANA

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The Crazy Mountains have been studied by Weed, Iddings, Pirsson (1894–98) and Wolff (1938). They include calc-alkalic stocks (?) plus other intrusives and alkaline sills, laccoliths, phacoliths, dikes and other discordant bodies. The present area of 55 square miles was mapped (1:20,000) in 1962–63 as typical for the alkaline bodies. Rock types include malignites, lamprophyres, nepheline syenites, monzonites, andesites and their variants. Principal minerals are aegirine-augite, augite, anorthoclase, sodic plagioclase, nepheline, analcite, sodalite, sodic amphiboles and micas. Pseudoleucite is associated with malignites.

Maximum intrusion occurred with folding and faulting, followed by an andesite-trachyandesite dike swarm. From west to east are a south-plunging syncline, and anticline with a steep eastern flank followed by a southeast-dipping homocline. Alkaline microsyenites and malignites occur as concordant bodies, north-trending dikes and other discordant bodies in the syncline and anticline. The microsyenites were intruded later than the associated malignites. Phacolithic bodies and other features indicate that folding occurred with successive intrusion. On the homocline a sill series strikes southwest. The sills are predominantly porphyritic microsyenites to micromonzonites, often with interstitial quartz. Toward the northern stock (?) sills are more numerous and sedimentary septa thinner.

In the central and eastern parts of the area a radiating dike set curves north to northwest. The dikes in the north center have petrological affinities with the alkaline rocks to the west (with exceptions). To the southwest radiating dikes include, in order of intrusion, camptonites, basaltic andesites and trachyandesites and focus on the southern stock. One camptonite dike is cut by the southwest-trending sill-set and was offset along bedding planes as folding and sill intrusion occurred. This sill set, in turn, is cut by composite andesite-trachyandesite dikes. Field and petrologic studies are being continued.

QUANTITATIVE PREDICTION OF MINERAL STABILITY

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Relations between chemical bond type and configuration and expected physico-chemical behavior of the silicates are outlined. It is suggested as a first approximation that the covalent bond energies, except for small differences, are independent of the silicate and other partially covalent mineral phases. Covalent and overlap repulsive energies may be largely ignored when deducing stability relations of minerals.

Combining Coulomb energies with appropriate corrections makes possible quantitative prediction of stability relations of minerals. Melting and decomposition temperatures of some minerals including corundum and quartz have been calculated from the binding energies. Agreement between calculated and observed melting points is exceptionally good when covalency, radius-ratio, and coordination effect corrections are made to the Coulomb binding energies. Employing the binding energies of four minerals: pyrophyllite, talc, montmorillonite, and muscovite-like pyrophyllite, it was found that the agreement between calculated energies, and the energies inferred from observed chemical behavior, was good only when the charges on the ions were reduced to account for covalency. Thermal stabilities of some phyllosilicates are predicted semiquantitatively. Calculated energies show that the stability of montmorillonite with respect to other phyllosilicates in most low-temperature geochemical environments is probably the result of hydration of the interlayer space. Also, when small amounts of magnesium are in a silicate system montmorillonite is the phase which minimizes the total energy of the system.

First results of energy calculations on an investigative level are very encouraging, and efforts should be made to improve the quality of the approximations.

XANTHOPHYLLITE FROM THE TOBACCO ROOT MOUNTAINS, MONTANA

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Xanthophyllite is found as large, deep green, tabular, pseudohexagonal crystals directly associated with diopside, serpentine, spinel, and calcite. In addition, the deposit contains idocrase, grossularite-andradite, and vermiculite. The xanthophyllite-bearing deposit comprises predominantly an irregularly-shaped body of light-green, aphanitic serpentine, 22 feet by approximately 42–50 feet, enclosed within a diorite stock. The *x*-ray powder data agree with published data except that this material shows a good (001) reflection not reported previously. The unit cell constants are: $a=5.19$, $b=9.00$, $c=9.80$ Å, $\beta=100°08'$;

$a:b:c=0.577:1:1.089$. Measured specific gravity (pycnometer), 3.15; hardness, $4\frac{1}{2}$ on cleavage (001), $5\frac{1}{2}$ on (hkO)·$\alpha=1.647$, $\beta=1.659$, $\gamma=1.660$; $2V=6–18°$; (−). The formula calculated from a chemical analysis is $Ca_{1.19}Mg_{2.94}(Al_{2.30}Si_{1.61})_4O_{10}(OH)_2$.

STRUCTURE OF A SYNTHETIC LITHIUM-FLUOR MICA[1]

HIROSHI TAKEDA AND J. D. H. DONNAY *The Johns Hopkins University, Baltimore, Maryland.*

Taeniolite, $K(Mg_2Li)Si_4O_{10}F_2$, was synthesized by the Mycalex Corporation of America for Dr. H. S. Yoder, Jr., who kindly provided the sample. The bulk composition of a fraction consisting of only clear hand-picked crystals is $K_{0.86}(Mg_{2.26}Li_{0.54}Al_{0.08})(Si_{3.83}Al_{0.17})O_{10}F_{2.03}$ (J. L. Miller, Jr., U. S. Bureau of Mines, Norris, Tenn.). The crystal structure has been determined in space group $C2/m$, using counter data for 62 okl reflections and photometer data of integrated Weissenberg photographs for 512 observed hkl reflections. The cell dimensions are $a=5.31$, $b=9.21$, $c=10.13$ Å±0.3%, $\beta=100°\ 1'\pm 10'$, rather close to those of fluorphlogopite. Least-squares refinement (using Busing *et al.*'s program) letting multipliers for atomic scattering factors vary, indicates more Mg than shown by the chemical analysis and some Li enrichment in position *2c*. Using the bulk composition and all hkl reflections, R=0.094 and the temperature factor of (Mg, Li) in position *4h* is 0.18; whereas, with the derived chemical formula R=0.085 and the above temperature factor increases to 0.65. The average (Si, Al)-O distance is then found to be 1.65 Å. This value is large enough to give support to the increased Al/Si ratio for the tetrahedral sites, which is necessitated by the raise in Mg content, since the total cation charge is kept constant. The distance (Mg, Li)-F is 2.03 Å, only 2% shorter than the distance (Mg, Li)-O which is 2.07 Å. The two sets of K–O bond lengths average 2.99 and 3.28 Å.

THE CRYSTAL STRUCTURES OF THE ZEOLITE FERRIERITE

PHILIP A. VAUGHAN, *Rutgers, The State University, New Brunswick, New Jersey.*

Ferrierite is a zeolite mineral which occurs at Kamloops Lake, British Columbia. I have determined the crystal structure of this mineral. The unit-cell dimensions are $a=19.156$ Å, $b=14.127$ Å, and $c=7.489$ Å, and the space group is *Immm*. An analysis of the sample (by the Norton Company) shows that the unit-cell content is very nearly $Na_{1.5}Mg_2Si_{30.5}Al_{5.5}O_{72}\cdot 18H_2O$.

Refinement consisted of three three-dimensional Fourier syntheses and six cycles of least squares. The part of the unit-cell content which is established as having crystallographic periodicity is $Si_{30.5}Al_{5.5}O_{72}\cdot 2Mg(H_2O)_6$. The sodium ions and remaining water molecules are located somewhat randomly in the large channels which exist in the structure parallel to the *c* axis. These channels are formed by rings of ten tetrahedra, and, with allowance for the van der Waals radius of oxygen, are roughly elliptical in cross section, with major and minor diameters of 5.4 and 4.3 Å.

As expected, the $M_{36}O_{72}$ framework consists of corner-sharing tetrahedra. The average (Si, Al)-O distances in the four crystallographically distinct tetrahedra are 1.615, 1.623, 1.597, and 1.596 Å. Thus, the Al atoms are presumed to be randomly distributed.

The $Mg(H_2O)_6^{2+}$ ions are located in cavities in the structure centered at OO 1/2 and 1/2 1/2 O. These cavities are connected to the main channels by 8-membered rings which are perpendicular to the *b* axis. These windows have dimensions of 4.6 by 2.8 Å and do not permit passage of the $Mg(H_2O)_6^{2+}$ ions.

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DIAMOND DISC PREPARATION OF POLISHED THIN SECTIONS FOR THE ELECTRON MICROPROBE

Paul Weiblen and Donald E. Cadwell, *Minnesota Mining and Manufacturing Company, St. Paul, Minn.*

Photomicrographs are presented of polished thin sections of: (1) Sudbury, Ont., ore, (2) Duluth gabbro, (3) Minnesota granulite gneiss with magnetite-ilmenite, (4) friable volcanic rocks, (5) Ajo porphyry copper ore, and (6) Homestake quartz-gold ore.

Preparation of the sections begins with diamond core-drilling of the rock specimen, grinding a circular cross section of the core with Diamond Discs, then vibratory polishing in two stages, the first with 6-micron diamond, and the second with 0.1-micron alumina. We cement the polished face to a ground slide, then saw off the thin section and grind it to final thickness on the Ingram thin section saw and grinder respectively. The standard wheel of the grinder is replaced by either Coarse or Extra Fine grade Diamond Discs, and the drive modified to provide variable speed in order to optimize performance of both grades. The finished section must be transferred to a transparent slide.

This method routinely and relatively quickly produces low-relief sections of the high quality required for electron probe microanalysis.

REGRESSIONS OF REFRACTIVE INDICES, DENSITY, AND LATTICE CONSTANTS ON THE COMPOSITION OF ORTHOPYROXENES

Horace Winchell and Bernard E. Leake, *Yale University, New Haven, Connecticut*

Regression formulas probably yield the best estimates now available for the properties of end-members and of other interesting compositions.

Regression-estimates of properties for some interesting compositions

	Enstatite			Hypersthene			Orthoferrosilite		
	$Mg_2Si_2O_6$	+Al[a]	+Al, Ca[b]	$FeMgSi_2O_6$	+Al[a]	+Al, Ca[b]	$Fe_2Si_2O_6$	+Al[a]	+Al, Ca[b]
α	1.6518± .0049	1.6505	1.6506	1.7115	1.7102	1.7085	1.7725	1.7682	1.7665
β	1.6562± .0031	1.6596	1.6607	1.7268	1.7302	1.7292	1.7840	1.8746	1.7836
γ	1.6621± .0017	1.6662	1.6671	1.7269	1.7310	1.7299	1.7926	1.7935	1.7924
G	3.216 ± .011	3.224	3.232	3.602	3.609	3.606	3.988	3.976	3.972
a	18.2448± .0071	18.2344	18.2344	18.3297	18.3193	18.3167	18.4637	18.4466	18.4441
b	8.8328± .0088	8.8084	8.8084	8.9374	8.9130	8.9099	9.1600	9.1245	9.1214
c	5.1834± .0023	5.1815	5.1823	5.2134	5.2114	5.2113	5.2575	5.2533	5.2532

Notes: [a] 0.10 Al; [b] 0.10 Al and 0.03 Ca.

These estimates agree with published values for similar compositions, but regression-estimates, for which standard errors can be calculated, are probably the best because they take into account all data (not just the Fe/Mg ratio, for example, assuming all other elements constant) for a large number of analyzed samples. Tables of the regression coefficients have been prepared for preliminary distribution. They show, for example, the amounts to be added to the above estimates for $Mg_2Si_2O_6$ to allow for substitutions of the several elements (Al, Fe^{3+}, Ti, Fe^{2+}, Mn, Ca, Na) in appropriate positions of the pyroxene formula ABC_2O_6.