SELECTED AUTHORS' ABSTRACTS

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BLASTOPOIKILITIC TEXTURES IN GABBROIC META-ANORTHOSITE OF THE DORE LAKE COMPLEX, CHIBOUGAMAU

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The Dore Lake Complex is an exceptional stratiform intrusion. Greenschist metamorphism of the complex produced rocks unusual in their mineralogy and excellently preserved original textures. The meta-anorthosite and gabbroic meta-anorthosite members consists of cumulus plagioclase replaced by albite and zoisite and intercumulus pyroxene replaced by chlorite or actinolite. In McKenzie township, the pyroxene poikocrysts are replaced by angular patches of chlorite. A pronounced alignment of microscopic grains of sphene in many disconnected patches of chlorite represent the original cleavage and/or exsolution direction of the pyroxene. In Rinfret township, labradorite shows little alteration but pyroxene is completely replaced by actinolite and minor chlorite. The actinolite is arranged in parallel laths, 0.09 mm wide and 2 to 3 mm long, made up of one or more unoriented crystals. The common orientation of the laths is up to 25 cm long and represents original poikilitic pyroxene. The general alignment of the laths probably identifies an original cleavage and/or exsolution direction in the pyroxene poikocryst. The influence of cleavage in isochemical metamorphism is clearly demonstrated.

THE ORIGIN OF BANDING IN THE MAIN DONEGAL GRANITE, IRELAND

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A salient feature of this Caledonian pluton is a regular, sub-vertical banding in which layers of dark, relatively fine-grained trondhjemite alternate with light coarse-grained granite layers. The presence of cross-cutting bands of light band composition and mineralogical studies both indicate that the light bands were derived by potash feldspathization of a parent of dark band composition. Sedimentation features are absent, and the geometry of the banding indicates that it results from the deformation of the pluton, largely in situ. The model proposed is one of segregation of alkalies into dilatant zones of differential movement produced during the deformation of a partly consolidated magma.

HARRISTITIC STRUCTURE IN THE GABBRO AT NAHANT, MASSACHUSETTS

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Arborescent aggregates of augite surrounded by calcic plagioclase resemble the harrisite structure on Rhum. These tree-like aggregates are composed of large pyroxene grains, up to two inches long, and extend inward from the border of a band in the Nahant Gabbro. The long axes of the pyroxene grains, as well as the arborescent forms, are roughly perpendicular to the attitude of the rythmic banding. Chemical, textural and petrographic investigations indicate that, during the formation of the arborescent structures, fractional crystallization occurred in an under-cooled magma of low viscosity. The crystallization of the pyroxene was followed by separation of the feldspar-rich halo which preceded eutectic crystallization of the holocrystalline gabbro which forms the upper part of the band. Although this structure has been noted in only one band at Nahant, a Maine locality exhibits two successive bands showing the arborescent or pyroxene-harrisite structure.

THE DETERMINATION OF THE LOW TEMPERATURE PLAGIOCLASE FELDSPARS BY PEAK HEIGHT MEASUREMENT

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Present *x*-ray powder diffraction methods for the determination of members of the low temperature plagioclase feldspar series are sometimes complicated by the need for knowledge of the geologic environment of the specimens analyzed. An attempt has been made to develop a method for the determination of the low temperature members of this series which is independent of geologic environment. The peak heights of selected *x*-ray powder diffractions for a number of low temperature plagioclase feldspars from different (in some cases unknown) geologic environments have been measured and related to anorthite content. The anorthite content of the specimens has been determined by chemical, independent *x*-ray powder, and optical methods. Twenty partial diffractograms of each of the specimens were made using two different sets of ratemeter-goniometer scan conditions. Peak heights of the selected diffractions were measured directly from the diffractograms and expressed in counts per second. Peak height data for the selected diffractions has been plotted versus the anorthite contents of the specimens using an I.B.M. 1620 computer equipped with an X–Y plotter. Best fit (least squares) parabolic curves have been drawn by the plotter using peak height and anorthite content data.

ON THE REALISTIC USE OF Rb-Sr ISOCHRON REGRESSION TREATMENTS

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An empirical investigation of the three regression treatments commonly employed in reducing isochron data (McIntyre *et al.*, York, and Wendt treatments), reveals that they calculate similar slope (age) and intercept (initial Sr^{87}/Sr^{86}) estimates, but dissimilar errors in these estimates. Hence any application of these treatments (together with a fourth, Terd model, this investigation), must involve consideration of the shortcomings of the models. It is demonstrable that the use of indexes such as (*i*) the McIntyre *et al.* mean square of weighted deviates, (*ii*) the precision of the experimental errors to be assigned to the data, (*iii*) the number of samples to be regressed, (*iv*) the range in Sr^{87}/Sr^{86} and (*v*) the range in Rb^{87}/Sr^{86}, will allow calculation of the most realistic isochron parameters. Providing that these parameters make allowance for small sample theory and adequate levels of confidence, then meaningful predictions may be made concerning the parent geological unit or body.

THE INITIAL Sr^{87}/Sr^{86} OF MICHIPICOTEN GREENSTONES AND ITS BEARING ON THE DEVELOPMENT OF THE MANTLE

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A Rb-Sr investigation of the geologically well documented Algoma District of the Michipicoten Area, reveals that the field distinction between the upper and lower

greenstones in that district is substantiated by significant differences in initial Sr^{87}/Sr^{86} ratios (at the 95% level of confidence). Values of 0.7028 ± 0.0003 for the upper and 0.7013 ± 0.0003 for the lower volcanics were obtained from isochrons based on seven and nine samples respectively. The isochrons displayed no significant difference in age however at the 95% level of confidence. Despite widespread metamorphic up-grading of both series of greenstones, this difference in initial Sr^{87}/Sr^{86} can be interpreted as reflecting a primary difference in the source region of the volcanics. If that source region is taken to be the upper mantle, this would imply differentiation in the mantle prior to approximately 2.7 b.y..

NEW MINERALS FROM AN UNUSUAL ANTIMONIAL ASSEMBLAGE FROM THE RED LAKE AREA, ONTARIO

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Two new minerals, CoSbS and $NiSb_2$, have been found in ore from the Red Lake area, Ontario. These minerals have compositions very close to stoichiometric CoSbS and $NiSb_2$ as determined by an electronprobe microanalyser using pure synthetic standards. The *x*-ray powder pattern of natural CoSbS corresponds to that of the synthetic equivalent. Synthetic CoSbS melts incongruently at about 876 ± 5°C, while synthetic $NiSb_2$ was found to melt incongruently to form Sb-rich NiSb + liquid at about 621 ± 5°C. The CoSbS mineral is far more abundant than $NiSb_2$ and they occur in ore which consists principally of pyrrhotite, sphalerite, chalcopyrite, and galena. Other opaque minerals associated with these new minerals, or occurring elsewhere in the ore, are antimonial silver, ϵ-phase (Ag with approx. 16% Sb), gudmundite, argentian tetrahedrite, cobaltite, pyrargyrite, arsenopyrite, stannite, ilmenite, breithauptite and marcasite.

NUCLEATION OF BIOTITE IN A COOLING TINGUAITE DYKE

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Kahlweit (1965) has shown that the number of nuclei formed, Z, of a phase can be related to the rate of cooling, T, of a supercooled solution by $Z = f(T^n)$, where n is determined by the growth process involved. The variation in Z of biotite across a 2.8 m wide dyke, in the metamorphic aureole around Mount St. Hilaire, a Monteregian Hill, yields two values of n: $n = 0.4$ close to the margin and 2.5 near the centre of the dyke, indicating two different growth mechanisms of biotite. Small, needle-like crystals of biotite close to the margin and larger, subhedral grains toward the centre support this conclusion.

THE REPLACEMENT OF CARBONATE PORPHYROBLASTS DURING PROGRADE METAMORPHISM IN THE WHETSTONE LAKE AREA, ONTARIO

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In biotite-zone calcareous schists of the Whetstone Lake area, southeastern Ontario, calcite and ankerite occur as rhomboidal porphyroblasts, up to several millimeters across and commonly free of silicate inclusions. With increasing metamorphic grade, both carbonates are involved in complex metamorphic reactions leading to the formation of oligoclase and epidote. One such reaction is of the form

$$\text{Albite} + \text{chlorite} + \text{muscovite} + \text{calcite} + \text{quartz} \leftrightarrow \text{oligoclase} + \text{biotite} + H_2O + CO_2$$

During the course of this reaction, rims of oligoclase and biotite form around the margins of the calcite rhombs. The calcite itself, however, is gradually replaced by clear quartz grains, sometimes with euhedral terminations, which ultimately coalesce to form equigranular mosaics with rhomboidal outlines. In order to explain this localized *growth* of quartz during the course of a metamorphic reaction that *consumes* quartz, it is postulated that the negative free energy change of the reaction induces an osmotic pressure gradient between the carbonate rhombs and their surrounding matrix, so that quartz dissolves in the matrix of the rock, and diffuses toward the porphyroblasts in sufficient quantity to form the oligoclase-biotite reaction rims and also to replace the calcite sovolumetrically.

MINERALOGY AND PETROLOGY OF TWO PEGMATITE TYPES IN ULTRAMAFITES, WESTERN MORAVIA, CZECHOSLOVAKIA

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Most alpine-type peridotites from meso- and katametamorphosed regions of eastern Moldanubicum are unconformable with enclosing schists. Their tectonic emplacement during regional dynamometamorphism was followed by equal-volume serpentinization in lower-grade, static environment. Magnesium outflow produced bands of chlorite and saponite in adjacent rocks, sometimes accompanied by zeolitization. Early pegmatites compose complicated stockworks in brecciated zones of the ultramafites. They are almost unzoned, consisting of plg or plg + q with occasional K-feldspar or corundum. Accessory minerals are rare, feldspars are rich in Ba, Sr. Early pegmatites underwent the same Mg-metasomatism ± zeolitization as the country rocks. They originated during regional metamorphism from fluids mobilized in acid country rocks and concentrated into the fractured peridotites. Infrequent late pegmatites form larger lenticular bodies with well-developed internal zoning, metasomatic units, and accumulations of Ti, Nb, Ta, Be, Li-minerals. The feldspars are poor in Ba, Sr, but sometimes enriched in Rb. These pegmatites crosscut the early chloritized veins but themselves are unaffected by this Mg-metasomatism. Their ultimate origin is not known, but should be distinctly later than serpentinization and preceding regional processes.

ORIGIN OF THE OLDER GRANITOID ROCKS OF GLAMORGAN TOWNSHIP, ONTARIO

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Of the three types of Grenville province granitic rock found in Glamorgan township the oldest is trondjhemitic in composition. It occurs principally as a well foliated gneiss and as conformable bands in migmatite. The average composition (based on 22 analyses) is 72.2% SiO_2, 0.4% TiO_2, 14.0% Al_2O_3, 1.6% Fe_2O_3, 1.5% FeO, 0.1% MnO, 0.7% MgO, 1.8% CaO, 4.8% Na_2O, 2.3% K_2O. Variation diagrams show a linear trend between the compositions of trondjhemitic gneiss and equivalent bands in migmatite at the acid end, and non-granitic bands in migmatite at the basic end. Local paragneiss compositions are intermediate in this trend. Several lines of evidence indicate that the most likely origin for the trondjhemite is by anatexis of paragneiss.

IRON OXIDE DEPOSITS OF THE INDIAN HEAD RANGE IN WESTERN NEWFOUNDLAND

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Rocks of Grenville age (900 m.y.) outcrop in western Newfoundland as an inlier in Palaeozoic sediments; they form the Indian Head Range near Stephenville. The rocks of the Range are of three principal types: anorthosite, pyroxene gneiss, and granitic gneiss. Lenses of iron oxide minerals (magnetite, hematite and ilmenite) are found in both the basic and granitic gneisses. The basic pyroxene gneiss and the iron oxide lenses may be genetically associated with the anorthosite. Some of the pyroxene gneiss has been granitized but the included iron oxide lenses have remained unassimilated. Measurement of titanium content in coexisting magnetite-ulvospinel and hematite-ilmenite can be used in conjunction with experimental work (Buddington and Lindsley, 1964) to demonstrate changes in temperature and oxygen pressure. A temperature gradient during metamorphism can be shown to exist; varying oxygen pressure can be correlated with variations expected in water pressure between granitic gneisses with hydrous minerals and basic gneisses consisting of anhydrous minerals.

CHEMICAL AND MINERALOGICAL ASPECTS OF SUBMARINE FERROMANGANESE DEPOSITS

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Analyses of over one hundred manganese nodules and encrustations from the Pacific and Indian Oceans show that their mineralogy and chemical composition varies both areally and with their depth of formation. This is partly the result of variations in the degree of oxidation of the environment in which the deposits were formed. Such variations determine both the nature of the minerals present in the deposits and the abundances of elements able to exist in more than one valency state. Other elemental variations can be related to the sources of the elements concerned and diagenetic processes operating on the sea floor.

A COMPARISON OF THE ALKALINE CARBONATITE COMPLEXES AT BRENT AND CALLANDER BAY, ONTARIO

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Both complexes are marked by almost circular depressions about 2 miles in diameter surrounded by fractured and fenitized Precambrian rocks. The outermost zone of fenitization is marked by shattering of the country rocks, presence of vein cryptoperthite, and fine veining of hematite, carbonate and Na pyroxene and/or amphibole. More strongly fenitized rocks display soda pyroxene or amphibole replacing quartz, and an increase in the amount of cryptoperthite at the expense of plagioclase. In intensely fenitized rocks the original texture is completely lost, and soda pyroxenes and amphiboles replace all dark minerals. Quartz and plagioclase are rare or absent. These rocks commonly display plastic deformation and grade in texture and composition to rocks of igneous appearance. A reddish colour is characteristic of all the fenites. Drilling in both craters has shown that they are filled with complexly brecciated material, interspersed with thin screens, or lenses of rocks of igneous appearance. The fenite zones are cut by complex basic alkaline dikes, often composed of heterogeneous fragments. The Brent and Callander Bay complexes are spectacular manifestations of a Paleozoic alkaline igneous province stretching more than 100 miles along the Nippissing graben.

GEOCHEMISTRY OF SOME GRANITIC ROCKS

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An hybrid series of Hecynian granitic rocks, from Northern Portugal, ranging from tonalite to granite, shows a distribution of major and trace elements paralleling those observed in normal calc-alkalic series. The granites probably originated by partial melting, followed by reaction with former basic material to form the intermediate types. The geochemistry of the rock-forming minerals brings some evidence in support of these hypotheses.

THE DISTRIBUTION OF CARBON AND OXYGEN ISOTOPES IN THE CARBONATES OF THE OKA CARBONATITE, QUEBEC, CANADA

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The Oka Complex is a carbonatite belonging to the alkaline intrusive suite of the Monteregian petrographic province. The carbon and oxygen isotopic composition of carbonates from this complex have been determined and found to vary over 7‰ in the case of carbon and about 13‰ in the case of oxygen. The mode of the δC^{13}–δO^{18} distribution for the carbonatite lies at $\delta C^{13} = -5.0$‰ *vs.* PDB and $\delta O^{18} = +7.4$‰ *vs.* SMOW. The observed isotopic composition distribution pattern could not be related to weathering or hydrothermal alteration. The carbon and oxygen isotopic composition frequency distributions of 650 samples are highly skewed towards increasing C^{13} and O^{18} concentrations. The δC^{13} frequency distribution may be interpreted in terms of a Rayleigh fractionation model, characterized by a fractionation factor of 0.9993, starting with a slightly inhomogeneous reservoir which can be represented by a mean isotopic composition of $\delta C^{13} = -4.8$‰ and a standard deviation of ±0.3‰. Dolomites and lamprophyres show heavier carbon isotopic compositions than the rest of the carbonatite rocks and contribute most to the observed skewness of the carbon isotopic composition frequency distribution. The C^{13} concentration of the calcites from the carbonate rocks was found to be slightly lower than that of calcites from the silicate rocks. Small local differences in the carbon isotopic composition exist in the complex and the C^{13} content decreases systematically towards the contacts with a gradient of about 0.25‰ per thousand feet. The variability in the O^{18} content is in excess of what would be expected on the basis of a Rayleigh fractionation process, and it is suggested that part of the increased variability may be due either to isotope exchange with, or incorporation of, the host gneisses. The mean oxygen isotopic composition of the sovites and rauhaugites shows a distinctly lower O^{18} content and smaller variability than the oxygen isotopic composition of carbonates from the silicate rocks. The O^{18} content increase in the carbonates from different rock types in the following sequence: carbonate rocks < ijolites and lamprophyres < okaites < rocks of possible metasomatic origin < fenites. General fractionation trends are outlined for the carbonatite complex; trend interpretations are however tentative because systematic isotopic composition effects are small.

STRUCTURE OF THE BRENT CRATER, ONTARIO

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The structure and origin of Brent Crater, Algonquin Park, a circular depression 2,900 m in diameter set in acidic Grenville gneisses, has been investigated by detailed geophysical, geological and diamond drilling investigations. Ordovician sedimentary rocks 300 m thick within the crater are underlain by a 610 m thick lens of allochthonous breccias, of which the upper and lower 120 m show strong shock metamorphism including melting. Hydrothermal alteration is general but alkali metasomatism is confined to the highly shocked rocks. All deformation and alteration dies out at depth in the gneisses underlying the breccias. The crater structure and petrology are explained by hypervelocity impact with an energy of about 10^{25} ergs, forming a deep ejecta void followed by extensive slumping.

THE DIFFERENTIATION OF AGPAITIC MAGMAS: THE ILIMAUSSAQ INTRUSION, SOUTH GREENLAND

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In the nepheline- and sodalite-rich rocks of the Ilimaussaq intrusion alkalies are in excess of alumina and total Fe, Zr, H_2O, Cl and F is high with a corresponding paucity of Ca and Mg. Furthermore Na is considerably in excess of K. The major chemistry has resulted in the agpaitic suite of minerals developing. The fractionation trend displayed by the K:Rb ratio shows a remarkably strong correlation with the chronology determined from the field evidence. Other ratios used include Sr:Ca, Ba:Rb, Ti:Zr, Ti:Nb and Zr:Nb. In general these ratios conform to established behaviour patterns during fractionation; an exception is the Zr:Nb ratio which increases with fractionation.

BROWNIAN MOVEMENT IN QUARTZ

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Quartz from mineralized specimens taken at the dumps of the Dunbrack Prospect, Musquodoboit River, Halifax Country, Nova Scotia, contain fairly plentiful liquid inclusions. Some of these liquid inclusions show, at moderately high magnification, moving gas bubbles. The diameter of the moving gas bubbles is in the order of 1μ. A film has been made by the Audio Visual Department, Dalhousie University (D. A. Gibson, D. Pike) of two such observations. The diameter of the bubble in the first frame (6804) is approximately 0.7μ. In the second frame (6817), a number of moving bubbles appear successively on different levels of the thin section. The diameter of these bubbles lies between 0.7 and 0.2μ. The mobility of the smaller bubbles is distinctly greater than that of the larger bubbles. The communication consists essentially in the presentation of the film.

CHEMICAL VARIATIONS AMONG THE AMPHIBOLES OF SHEFFORD MOUNTAIN, A MONTEREGIAN INTRUSION IN SOUTHERN QUEBEC

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The amphiboles in a suite of eleven rocks from the differentiation sequence alkalic gabbro-diorite-monzonite-feldspathoidal and quartz syenites, in the Monteregian intrusive complex of Shefford Mountain, have been analysed with the electron microprobe. With decreasing Mg/Mg + Fe + Mn in the amphiboles, which correlates overall with decreasing basicity of the host rocks, the amphiboles become poorer in Ti, Al and Ca and richer in Mn; enrichment in Na becomes apparent in the amphiboles of the syenites. Fluctuations in these trends is notable among the brown amphiboles of the earlier stages of differentiation and are probably attributable to variations in chemical and physical conditions of crystallization of the magma. The characteristic amphibole of the gabbros and diorites is kaersutite, which, in the monzodiorites and monzonites, becomes increasingly zoned to greenish hastingsite. In the feldspathoidal syenites, the amphibole is ferrohastingsite, whereas in quartz syenite, it is arfvedsonitic, containing very little calcium but less sodium than true arfvedsonite. The kaersutite → hastingsite → ferrohastingsite transformation represents a continuous reaction series. It could not be determined if the change from ferrohastingsite to arfvedsonitic amphibole is continuous but the transitional nature of the product suggests limited solid solution between the hastingsite and alkali amphiboles.

TRANSITION ELEMENT DISTRIBUTION AMONG ORTHOPYROXENE, CLINOPYROXENE AND HORNBLENDE IN BASIC GRANULITES

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Metamorphism of a layered norite-pyroxenite sill from Dumbleyung, southwest Australia has resulted in a two pyroxene-hornblende-plagioclase granulite. Nernst distribution coefficients of Sc, T, V, Cr, Mn, Co, Ni, Cu, and Zr among the three mafic mineral phases suggest equilibrium between clinopyroxene and hornblende, but not always between these minerals and orthopyroxene. The degree to which equilibrium is reached is related to the different bond energies of the trace elements. The attainment of equilibrium is limited by the diffusion rates of the trace element and does not operate over distances of more than a few centimeters. The distribution of the transition elements with unfilled *d* orbitals is compatible with that predicted by crystal field theory. Those elements not stabilized by crystal field effects show distributions that agree with Nockolds' total single valence bonding energy values.

CALCULATED PHASE DIAGRAM OF THE SYSTEM $CaCO_3$–$SrCO_3$

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The two compounds $CaCO_3$ and $SrCO_3$ both exhibit an orthorhombic ↔ rhombohedral transition, and, in the system $CaCO_3$–$SrCO_3$, orthorhombic and rhombohedral solid solutions may coexist over a considerable range of pressure and temperature. From existing experimental data, it is possible to derive ΔV and ΔS of the transitions in pure $CaCO_3$ and $SrCO_3$, if it is assumed that these values remain constant and that the solid solutions are ideal. On the basis of the same assumptions, the derived values of ΔV and ΔS may be used to calculate the composition of coexisting solid solutions at any combination of pressure and temperature. In this way, experimentally determined phase relations may be extrapolated to conditions at which no experimental data are available.

LE DIAGRAMME LOGIQUE DE LA NORME C. I. P. W.

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Le diagramme logique, issu du programme du calcul électronique de la norme C.I.P.W., réalisé par Gélinas et Sisi permet une compréhension plus facile du calcul manuel de la norme. Un texte basé sur ce diagramme logique explique toutes les étapes des calculs. De plus des tableaux appropriés permettent de compiler les résultats. Cette méthode de calcul manuel a été éprouvée lors d'exercices de laboratoires de pétrologie. Les incompatibilités minéralogiques deviennent apparentes au simple examen du cheminement des analyses chimiques des roches alcalines et calco-alcalines. Enfin, le schéma est très utile pour déterminer les minéraux virtuels substituts des micas et des amphiboles.

ORIGIN OF ARSENIC-ANTIMONY MINERALIZATION NEAR MORETON'S HARBOUR, NORTHERN NEWFOUNDLAND

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Basic volcanic rocks of Ordovician age near Moreton's Harbour, Newfoundland (pillow lavas, massive flows, and pyroclastics) are intruded by numerous basic and acid dykes. The rocks are cut by a network of thin veins containing abundant arsenopyrite and some stibnite, associated with pyrite, pyrrhotite, and minor sphalerite, galena and chalcopyrite. In a few veins, stibnite predominates. Both arsenopyrite and stibnite veins have been mined on a small scale for their associated gold content. The widespread arsenopyrite has been used to determine P–T conditions of formation of the veins, applying the methods of L. A. Clark and A. H. Clark. *X*-ray diffraction analysis of 30 specimens shows that the arsenic content of the arsenopyrite varies between 30 and 34 atomic % ($d(131)$ spacing from 1.6301 to 1.6338 Å.), indicating that the probable temperature range of crystallization extended from about 600° to 420°C under confining pressures of 2000 bars. Two periods of arsenopyrite are indicated. The As-Sb veins are related structurally to the acid dykes (the most competent rock in the area) and genetically to granodioritic intrusive rocks of Devonian age outcropping three miles east of Moreton's Harbour.

DIATREMES IN THE MONTREAL-OKA AREA

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Diatremes are common in the western part of the Monteregian petrographic province. About 90 per cent of the known diatremes are located within 5 miles of the Oka carbonatite complex. Most are associated with alkali ultramafic rocks of Monteregian age (110 m.y.) and affinity, and are formed by the outgassing of carbonate-rich alnoite and/or kimberlite magmas at depth. They occur in small pipes, fissures, and dykes, as polymict breccias in a comminuted country rock matrix, as carbonatitic breccias (polymict fragments in a matrix of either calcite, dolomite, or ankerite), as tuffisite breccias (lapilli-rich with either alnoitic or kimberlitic affinities), as porphyritic mica peridotite (generally massive alnoite), and as poikilitic monticellite-phlogopite-olivine rocks. The breccia pipes have recorded the presence of rock types at the time of intrusion that have long since been removed by erosion. Extreme stratigraphic mixing (a minimum of 10,000 feet and probably as much as several miles). the presence of lapilli, polished fragments and rounded inclusions (from depth) suggest a gas-streaming or fluidization mechanism of emplacement with cell action. The polymict breccias, tuffisite breccias, alnoites, and carbonatitic breccias are thought to be genetically related in elevation. The kimberlite, and the monticellite-phlogopite peridotites probably represent derivative or distinct magma types. H_2O, F, Al_2O_3, rare earths, Nb, Sr, Ti, Zr, and Ba, poor in SiO_2, and are considered as the "pegmatitic" phase of the alkali ultramafic parent magma of probable mantle composition and origin. An initial Sr^{87}/Sr^{86} ratio of 0.7032 for the sovite, and a radiometric age of about 110 m.y., similar to the other Monteregian plutons, suggests that the complex was formed from volatile-rich differentiates of mantle material generated and outgassed in the western (deeper) part of the Monteregian belt. Pyrochlore is the main economic mineral, though bi-product apatite, magnetite, and calcite have also been exploited. The St. Lawrence Columbium and Metals Corporation produce about 7 million pounds of pyrochlore concentrates annually.

THE OKA CARBONATITE AND ALKALINE COMPLEX

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The Oka complex consists of a number of mineralogically distinct carbonate rocks (calcite-rich, sovites, and dolomite-rich, rauhaugites), melilite and titanaugite-bearing silicate rocks (okaites and jacupirangites), nephelinites (melteigites, ijolites, urtites and juvites), in two intersecting ring structures 4.5 by 1.5 miles wide. It is emplaced along the crest of the northwesterly trending Beauharnois arch, in northeast trending gneisses, quartzite and marble of the Grenville Series and layered anorthosite of the Morin Series. Marginal to the complex is an aureole of veined and metasomatically altered rocks (fenites). Late lamprophyre dykes and pipes (fourchite, alnoite, alnoite tuffisite breccia, carbonatitic breccias and polymict breccias) are intruded in a remarkably geometrical pattern about the long axis of the complex. Differentiation schemes for the silicate rocks are outlined. The alnoites are thought to represent closing phase kimberlite type volcanism, emplaced by a gas streaming pipe mechanism as diatreme breccias. Minerals characterized by cations with high ionic potential (high charge/small ionic radius) are common, especially in the carbonate rocks. The sovites are enriched in the following trace elements: F, P, S, Sc, Ti, V, Mn, Cu, Sr, Y, Zr, Nb, Ba, La, Ce, Yb, Th, U. Most minerals reflect an environment rich in alkalis, CO_2, They are all inferred to have a deep-seated origin probably associated with the Ottawa Valley graben and Monteregian fault system, but that their near surface location was strongly influenced by supracrustal control in the form of fractures associated with folding of the Beauharnois arch.

GEOCHEMISTRY OF THE CHIBOUGAMAU METAVOLCANICS, QUEBEC

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In the Chibougamau region of Quebec more than 45,000 ft of picritic and basaltic pillow lavas are intercalated by water-laid dacitic to rhyolitic tuffaceous greywacke. Subsequently the whole group have been invaded by thick noritic, pyroxenitic and anorthositic sills, isoclinaly folded in the Kenoran Orogeny and regionally metamorphosed to the greenschist facies. Emplacement of plutons and small batholiths of quartz diorite, tonalite, soda granodiorite and granite has created contact aureoles of hornblende and biotite hornfels within the metavolcanics. Chemically the predominent lava is a low-potassium olivine tholeiite similar to present day oceanic tholeiites, though picrites and icelandites are also common. The low alumina content has resulted in the early crystallization of pyroxene and in the fractionated sills this has produced extreme enrichment in soda. Fractionation trends of major and trace elements are described. The Ni, Cu, Zn contents are generally rather low throughout (10-400 ppm) and are apparently unrelated to the location of the ore bodies of the region.

A NEW COPPER SELENIDE FROM MARTIN LAKE, SASKATCHEWAN

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Electron probe analyses using synthetic Cu selenides as standards gave Cu 51.1, 52.0; Se 49.7, 44.0; S—, 2.7; sum 100.8, 99.7%, corresponding to $Cu_{5.11}Se_{4.0}$ and $Cu_{5.10}Se_{3.48}S_{0.52}$, respectively. Attempts to synthesize the mineral above 120°C failed. *X*-ray powder data are indexed on an orthorhombic cell with $a = 8.20$, $b = 12.04$, $c = 6.46$A. The strongest lines are 3.235 (10)(002), 3.015(6)(040), 1.997 (8)(060), 1.893 (5)(033), 1.817 (3)(223), 1.664 (4)(422). With $Z = 4$, calculated s.g. is 6.59. In reflected light the mineral is strongly bireflecting with colors in air ranging from light gray to bluish gray in air, like klockmannite. Anisotropy is very distinct with polarization colors (nicols crossed, in air) white to dark blue (for klockmannite light blue to bright yellow). Reflectivity values (average of 10 grains) at 4 wavelengths (470–650 nm) were max. 24.0–25.8, min. 19.2–14.6%. Micro-hardness (average of 10 grains) with a 15 g. weight were 68.8–93.5, average 78.1 kg/sq. mm. The mineral occurs as lath-shaped inclusions (up to 40 × 100 microns) in umangite, and as stringers and veins with massive areas up to 300 microns in hematite-stained carbonate vein material in basalt, from the Martin

Lake mine, Uranium City, Lake Athabasca, Saskatchewan, Canada. Associated minerals include umangite, clausthalite, berzelianite, klockmannite, eskebornite, tyrrellite, native Cu, native Ag, pitchblende, pyrite, hematite, quartz, barite, calcite, feldspar. The mineral is no. 154 in the Peacock Atlas (*Geol. Soc. Am. Mem.* **85**, 1962).

METASOMATIC POTASH FELDSPAR ROCKS ASSOCIATED WITH ALKALIC IGNEOUS COMPLEXES

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Anchimonomineralic potash feldspar rocks (orthosite, alkorthosite, orthoclasite, perthosite, trachyte, feldspathic breccia) are widespread components of alkalic-carbonatitic complexes or provinces in many localities (*e.g.*, Alnö, Sweden; Mbeya, Tanzania; Chilwa Ialand, Malawi; Rufunsa Valley, Zambia; Wet Mountains, Colorado, U.S.A.). Textures vary from granitoid to trachytoid to fragmental. Where associated directly with carbonatite, these rocks are generally older, but locally rheomorphic (?) dikes trangress carbonatite. They occur as 1) units within complexes, 2) in wall rocks adjacent to complexes, 3) as veins, dikes, pipes, and linear zones apart from complexes but within alkalic provinces. Commonly red ("burnt rock") owing to abundant minutely disseminated hematite, the rocks also may contain concentrations of rare earths and thorium (as thorite) and normally are markedly radioactive. The feldspars are turbid (owing to dusty hematite), show fine gridiron twinning, and may have relict cores of clear, older feldspar. *X*-ray determinations of their Na contents (using the $\bar{2}01$ *d*-spacing and correcting for structural state) indicate that they contain usually less than 3 mole per cent albite. Structural state, $\Delta = 12.5\ [d(131)-d(1\bar{3}1)]$, studies show that they are near-maximum microclines with a range of Δ of about 0.85–0.92. Further evidence of their low-temperature genetic environment is advanced by the co-presence of chalcedony, opal, and Schachbrett albite, and associated fluorite, barite, and quartz crystals. The rocks were formed by potash metasomatism, and are variants of fenites, representing a relatively high-level type of alteration associated especially with complexes displaying sub-volcanic or hypabyssal characteristics. The Laacher See sanidinites are their high-temperature analogs.

ALKALI-AMPHIBOLES FROM NEAR MEACH LAKE, QUEBEC

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The compositions of alkali-amphiboles are clearly represented on triangular diagrams with vertices R^{1+}, R^{2+} and V (R^{1+} and R^{2+} representing monovalent and divalent cations in the M_4, and A^1 and V vacancies in the A and A^1 structural sites). Most amphiboles from the Meach Lake aplite complex are close to the richterite-magnesian riebeckite join. Members near the edge of veins are enriched in alkalis. A rare calc-alkalic amphibole ($R^{1+} = R^{2+}$) occurs as foot-long crystals. Monoclinic dispersion schemes are useful in distinguishing magnesian from iron-rich alkali-amphiboles. The respective schemes can be explained with structural considerations.

WAKEFIELDITE, NATURAL YVO_4

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X-ray fluorescent analysis showed Wakefieldite to be composed essentially of Y and V, appreciable Fe and Si (at least partly as chlorite impurity) and minor U. The *X*-ray powder pattern was identical to synthetic YVO_4, a zircon structure. $a = 7.10$, $c = 6.30$ Å, $Z = 4$, $G = 4.26$ (calc.). Strongest lines are 4.67 (45), 3.56 (100), 2.66 (55), 2.512 (30), 2.214 (30), 1.825 Å (50). The colour is pale tan. It is optically uniaxial, positive, $\omega = 2.00$, $\epsilon = 2.14$ (synthetic). It is uncommon in Precambrian pegmatite in the Evans-Lou feldspar mine near Wakefield, Quebec with quartz, allanite, biotite, chlorite, bismutite, and unidentified rare-earth minerals.

THE CRYSTAL STRUCTURE OF TWO HEXAGONAL CHLORAPATITE

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Atomic parameters (positional, temperature and site-occupation) of two naturally occurring hexagonal chloropatites were refined by least squares method, using three-dimensional intensity data collected on a manual equi-inclination single crystal diffractometer. One chlorapatite used, from Honshu, Japan, has the composition of $Ca_{4.87}\,Mn_{0.11}\,(PO_4)_{3.01}\,(Cl_{0.55}\,F_{0.32}\,OH_{0.03})$ with $a = 9.501$ Å and $c = 6.841$ Å. The other, from Bramble, Norway, has the composition of $Ca_{4.84}\,(PO_4)_{3.06}\,(Cl_{0.88}\,F_{0.06}\,OH_{0.05})$ with $a = 9.606$ Å and $c = 6.782$ Å. 572 and 575 unique reflections were employed and yielded R-factors of 4.35% and 3.92% respectively for the Japanese and the Norwegian minerals. The basic structures are essentially the same as that of the pure Cl end member, which is monoclinic ($P2_1/b$, $b = 2a$) and has an ordered arrangement of Cl atoms. In the Norwegian chlorapatite Cl is situated at 1.25 Å from the nearest mirror plane, corresponding to the position of Cl in the pure Cl end member. In the Japanese chlorapatite Cl is situated at 0.90 Å from the mirror plane. In both minerals Cl atoms are disordered as required by symmetry. F in the Japanese mineral and OH in the Norwegian mineral were found to occupy positions corresponding to those of F and OH in fluorapatite and hydroxyapatite respectively, F being on the mirror plane and OH, 0.34 Å off the mirror plane. Thus Cl, F and OH are not diadochic in the apatite structure. It may be shown geometrically that the introduction of F or OH in the chlorapatite is accompanied by the introduction of chlorine "vacancy". Both F (or OH) and "vacancy" promote the disorder of Cl atoms and thus have the effect of stablizing the hexagonal structure. The lowest energy configuration would be that where OH and F form domains of hydroxyl and fluorapatites.

PETROGRAPHIC AND STRATIGRAPHIC STUDIES OF THE PRECAMBRIAN IN THE ISKWASUM LAKE AREA OF NORTHERN MANITOBA

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The oldest rocks of the area belong to the Wekusko Group. They consist of lava flows with associated pyroclastics, metasediments and related intrusions. Sulphide-bearing, serpentinized intrusive bodies are found within the Wekusko Group. Extensive diamond drilling has outlined a large serpentinite body in Iskwasum Lake. Field relationships show the presence of at least four large structurally and petrographically separable granitic plutons intruding the Wekusko Group. One of these, in the north, is characterized by quartz-eye granite; others contain adamellite, granodiorite and tonalite. Garnetiferous gneisses and migmatite underlie the eastern part of the map-area. The maximum grade of regional metamorphism of the map-area is generally lower than the almandine-amphibolite subfacies. Greenschists of chlorite, epidote, sphene, plagioclase, and actinolite are characteristic.

THE OXIDE MINERALS OF THE WHITESTONE ANORTHOSITE, DUNCHURCH, ONTARIO

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Oxides in the foliated garnet-bearing border facies of the Whitestone anorthosite, Dunchurch, Ont., consist of 80–90% hemo-ilmenite and some magnetite and ferrian ilmenite. TiO_2-, poor magnetites have average unit cell dimensions of 8.396 ± 0.004 Å. The bulk composition of the rhombohedral phase varies between Hem_{10} and Hem_{60} (mol %), probably as a result of local variations in $f(O_2)$. Two generations of exsolution in hemo-ilmenite have similar compositions (Hem_{70} and Ilm_{90}), which suggest an assymetric hematite-ilmenite solvus at more ilmenite-rich compositions than determined by C. M. Carmichael (1961). In hemo-ilmenite adjacent to magnetite, hematite lamellae thin and disappear leaving a zone less than 50μ wide of homogeneous ferrian ilmenite (Ilm_{90}). A microprobe scan across the zone indicates no compositional gradients. The lower limit of oxidizing conditions for recrystallization or growth of magnetite and reaction with the rhombohedral phase can be inferred.

THE CRYSTAL STRUCTURE OF GEHLENITE, $Ca_2Al(Al, Si)_2O_7$

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This paper describes the crystal structure of gehlenite, a specimen chosen from the contact metamorphic limestone complex of Crestmore, California. The *x*-ray-emission microanalysis yielded the following composition:

$$(Ca_{1.96}Sr_{0.03}Mn_{0.01})(Al_{1.93}Mg_{0.05}Fe_{0.02}Si_{1.02})O_7$$

A least squares refinement of *x*-ray powder data gave the cell dimensions as a = 7.7173(6)Å and c = 5.0860(8)Å. Using 3D diffractometer data (1487 reflections) the crystal structure was refined to an $R' = (\Sigma w(F_O - K_iF_c)^2)^{\frac{1}{2}}/\Sigma(wF_O^2)^{\frac{1}{2}}) = 0.037$, by the least squares method. The interatomic distances obtained from the refined structure are correct to a few thousandths of an Å. In the space group $P\bar{4}2_1m$ the crystal structure of gehlenite has two sets of non-equivalent tetrahedra—two equivalent tetrahedra (T_1 and T_2) at point symmetry $\bar{4}$ and four equivalent tetrahedra (T_3 to T_6) at point symmetry *m*. Four Al atoms and two Si atoms are distributed among these six tetrahedra. Smith (1953) proposed two probable ordering arrangements: (1) Al_1 in T_1 and T_2 with $Al_{\frac{1}{2}}Si_{\frac{1}{2}}$ in T_3–T_6, or, (2) Si_1 in T_1 and T_2 with Al_1 in T_3–T_6. Interatomic distances obtained from the crystal structure refinement of Crestmore gehlenite show that this gehlenite has a partially ordered structure with Al_1 in T_1 and T_2, and $Al_{\frac{1}{2}}Si_{\frac{1}{2}}$ in T_3–T_6. Sahama and Lehtinen (1967) obtained infrared evidence for the same Si, Al distribution. Thin section study of gehlenite from Crestmore revealed some interesting features: anomalous 2V, ultrablue interference color at extinction position and polysynthetic lamellar and cross-hatched structures. *X*-ray photographs of such grains showed multiple spots and diffuse streaks associated with some Bragg maxima. The cross-hatched and lamellar structure are interpreted as polysynthetic twinning. It is proposed that certain regions of the single crystals consist of nearly fully ordered domains of triclinic (space group *P*1) gehlenite twinned on {100} and {010} or {110} and {110}. It is discussed how such a twinning could lead to Al, Si disordering giving an avergage space group of $P\bar{4}2_1m$.

THE ROLE OF OXIDATION IN THE GENESIS OF MAGMATIC SULFIDE DEPOSITS

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The hypotheses that magmatic sulfide deposits were intruded in solution in silicate magma and later separated by physicochemical means is evaluated in the light of work in the iron sulfide-iron oxide-silica system. Activity of FeO, *a*(FeO), is the main factor controlling sulfide solubility in magma. Lowering of *a*(FeO) causes saturation and separation of an immiscible sulfide-oxide liquid phase. In this way crystallization of FeO-bearing minerals may cause sulfide liquid separation, but since these deposits are usually at or near the base of intrusions the sulfide would have to separate and settle before extensive silicate crystallization. The value of *a*(FeO) is also lowered by oxidizing FeO to Fe_2O_3 which may remain in the liquid or separate in magnetite and other minerals. In the experimental system, ferric-iron silicate liquids dissolve much less sulfide than ferrous liquids. Hence, rapid oxidation of silicate magma would release dissolved sulfide as sulfide-oxide liquid. Water, being readily available in the upper crust and soluble in magma, is considered to be the major source of oxygen. It can raise the oxidation state to the required degree for sulfide separation, especially when the system is open for the release of hydrogen. Igneous rocks associated with these sulfide deposits need not be highly oxidized. If the oxidized magma is sealed by solidification at its margin, it may precipitate Fe_2O_3-rich minerals and subsequently crystallize under a low oxidation state.

NEW DATA ON THE OPTICAL PROPERTIES AND TRACE ELEMENT DISTRIBUTION IN THE FELDSPARS AND WERNERITES OF S.E. MADAGASCAR

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The feldspars and the wernerites were separated from the pyroxenites, which occur in close association with the charnockites and have been considered to be of metamorphic origin. The indices of refraction of the feldspars, α, vary from 1.555 to 1.559, and γ, from 1.562 to 1.566; birefringence from 0.005 to 0.009; 2V from 73° to 85° with a negative optic sign and their anorthite contents vary from An_{52} to An_{62}—a labradorite variety. The wernerites are uniaxial negative whose indices of refraction, ϵ, vary from 1.551 to 1.568, and ω, from 1.580 to 1.607; birefringence from 0.029 to 0.039—a meionite variety. Wernerites seem to be after the feldspars, as evidenced by the presence of the skeletal lamellar twinning in wernerites. The spectrographic analyses of the feldspars and wernerites are as follows: *Feldspars*—Be, 10–110 ppm; B, 30–110 ppm; Cr, 10–25 ppm; Mn, 30–115 ppm; Co, 10–30 ppm; Ni, 3–10 ppm; Cu, 20–35 ppm; Zn, 10–38 ppm; Ga, 30–41 ppm; Sr, 1000–2000 ppm; Y, 3–10 ppm; Ba, 30–180 ppm; Yb, 1–8 ppm; and Pb, 3–15 ppm. *Wernerites*—Be, 3–36 ppm; B, 10–35 ppm; Cr, 3–7 ppm; Mn, 30–151 ppm; Co, 10–13 ppm; Ni, 3–6 ppm; Cu, 3–35 ppm; Zn, 10–15 ppm; Ga, 10–39 ppm; Sr, 315–2950 ppm; Y, 3–10 ppm; Ba, 30–150 ppm; Yb, 3–5 ppm; and Pb, 10–40 ppm. The mean R values of the feldspars and wernerites are 1.647 and 1.200 respectively, which are conspicuously similar to the R values obtained by others.

ZEMANNITE, A NEW TELLURITE MINERAL FROM MOCTEZUM, SONORA, MEXICO

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The mineral occurs as minute (less than one mm) hexagonal prisms terminated by a dipyramid. It is light to dark brown, has an adamantine lustre, and is very brittle. Optically, it is uniaxial positive; $\omega = 1.85$, $\epsilon = 1.93$. The density is greater than 4.05 g/cm³. Crystal structure study gave the following: space group $P6_3/m–C^2_{6h}$, $a = 9.41 \pm 0.02$ Å, $c = 7.64 \pm 0.02$ Å, Z = 2. The structure shows that the mineral is a zeolite-like tellurite with a negatively charged framework of $Zn_2(TeO_3)_3$ having large (diam. = 8.28 Å) open channels parallel [001]. These channels are statistically occupied by Na and H ions and possibly by H_2O. Some Fe substitutes for Zn. Partial analyses and the crystal structure analysis indicate the formula: $(Zn, Fe)_2 (TeO_3)_3 Na_xH_{2-x} \cdot yH_2O$. Strongest lines in the x-ray powder pattern (in Å for Cu $K\alpha$) are: 8.15 (10) (100), 2.778 (9) (202), 4.07 (8) (200), 2.96 (6) (112), 2.845 (6) (211), and 1.726 (6) (204, 223). Thirty-nine spacings were measured and indexed from d = 8.15 Å to d = 1.316 Å. The name is in honor of Prof. Dr. Josef Zemann, University of Vienna, who has contributed so greatly to our knowledge of the structure of tellurium compounds. The mineral and name were approved by the Commission on New Minerals and Mineral Names, I.M.A.

NICKEL-CARBONATE FROM NORTHEAST TRANSVAAL

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The first occurrence of anhydrous nickel carbonate of the calcite group is reported from the Native Pafuri Trust of Northeast Transvaal in the Republic of South Africa. The mineral is shown to be the end-member $NiCO_3$ with virtually no magnesium or calcium in substitution. A comparative analysis is presented of this material with magnesian gaspeite from both the Gaspe peninsula and from the new Kambalda nickel mine in Western Australia. Complete chemical analyses are given including extensive electron microprobe analyses. X-ray lattice parameters of these minerals are refined and compared with the chemical analyses. Infrared analyses are also presented. In addition to the first occurrence of end-member $NiCO_3$, it is found that an extensive solid solution also exists between $NiCO_3$ and $ZnCO_3$. A thorough petrological and geochemical study has been made of the associated minerals leading to the paragenesis of the mineral assemblage. Field evidence and laboratory studies indicate the $NiCO_3$ from Pafuri is a surface weathering product of primary nickel sulfides.

METASOMATIC AUREOLE OF THE WHITESTONE ANORTHOSITE

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In the area of Whitestone Lake, 20 miles N.N.E. of Parry Sound, Ontario, a massif-type anorthosite is intruded into an upper amphibolite-grade assemblage of migmatites, amphibolites and marble. Iron and titanium rich fluids emanating from the anorthosite have metasomatically altered the juxtaposed gneisses to a degree controlled by their mineralogy and, with concomitant heat, have raised these rocks to granulite facies. It is proposed that the paragenesis developed in the rocks of the aureole, cpx + garnet + qtz ± opx, is a function of an increase in the Fe/Mg ratio due to the metasomatism rather than an increase in pressure. There has been no significant regional metamorphism subsequent to the development of this aureole, implying that the intrusion of the anorthosite is one of the youngest events in the history of this Grenville province locale.

CRYSTAL CHEMISTRY OF THE BASIC IRON PHOSPHATES

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A general structural principle is widespread among the basic phosphates of ferrous and ferric iron. This principle is based on a highly stable polyatomic complex involving ferrous-ferric oxy-hydroxy octahedral face-sharing triplets. The orientation of the associated corner-linked octahedra and tetrahedra is so similar in several mineral structures that a general hierarchy of structure types has been derived. Crystal structures of the various members are dictated by the ways in which the fundamental polyatomic octahedral three-cluster and its nearest neighborhood of octahedra and tetrahedra link along a third 'variable' axis. The refined crystal structures of dufrenite and rockbridgeite are revealed for the first time. Structure cell and indexed powder data are offered for dufrenite, rockbridgeite, beraunite, laubmannite and Mineral A, a new species. Data in the literature are misleading and largely in error for most of these compounds. Members of the basic ferrous-ferric phosphate family known to possess the octahedral face-sharing three-cluster include barbosalite, lipscombite, dufrenite, rockbridgeite, beraunite, laubmannite and Mineral A. Other likely compounds which may also involve the three-cluster include souzalite, azovskite, cacoxenite, delvauxite, avelinoite, richellite, egueite, tinticite and pitticite.

THE LEADHILLITE-SUSANNITE RELATION

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X-ray single-crystal, optical, electron-probe, and infrared investigations established that leadhillite and susannite are the monoclinic and trigonal dimorphs, respectively, of $Pb_4(SO_4)(CO_3)_2(OH)$. Leadhillite (Tintic, Utah) is monoclinic, $P2_1/a$, with $a = 9.08$ Å, $b = 20.76$ Å, $c = 11.56$ Å, $\beta = 90° 27.5'$, and $2V \approx 10°$. Susannite (Leadhills, Scotland) is trigonal, $R\bar{3}$, with $a = 9.05$ Å, $c = 11.54$ Å, and $2V = 0°–3°$; their powder patterns are indistinguishable. Precession photographs of leadhillite, taken first at room temperature and then at 200°C, showed conversion to single-crystal susannite; on cooling to room temperature the structure reverted to that of leadhillite. This inversion was also observed optically. Leadhillite, therefore, is a low-temperature polymorph of susannite. Susannite decomposes at about 300°C to $Pb_5(SO_4)O_4$.

THE MINERALOGY OF THE MARBRIDGE NO. 3 AND NO. 4 NICKEL-IRON SULFIDE DEPOSITS

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The Marbridge property situated in LaMotte township near Malartic, Quebec, includes four nickel sulfide deposits which were mined from 1962 until 1968. The No. 3 and No. 4 deposits are situated towards the upper contacts of roughly conformable lenses of serpentinized peridotite that have been intruded into a south-easterly striking belt of sedimentary and volcanic rocks. The belt passes between the Preissac and LaMotte batholiths and has been subjected to amphibolite-grade metamorphism. The sulfide mineralogy of both deposits has been studied optically and with the electron probe. The No. 3 deposit exhibits marked mineralogical zoning parallel to the peridotite-country rock contact; the pyrite-pyrrhotite mineralogy of the country rocks gives way in the peridotite to a zone of pyrite-pyrrhotite-pentlandite ore (zone 1) followed by (zone 2) of pyrite-millerite-pentlandite ore. The proportion of millerite to pyrite increases progressively across zone 2 into the peridotite. Heazlewoodite and millerite occur in the centre of the peridotite (zone 3), outside the limits of mineable sulfide. Violarite, magnetite and some secondary millerite are alteration products after the pentlandite of zone 2. The average Ni:Fe weight per cent ratio of pentlandite in zone 1 is 1.21, in zone 2 is 1.75 and in zone 3 is 1.91. Pyrite and pentlandite together with very minor millerite are the principle minerals of the No. 4 deposit. No mineralogical zoning is apparent across the deposit; however the Ni:Fe ratio of penlandite increases progressively from 1.43 close to the peridotite-country rock contact to 1.76 in the centre of the peridotite. Final emplacement of the sulfide ore post-dates intrusion of meta-gabbro dykes which cut the host peridotite. The mineralogical variation at the No. 3 and the chemical variation at the No. 4 deposits are thought to represent compositional zoning induced in the ore during metamorphism.

METAMORPHISM OF CALCAREOUS XENOLITHS IN LAVAS OF SANTORINI VOLCANO, GREECE

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Marble fragments, found as xenoliths in hyalodacites of Santorini volcano, Greece, display the primary metamorphic assemblages ferrisalite-wollastonite-plagioclase, anhydrite-fassaite-gypsum and melilite-wollastonite-magnetite. The three examples discussed show hybridization with enclosing magma. Concentric zoning of the first example indicates the introduction from enclosing magma of silica, alumina and alkalies. Dark green prismatic ferrisalite ($Di_{39}\ Hd_{30}\ Tsch_{24}\ (Ac + Jd)_7$) forms an abundant mesh, and similar pyroxene rims rare coarse augite ($Wo_{42}En_{42}Fs_{16}$). Interstitial orange glass differs from brown glass of the dacites in richness in lime, alkalies and ferric iron. Zoned melilite ($Ge_{82}Åk_{18}$–$Ge_{50}Åk_{43}Na\text{-}Mel_7$) of the third example is obliterated, near the contact with enclosing dacite, by fibrous cebollite, and titaniferous magnetite commonly develops a rim of Ti-andradite. Consideration of $f(O_2)$-T data for the reaction

$$\text{Andradite} \leftrightarrows \text{Magnetite} + \text{Wollastonite} + O_2 \text{ (Gustafson 1968)}$$

and the application of $f(O_2)$ values estimated for basaltic and dacitic lavas of Santorini, indicates a minimum temperature of around 900°C for formation of the primary assemblage, suggesting initial contact metamorphism by a basaltic magma. The formation of andradite during retrograde metamorphism by enclosing dacite indicates a maximum temperature of around 800°C. Similar temperatures of metamorphism (around 800°C), and $f(O_2)$ higher than could be imposed by the dacite magma, are indicated by the stability of the first two assemblages described.

A REDEFINITION OF THE CHEMICAL COMPOSITION OF OSUMILITE

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Osumilite, $(K, Na, Ca)\ (Fe, Mg, Mn, Al)_5\ (Si, Al)_{12}O_{30}$, from the type locality, Sakkabira, Japan, has been reanalyzed. The original analysis by Minato (Miyashiro, 1956) was performed on a small quantity of material that contained an unavoidable impurity level when done by wet chemical methods. The new analysis, by electron microprobe, avoids this problem and yields results which differ significantly from the original analysis. For major oxides relative errors in the original analysis range up to 80%; for minor oxides up to 400%. Analyses were also made on osumilites from the only other two world localities: Sardinia (Rossi, 1963), and from a new locality at Obsidian Cliffs, Oregon. In the Oregon occurrence the paragenesis indicates the kind of metastability of osumilite determined by Schreyer and Seifert (1967). Analyses of the closely related meteoritic minerals roedderite, $(Na, K)_2(Mg)_5Si_{12}O_{30}$, merrihueite,

$$(Na, K)_2(Fe, Mg)_5Si_{12}O_{30},$$

and the new mineral yagiite, $(Na, K)_{1.5}(Mg, Fe, Al, Ti)_5(Si, Al)_{12}O_{30}$ are compared to the terrestrial osumilites.

PROTEROZOIC IGNIMBRITES ON THE AVALON PENINSULA, NEWFOUNDLAND

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The Harbour Main Group of Proterozoic age, exposed on the Avalon Peninsula of Newfoundland, consists mainly of volcanic rocks with minor sediments. In the western part of the area, the volcanic sequence contains several ignimbrite units of rhyolitic composition; the ignimbrites are remarkably well preserved. In one well exposed stratigraphic section 1000 ft. thick, three units of ash-flow tuff are interbedded with coarse agglomerate and a possible lahar unit. The upper agglomerate bed contains mixed basic and acid fragments and is overlain by basaltic flows. In the eastern part of the Harbour Main volcanics, the rocks are predominantly basic flows with some pillow lavas. The central part, containing both acid and basic volcanic rocks, is intruded by a granitic pluton. Although intense faulting and steep folding make detailed correlations difficult, the contrasting types of volcanism of the western and eastern flanks of the Harbour Main Group may reflect the development of a geosynclinal volcanic cycle in Proterozoic time, connected with the Avalon Orogeny. The ignimbrites may represent the upper, gas-charged part of the granitic magma, the lower part of which has crystallized in place to form the present Holyrood batholith.

THE INTERPRETATION OF NATURAL CHEMICAL DATA IN VARIATION DIAGRAMS

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The interpretation of natural chemical data is accomplished most directly and easily in variation diagrams which, unlike Harker and Larsen diagrams, do not distort the apparent relationship between the variables being examined. A certain type of ratio diagram in which the divisor is mathematically a constant does not distort the observed relationship. Using this type of diagram, quantitative predictions may be made and checked with observed variations to test rival hypotheses. Data from the Palisade Sill is used as an example.

ASSOCIATIONS MINERALES DES ACCIDENTS PEGMATITIQUES DU MONT ST-HILAIRE, P.Q.

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Les diagrammes $\mu_{Na_2O}-\mu_{SiO_2}-\mu_{ZrO_2}-\mu_{MnO}$, construits selon les principes définis par Korzhinsky et J. B. Thomson expliquent plusieurs des zones monominérales des accidents pegmatitiques de la carrière De-Mix du Mont St-Hilaire. Les phases pegmatitiques portent surtout sur les minéraux suivants: néphéline, sodalite, albite, aégirine, eudialyte, catapléiite, sérandite, natrolite, microcline, polylithionite et analcime. Des solutions hydrothermales ont aussi effectué une redistribution des éléments des pegmatites dans de nombreuses phases cristallines dont plusieurs nouvelles et un nombre important de phases très rares: astrophyllite, analcime, catapléiite, leucophane, leifite, ancylite, bastnaesite, lemoynite, UK-19-1 et UK-19-2 ainsi que plusieurs autres non encore définis.

UK-19-1 et UK-19-2, DEUX NOUVEAUX SILICATES HYDRATES DE NIOBIUM DE MONT ST-HILAIRE, P.Q.

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Le spécimen UK-19-1 constitue probablement une nouvelle espèce minérale. Sa composition chimique, déterminée à la sonde électronique est: SiO_2 46.0, Nb_2O_5 25.5, TiO_2 7.1, K_2O 4.3, Na_2O 3.7, CaO 2.8, H_2O 10.0; total 99.4%. Le groupe d'espace est $Cm/m2$: a = 7.34 Å, b = 14.08 Å, c = 7.15 Å. Les cristaux sont roses pâles en masse:

ils sont de très petites tailles (0.1–0.2 mm.). Ils sont associés à l'analcime, l'aégirine et l'hisingérite (?). Les formes {010} et {001} sont imparfaitement développées. Le spécimen UK-19-2 est probablement aussi une nouvelle espèce distincte de UK-19-1 (groupe d'espace différent). L'analyse à la sonde électronique a donné: SiO_2 42.4, Nb_2O_5 30.9, TiO_2 8.4, K_2O 0.4, Na_2O 5.5, CaO 0.7, H_2O 11.1, total: 99.4%. Le groupe d'espace est $Pb/a2$: a = 7.42 Å, b = 14.23 Å, c = 7.16 Å. Les cristaux sont vitreux et transparents: les formes {010}, {001} et {110} sont bien développées. Leur taille varie entre 0.2 et 0.5 mm. Ils sont associés à l'analcime, une dolomie brune, la polylithionite et l'aégirine. L'un et l'autre de ces deux nouvelles espèces appartiennent probablement à la phase hydrothermale.

NATIVE SILVER AND SILVER-ANTIMONY MINERALS IN THE COBALT-GOWGANDA ORES

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The silver-antimony minerals in the Cobalt-Gowganda ores are silver, allargentum and dyscrasite. Three types of silver are present, and are classified as silver$_1$, silver$_2$ and normal native silver on the basis of their compositions and modes of occurrence. Silver$_1$ is the main type, and it contains moderate amounts of antimony and mercury in solid solution. Silver$_2$ contains large amounts of antimony and some mercury, and is interpreted as being an exsolution from allargentum. Normal native silver is a late variety that is present as veinlets, disseminated grains and wire silver, and it does not contain appreciable amounts of antimony or mercury in solid solution. Allargentum is the naturally occurring equivalent of the ϵ-phase of the synthetic Ag-Sb system, but it has been erroneously referred to as dyscrasite by previous workers. It occurs as discrete grains in silver$_1$, as lamellae in silver$_2$, and as veinlets in calcite veins. Dyscrasite is rare in the Cobalt-Gowganda ores, and was found only as intergrowths with allargentum. The composition of the various silver-bearing minerals, as determined by means of the electron probe microanalyser, are as follows:

	Silver Wt. %	Antimony Wt. %	Mercury Wt. %
Normal Silver	100.0	0.0	0.0
Silver$_1$	88.5–99.3	0.0–5.3	0.4–8.1
Silver$_2$	88.6–92.2	6.9–8.4	0.9–3.3
Allargentum	84.0–85.6	14.4–15.9	0.0–0.9
Dyscrasite	79.9	19.7	0.4

PHASE RELATIONS IN PARTS OF THE SYSTEM DIOPSIDE–NEPHELINE–KALSILITE–SILICA AND THEIR IMPORTANCE TO ALKALINE ROCK GENESIS

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As part of a study of the effects of adding basic molecules to petrogeny's residua system (nepheline–kalsilite–silica), the joins diopside–nepheline–sanidine and diopside–albite–leucite have been investigated at one atmosphere. From these joins a quaternary invariant point and a quaternary minimum in the system diopside–nepheline–kalsilite–silica have been located close to the undersaturated minimum in the residua system. These phase relations provide a better basis for the interpretation of the genesis of both mafic and felsic alkaline undersaturated rocks than petrogeny's residua system.

STUDY OF CARBONATE MINERALS FROM THE CARBONATITE AT OKA, QUEBEC

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Carbonates, mainly calcite, were separated from some 140 specimens of carbonatite from Oka, and their chemistry and physical properties determined. The specimens studied are from the various phases of the complex and from drill holes across the ore zone at the St. Lawrence Columbium Mine. The work done involved the determination of Nb_2O_5 in the rocks by *x*-ray fluorescence methods, and the determination of Ba, Sr, Mn, Mg and Fe in the contained carbonates by atomic absorption spectroscopy. Physical properties studied include: lattice spacings (211) and (122), refractive indice (ω), axial angle (2V), fluorescence in U.V., and infrared absorption spectra. The Nb_2O_5 content of the rocks studied varies from 0.08% to 1.50% and averages 0.39%. Similarly, the chemistry of the contained calcites varies widely; the following ranges and average values were obtained: Sr (1.90–0.013; average 1.03%), Ba (0.95–0.01; average 0.216%), Mg (1.74–0.01; average 0.29%), Fe (0.25–0.002; average 0.067%), Mn (1.30–0.003; average 0.39%). Of these, only Mg, Fe and Mn show correlation with each other whereas no correlation could be established between Ba and Sr and the other elements. Similarly, no correlation could be established between Nb_2O_5 content of the rock and the chemistry of the carbonate minerals. Small scale cation substitution in the carbonate affects principally the lattice spacings whereas band position of the I.R. spectra are not significantly changed. Fluorescence in ultraviolet and the biaxial character of some calcites do not bear simple relationships to the chemistry of the mineral. These two properties may be related, in part at least, to the thermal and structural history of the mineral.

EVOLUTION OF ZONED MICAS AND ASSOCIATED SILICATES IN THE OKA CARBONATITE

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Electron probe studies of silicate phenocrysts revealed that optical zoning coincides with changes in chemical composition. Distribution coefficients of Si, Al, Fe''', Fe'', Ti and Mg between adjacent mica zones indicate a straight line relationship between ferric and ferrous iron, and a more complex relation between other constituents. The opposite trends of magnesium and iron are modified by variations in aluminium and titanium. Variations within the zones are accounted for by gradual differentiation of magma, whereas the abrupt changes between zones result from crystallization of associated minerals and emplacement of certain elements into magma.

RAPID ROCK ANALYSES BY ELECTRON PROBE

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Glasses produced by direct fusion of rock powders have been successfully analysed for Si, Al, Ti, total Fe, Mn, Mg, Ca, K, Na, and P using the ARL-EMX electron microprobe. The use of a versatile data reduction and correction programme permits a wide choice of standards, which may be those used in routine mineral analyses, thus eliminating the need to have a series of standard rock glasses. Tests of the precision and accuracy of both the fusion and analytical techniques have been made using W1 and other rock standards in the range basalt–granite. The results indicate that the approach is no less satisfactory than conventional rapid methods. Obvious limitations are imposed where the rock has high contents of H_2O or CO_2 or an excessively high liquidus temperature. The principal advantage of this method is the rapidity with which large numbers of multi-element analyses can be obtained.

RELATION DES PHASES DANS LE SYSTEME Fe–C–S + (H_2O)

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Le système Fe–C–O–S a été étudié pour des températures allant de 75 à 800°C et des pressions de 1 à 2,500 bars. Lorsque H_2O est ajouté au système, la stabilité des assemblages diminue de quelques 15 à 20°C. Les résultats expérimentaux ayant une signification particulière seront discutés. Les applications géologiques des résultats expérimentaux peuvent être divisées en quatre parties: Partie 1—Texture des produits expérimentaux; Partie 2— Emploi des assemblages comme géothermomètres; Partie 3— Emploi des assemblages comme géomanomètres; Partie 4—Emploi des assemblages comme indices servant à reconnaître l'origine et/ou le degré de métamorphisme des formations de fer. Ceci est suivi de l'application des résultats expérimentaux aux formations de fer de la fosse du Labrador et du district de Michipicoten.

TRACE ELEMENT TRENDS DURING FRACTIONAL MELTING. SOME THEORETICAL CONSIDERATIONS

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Partial melting of multiphase solids has led to element fractionations during the evolution of the earth's crust and to the generation of magmas. Recent work by P. W. Gast indicated possible melting effects on coherent-element ratios. Even assuming constant melting proportions of phases and constant partition coefficients, the possible courses of minor element fractionation are more numerous than has been previously realised. Paradoxical trends can appear, such as the increase of K/Rb ratios both in the liquid and in the residual solids.

SYNTHESIS OF A COPPER-IRON DISULFIDE PHASE

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Fukuchilite, a new mineral recently found in Kuroko-type sulfide deposits in Japan, has the suggested composition of Cu_3FeS_8 (Kajiwara, 1969). The CuS_2–FeS_2 join has been investigated hydrothermally by reaction of metal sulfate solutions in the presence of excess ammonium polysulfide. A phase having the same *x*-ray powder diffraction pattern and optical properties as fukuchilite is apparently stable in experiments at 225°C. The data indicate extensive solid solubility along the join. The *x*-ray powder data of the synthesized phases are completely comparable to that of pyrite and indicate expansion of the cell dimension in proportion to the amount of copper in solid solution (*e.g.*, $a = 5.59$ Å for solid solution bearing 50 mol. % CuS_2).

PETROLOGY OF VOLCANIC ROCKS OF NORTH MOUNTAIN, NOVA SCOTIA

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The Triassic volcanic rocks of North Mountain, Nova Scotia, consist of basalt flows which extend from Cape Split to Briar Island. A drill hole put down near Margaretville

for copper ore bodies disclosed the total thickness of the flows to be 742 feet. The thickness, however, varies depending upon local topography. The maximum number of flows seen are four at Cape Blomidon, Digby Gut, Wasson Bluff and Isle Haute. The three upper flows are seen in several outcrops along the coast of Bay of Fundy. Between the third flow and the youngest flow, interflow sediments occur which are continuous throughout North Mountain. This indicates that the eruptions of the basalts have been in two distinct phases. The basalts are tholeiitic. The composition of the plagioclase varies from An_{33} (microlites) to An_{73} (microphenocrysts). Clinopyroxenes range from Ca-rich pigeonite to subcalcic augite to augite. Zoning is common among clinopyroxenes with their core being either pigeonite or subcalcic augite. Reversal in zoning has not been observed. Orthopyroxene and olivine are rare. The ratios of pyroxene and plagioclase with respect to glass indicate that both these minerals crystallised at the same rate until the flows were 90 percent crystalline. Differences between the flows with respect to texture and modes are not discernible. Major elements analyses of 57 samples have been completed; the results will be ready for publication in a short time. The eruptions have been in the form of fissures; no volcanic necks which might have formed central vents, are seen. Pillow lavas occur at Scots Bay and Horse Shoe Cove and several other localities. The volcanogenic rocks near McKay Head are peperites; earlier these were considered to be sedimentary conglomerates.

AN EXPERIMENTAL MODEL FOR THE METAMORPHISM OF SILICEOUS CARBONATES

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The regional metamorphism of quartz-bearing carbonates produces assemblages of minerals from the following list: quartz, calcite, dolomite, talc, tremolite, diopside, forsterite, and enstatite. A total of 49 reactions can be written among these eight mineral phases but only five of the 49 are independent. Equilibrium data for five independent reactions have been experimentally measured by imposing temperature, pressure, and hydrogen fugacity on a charge containing graphite in equilibrium with a C–O–H gas. These data are used to calculate diagrams showing the stability of mineral assemblages as a function of temperature, pressure, and gas composition.

THE CRYSTAL STRUCTURES OF HEDENBERGITE AND FERROSALITE

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The crystal structures of hedenbergite synthesized at 998°C and 20 kilobars and of natural ferrosalite have been refined using least-squares techniques on counter-diffractometer *x*-ray intensity data. Both minerals are monoclinic, space group *C2/c*. The unit cell parameters of hedenbergite are $a = 9.844$ Å, $b = 9.028$ Å, $c = 5.246$ Å, and $\beta = 104.80°$; those of ferrosalite are $a = 9.788$ Å, $b = 8.969$ Å, $c = 5.253$ Å, and $\beta = 105.63°$. These two pyroxenes have structures close to that of diopside, and contain sheets of 8-coordinated calcium polyhedra and octahedrally coordinated iron and iron-magnesium polyhedra. The refinement of ferrosalite showed only calcium in the 8-coordinated M2 position, and 51% iron and 49% magnesium in the disordered octahedral M1 position; these values compare with an electron microprobe analysis which found 0.54 iron atoms and 0.50 magnesium atoms for every six oxygen atoms in the mineral. The parallel sheets of metal polyhedra are connected by silicate chains having 03′–03–03″ angles of 164.5° in hedenbergite and 165.9° in ferrosalite. Mean cation–oxygen distances for hedenbergite are Si–O = 1.633 Å, Ca–O = 2.514 Å and Fe–O = 2.131 Å; those for ferrosalite are Si–O = 1.635 Å, Ca–O = 2.502 Å, and (Fe, Mg)–O = 2.098 Å. The final statistically weighted *R* values are 0.025 and 0.033 for hedenbergite and ferrosalite respectively.

REINVESTIGATION OF THE CRYSTAL STRUCTURE OF GILLESPITE

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Gillespite, $BaFeSi_4O_{10}$, exhibits an interesting and rare type of coordination for ferrous iron. In this material, Fe^{++} occupies the center of a square-planar arrangement of oxygen atoms, in contrast to the more common octahedral condition. Based on a study of polarized absorption spectra, Burns, Clark and Stone (1966) have deduced the most probable order of *3d* orbitals for the high-spin configuration of Fe^{++} in gillespite. The mineral has also been investigated by Mössbauer spectroscopy (Clark, Bancroft and Stone, 1967). The present study complements these investigations. The refinement of the crystal structure was based on measurement of diffracted intensities by counter methods, employing MoKα radiation. The atomic coordinates of Pabst (1943) were used as a starting point. New parameters were derived by least-squares computations employing both isotropic and anisotropic temperature factors. Absorption corrections were computed by an integration procedure. Gillespite has tetragonal symmetry (space group P_4/ncc), the structure consisting of Si_8O_{20} sheets perpendicular to the *c* axis. Oxygen atoms are of three types: O'' is shared between tetrahedra within a sheet, O' by contiguous sheets, while O''' is an unshared vertex.

Fe^{++} is coordinated by O''' (of one sheet only) in the square arrangement, with the plane of the square perpendicular to the *c* axis. The Fe–O''' interatomic distance is 2.003 Å, with second neighbors O' and O'' at distances of 3.686–4.743 Å. Ba is coordinated by O''' of adjacent sheets, in an eight-fold configuration (Ba–O = 2.746 Å). The mean Si–O distance is 1.599 Å.

MERCURY IN TWO INTRUSIVE COMPLEXES, ROUGEMONT AND LAKE DUFAULT, QUEBEC

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Mercury content of rock specimens from a Monteregian intrusive (Rougemont) and Precambrian granodiorite and diorite intrusives near Noranda, Quebec (Lake Dufault) have been determined. Ranges and median values for concentration of mercury (in parts per billion) in these rocks are: Rougemont (7 to 125, 36), Lake Dufault (8 to 269, 29). Mercury tends to show a correlation with sulphur content of the rocks.

CHLORINE AND BROMINE IN CARBONATE ROCKS IN RELATION TO THE CHEMICAL HISTORY OF OCEAN WATER

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The geochemistry of Cl and Br in the water and acid soluble phases of limestones and dolomites from Recent to pre-Cambrian age has been investigated. The results have shown: 1) The Cl/Br ratio of the water and acid soluble phases increases from 15/1 in the pre-Cambrian (2×10^9 years) carbonates to 90/1 in Recent carbonates. This is interpreted as indicating an increase in the Cl/Br ratio of the oceans throughout geologic time. A geochemical mass balance has shown that the fractionation is the result of Br removal from ocean water by normal sedimentary processes. 2) Over 90% of the Cl and 55% of the Br in carbonates are in a water soluble form 3) Average Cl and Br abundances in limestones and dolomites are:

	Acid Soluble		Water Soluble	
	Cl(ppm)	Br(ppm)	Cl(ppm)	Br(ppm)
Limestones	720	17.9	647	9.6
Dolomites	1589	31.0	970	12.5

PHASE EQUILIBRIUM STUDIES BEARING ON GENETIC LINKS BETWEEN ALKALINE AND SUBALKALINE MAGMAS, WITH SPECIAL REFERENCES TO THE LIMESTONE ASSIMILATION HYPOTHESIS

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The limestone assimilation hypotheses for forming alkaline magmas from subalkaline magmas is based on circumstantial petrological evidence. It requires (1) desilication and (2) alkali transfer by CO_2 and H_2O. Recent experimental results indicate that limestone assimilation causes crystallization, and that the thermal barrier between granitic and feldspathoidal liquids persists in the presence of H_2O and CO_2 to high pressures. Desilication of SiO_2-oversaturated magmas remains an unlikely process. Results in silicate–salt–volatile systems suggest that alkali transfer is only effective from liquids already enriched in alkalis. In general, experimental studies have failed to validate proposed genetic links between alkaline and subalkaline magmas.