# SELECTED AUTHOR'S ABSTRACTS

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### SILICA-POOR HASTINGSITIC AMPHIBOLES FROM METASOMATIC ALKALINE GNEISSES AT WOLFE, EASTERN ONTARIO.

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The chemical characteristics of amphiboles in metasomatic alkaline gneisses of several lithological varieties have been studied utilizing fifteen new amphibole analyses. All can be classed as hastingsites, magnesian hastingsites and sub-silicic magnesian hastingsites and have Si contents ranging from 5.27 to 6.12 atoms in the half-unit cell. These fall amongst the most silica-poor amphiboles recorded in Leake's (1968) compilation. Progressive changes in composition relate directly to intensity of nephelinization in the individual rock layers and provide a useful index to this phenomenon even in the absence of nepheline. A premetasomatic tschermakitic hornblende to pargasitic hornblende composition is indicated for most of the amphiboles.

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### DISTRIBUTION OF URANIUM IN THE CRUST OF THE NORTHWESTERN CANADIAN SHIELD AS SHOWN BY LAKE SEDIMENT ANALYSIS

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In 1972 a reconnaissance geochemical survey was carried out by the Geological Survey of Canada in the northwestern Canadian Shield. Samples of nearshore lake sediment were collected, by helicopter, from 36,000 square miles of the Bear and Slave Geological Provinces. Sample density was one per 10 square miles. These samples have since been analysed for 27 different elements. This paper is concerned with the distribution of uranium in 1,241 samples from the western third of the survey area. This region mainly comprises the Proterozoic Bear Province.

The Bear Province, which is a metallogenic province for uranium, also appears to be a geochemical province for this element. Uranium is four times more abundant in lake sediments from this area (5.3 ppm U) compared to the eastern part of the Slave Province (1.3 ppm U). The lake sediment data are in agreement with analyses of composite rock samples from two parts of the survey area reported by Eade & Fahrig (1971).

Within the Bear Province the regional distribution of uranium is controlled jointly by the distribution of Proterozoic granitic rocks and by major faults and lineaments. Thus uranium values in lake sediments of 5 ppm or more only occur in or near Proterozoic granitic areas. Within these areas, uranium is distributed along two sets of equispaced linear trends. The highest contents in lake sediment, which include values to 300 ppm U, commonly occur near the intersections of the two trends. These trends correspond to a set of northeast and a set of northwest strike-slip faults and lineaments that were produced by east-west compression of the Bear Province during and after the Hudsonian Orogeny (1750 m.y.). Outside the western margin of the survey area complex epigenetic mineralization is associated with northeasterly-trending faults. Uranium has been produced from veins of this type at Port Radium and at the Rayrock Mine. Since it is associated with faults, this type of mineralization tends to occur in topographic depressions, that often contain lakes and swamps. Lake sediment analysis is believed to be an excellent means of detecting such mineralization, both within the survey area and elsewhere in the Canadian Shield. The data obtained during 1972 provide a basis for more detailed prospecting in the region.

### THE CRYSTAL STRUCTURE OF GAIDONNAYITE, ORTHORHOMBIC $Na_2ZrSi_3O_9 \cdot 2H_2O$

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The electron-probe analysis of a new mineral, gaidonnayite, from the nepheline syenite, Mt. St. Hilaire, Quebec, corresponds to $(Na_{1.72}K_{0.19})(Zr_{1.00}Nb_{0.09}Ti_{.02})Si_{2.88}O_9 \cdot 2.10H_2O$ or ideally $Na_2ZrSi_3O_9 \cdot 2H_2O$. The mineral is thus a dimorph of catapleiite. It is orthorhombic, $P2_1nb$ with $a = 11.740(3)$ Å, $b = 12.820(3)$, $c = 6.691(1)$, $Z = 4$, $D$(meas) $= 2.67$ and $D$(cal) $= 2.70$ g/cm³. Optically it is biaxial with $\alpha = 1.573(1)$, $\beta = 1.592(1)$, $\gamma = 1.599(1)$, $2V = 59° (1)$, $X = a$, $Y = b$, and $Z = c$. Both the name and the mineral have been approved by the Committee on New Minerals and Mineral Names, IMA.

The structure was solved by three dimensional Patterson synthesis and refined by a full-matrix least-squares method. A total of 1,210 reflections, collected on a manual single crystal diffractometer, was used. The final $R$ value is 0.039. The structure is based on wave-shaped single chains of $SiO_4$ tetrahedra repeating at every sixth tetrahedron along $[101]$ and $[10\bar{1}]$. Zr is octahedrally coordinated with six oxygen atoms and each of the two Na atoms is octahedrally coordinated with 4 oxygen atoms and 2 water molecules. The mean Si-O distances in the three independent tetrahedra are 1.630, 1.619 and 1.622Å. All the bridging Si-O distances are significantly longer than the non-bridging Si-O distances. The three independent Si-O-Si bridge angles are 131.1, 134.6 and 136.3°.

## DIAGENESIS OF IRON OXIDES IN LAKE SUPERIOR TYPE IRON FORMATION OF THE LABRADOR TROUGH AND ITS IMPLICATIONS FOR THE EVOLUTION OF TACONITE IRON ORE

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Hematite dust is the earliest iron mineral in the ferric facies of the iron formation, iron silicates and carbonates are the earliest minerals of the ferrous facies. Micro-crystalline magnetite and hematite (specularite) have replacement textures relative to delicate sedimentary textures. These minerals grow mainly during the earliest stages of diagenesis, coincident with dehydration of silica-gel, and with cementation and compaction. Iron and silica were partly separated during the development of "metallic" mesobands, composed mainly of specularite and magnetite. These "metallic" mesobands suffered strong compaction and formed during early diagenesis. Minor amounts of magnetite and specularite also formed during later stages of diagenesis and during low-grade regional metamorphism.

The growth of magnetite and specularite is related to complex redox reactions. In the ferric facies, ferric oxide or hydroxide probably has been reduced to $Fe^{2+}$ by organic matter. The ferrous ion then migrated into relatively permeable beds, where it has been oxidized to magnetite and specularite by oxygenated ground water. In the ferrous facies "metallic" bands formed by infiltration of oxygenated ground water along bedding planes, and consequent oxidation of iron carbonate. Other reactions are less important.

The evolution of "metallic" mesobands is controlled by the permeability of the rock during the earliest diagenetic stage. Therefore it depends on textural facies and on bedding properties. It is hoped that textural studies of iron formations might contribute to (1) predicting those zones where a large portion of the available iron has been converted to magnetite and specularite and (2) predicting the degree to which the micro-crystalline iron oxides can be liberated during beneficiation of taconite iron ore.

## THE DIAGRAM $MgO/Al_2O_3$ VERSUS $(Na_2O + K_2O)/(TOTAL\ FeO + TiO_2)$ : A DISTINCT GEOCHEMICAL SEPARATION OF THE CALC-ALKALINE AND THOLEIITIC ROCK SERIES

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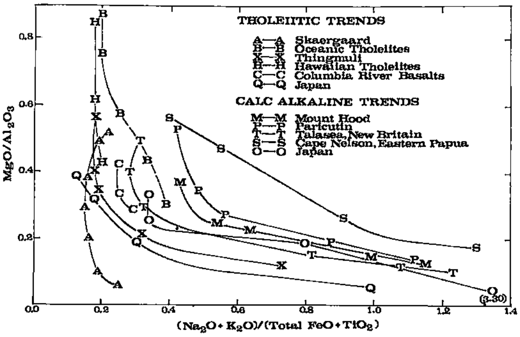
A new method of petrochemical representation is presented which discriminates plots of calc-alkaline versus tholeiitic rocks and their differentiation trends, and which: (1) is applicable to a majority of subalkaline igneous provinces, (2) minimizes the effect of alteration, and (3) provides a 95 per cent effective separation of the two subalkaline rock series.

In application, this plot also distinguishes between two types of high-alumina basalt, i.e. high-alumina tholeiites and high-alumina calc-alkaline basalts, and indicates the derivation of Archean calc-alkaline sequences from a high-alumina (porphyritic) tholeiite magma.



## ECONOMIC GEOLOGY AND MINERALOGY OF PETALITE AND SPODUMENE PEGMATITES

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Petalite, one of the rarest pegmatitic lithium minerals, is a magmatic species of primary economic importance in the fabrication of glass-ceramics, a family of materials that can be tailor-made to supply varied combinations of optical and physical properties. Petalite alters to an isochemical spodumene-quartz intergrowth which can also substitute for petalite in glass-ceramics. The chief advantage of petalite or its spodumene-quartz derivative lies in its exceedingly low contents of $Fe^{3+}$ and alkalis.

In contrast, primary spodumene appears in a variety of occurrences: 1) as phenocrysts in poorly zoned pegmatites; 2) as a constituent of one or more zones, principally intermediate zones and cores, in the latter as giant crystals; 3) in replacement units and 4) in vugs. Early spodumene is characterized by high $Fe^{3+}$ contents correlative with its greenish color. Such spodumene, which is the most abundant and economically the most feasible to recover, cannot be used in glass-ceramics. It is calcined to lithium carbonate which for chemical and economic reasons cannot be used for glass-ceramics. Two processes have been patented to remove isomorphous $Fe^{3+}$ from such spodumenes: 1) the Foote process converts $\alpha$- to $\beta$-spodumene and exposes it to chlorine in a high-temperature, high-pressure environment in which iron is volatilized as iron chloride, 2) the Pumeral process, after the same transformation, uses hydrogen at elevated temperatures and moderate pressure to reduce the $Fe^{3+}$ to $\alpha$-iron, which can then be magnetically removed.

## GENERATION OF BASE METAL SULPHIDE DEPOSITS ON THE SEA-FLOOR

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Recent studies of volcanogenic base metal sulphide deposits and of metalliferous sediments in the Red Sea indicate precipitation of iron and base metals under conditions varying from reducing to oxidizing, at or near sites of fumarolic brine emission onto the sea floor. Differing lithofacies of iron-rich sediments were apparently deposited penecontemporaneously, mainly in response to changing chemical, biological and sedimentary lithofacies conditions.

Various metals introduced in the brines have differing properties in these varying chemical environments, and are therefore deposited at different stratigraphic locations. Iron-rich sediments associated with the Cyprus cupreous pyrite bodies show increasing Mn/Fe ratios upward and away from the ores. Amongst Co, Ni and Cr, all present in the ophiolitic volcanic host rocks in Cyprus, Co is relatively enriched in the sulphide bodies, Ni is strongly enriched in the Fe-Mn rich sediments, and Cr is depleted in both but is probably enriched in distal Mn-Fe sediments. Amongst the three base metals, Cu and Zn are enriched in the sulphide bodies whereas Pb apparently passes through the system. Both Ag and Au are enriched in the sulphide bodies but only Ag is present in anomalous amounts in the Fe-Mn rich sediments. These variations, considered in conjunction with Eh-pH diagrams strongly suggest that rapidly changing Eh is a major factor controlling metal deposition on the sea floor.

These concepts of sea floor deposition controlling distribution of metals may also be applicable to other types of stratabound metalliferous deposits, like certain skarn, greisen and gold ores, heretofore considered to be of epigenetic origin. Because of their geochemical characteristics, certain metals such as Sn, W, Pb and perhaps Au may not be deposited near the fumarolic source. They would be more widely dispersed, ultimately to be deposited in peripheral areas by such processes as clay mineral absorption, and carbonate deposition. Although these possibilities have not been widely investigated and require substantiation, certain field relationships and mineral associations in Archean gold ores, in lead-bearing Phanerozoic carbonates, and in some Sn-W deposits merit reconsideration in the light of these possibilities.

## ENVIRONMENTS OF FORMATION OF CONCORDANT AND PENECONCORDANT COPPER DEPOSITS IN SEDIMENTARY SEQUENCES

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Concordant and peneconcordant copper deposits in sedimentary sequences account for approximately one fifth of the world's copper production. Although a considerable amount of work has been done on these deposits, there still seems to be no consensus as to their origins or environments of formation. This paper is an analysis of some general characterictics of these deposits and attempts to outline some of the similarities that exist in their environments of formation.

Available data indicate that there are at least two fundamental types of concordant and peneconcordant copper deposits in sedimentary sequences — "Red-Bed" copper deposits or those formed in sediments deposited in continental environments, and "Kupferschiefer-type" deposits or those formed in sediments deposited in paralic or marginal marine environments. Although significant production has come from some "Red-Bed" copper deposits, Kupferschiefer-type deposits have proved to be by far the more important type.

Paleomagnetic data and distribution of major evaporite deposits indicate that both types of copper deposits characteristically formed in low latitude arid and semi-arid areas. Other features of the sediments and sedimentary surroundings also support this conclusion. Such information is strong evidence that these copper deposits are a product of the environment of sedimentation. This is apparently so even though most "Red-Bed" and some Kupferschiefer-type deposits are, in the strictest sense, epigenetic.

Copper has evidently been deposited in many diverse continental and paralic environments. Yet, a prime site for the formation of the important Kupferschiefer-type deposits is in the basal rocks of a marine transgression following a long period of continental sedimentation. Such environmental conditions existed for the Kupferschiefer, Kupfermergel, Zambian copperbelt, White Pine, Redstone and other deposits. However, in some areas there are indications of an oscillation of continental and marine environments with repeated copper deposition.

Although solution, transport and depositional mechanisms of the copper remain somewhat speculative, it appears as if they were largely controlled by the paleoclimatic conditions at the time of sedimentation. The most reasonable source for the copper was mafic igneous or metamorphic material, whether or not it was first incorporated into a sediment. Such copper would have been released either at the surface by weathering or by the subsurface breakdown of minerals. In view of the arid or semi-arid natures of the environments involved it is probable that the copper was, for the most part, transported in groundwater. Deposition was likely initiated by contact with any local or regional reducing sites. In the case of "Red-Bed" copper deposits it was typically an area with plant debris or early pyrite; whereas, for Kupferschiefer-type deposits it was typically a more regionally distributed anoxic basin or sediment. Sulphur, either directly or indirectly, was probably supplied as product of biogenic activity. In a few deposits where there was insufficient sulphur available at the site of deposition, copper was precipitated as the native metal.

For any given deposit or group of deposits there were undoubtedly numerous, varied local controls not accounted for by this general model. Nevertheless, this model does put major constraints on the environments of formation, provides useful guides for exploration, and outlines the conditions that should be sought in searching for modern counterparts. It also indicates that this type of deposit may become a very useful paleoclimatic and environmental indicator, especially in Precambrian and metamorphic terranes.

## PHASE RELATIONS IN THE NiS-S SYSTEM BETWEEN 500 and 1030°C

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Phase relations in the NiS-S system have been investigated by experiments performed in rigid silica-glass capsules. The results of these experiments indicate that $\alpha Ni_{1-x}$ and vaesite ($NiS_2$) melt eutectically at $993 \pm 3$°C and $38.3 \pm 0.3$ weight percent sulphur. $\alpha Ni_{1-x}S$ melts congruently at $999 \pm 3$°C and $36.9 \pm 0.4$ weight percent sulphur. A phase change in $\alpha Ni_{1-x}S$ containing 37.4 weight per cent sulphur is suspected at $625 \pm 25$°C.

Vaesite melts incongruently at $1022 \pm 3$°C to two immiscible liquids containing $48.0 \pm 1.8$ and approximately 99.5 weight per cent sulphur giving rise to a syntectic type phase relation. $P_{S_2}$ at the syntectic temperature is estimated to be between 60 and 108 atmospheres.

A syntectic reaction is reported for the first time in sulphide systems and may be expressed as follows.

$$\text{Nickel-rich liquid} + \text{Sulphur-rich liquid} + \text{Vapour} \underset{1022 \pm 3^\circ\text{C}}{\overset{\text{cooling}}{\rightleftarrows}} \text{Vaesite} + \text{Vapour}$$

These results are at variance with the published data of Kullerud & Yund (1962). Some of the probable reasons for these differences are discussed.

## CHARGE-TRANSFER ABSORPTION AND Si-SUBSTITUTION IN SILICATES

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Crystal-field interpretations of optical absorption spectra have contributed greatly to an understanding of the properties of transition-metal ions in silicate minerals. Absorption bands can be assigned to electronic transitions between *d*-levels within a given cation, giving such information as valence states and site locations. More recently, it has been shown that second-nearest-neighbour interactions have a pronounced influence on the nature of spectra of trivalent metal ions. Three effects need be considered, (i) metal-metal electron-transfer giving rise to intense absorption in the visible region, (ii) increase UV-centred oxygen → metal charge-transfer absorption sweeping into the visible region, and (iii) intensity changes in the intra-cation crystal-field bands due to factor (ii). Effect (iii) can lead to information on the distribution of metal ions between different sites in the crystal, especially with regard to substitution for tetrahedral—$Si^{4+}$ ions of $Fe^{3+}$ and $Al^{3+}$. Examples are given of the importance of $M^{3+}$-O-tetrahedral $Fe^{3+}/Al^{3+}$ units in light absorption by minerals.

## COMPOSITIONAL RANGE AND STABILITY OF VIOLARITE

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Phases of the general composition $(Fe,Ni)_3S_4$ from a variety of deposits have been studied by electron microprobe analysis. The great majority of the violarites have compositions in the range 55 to 57 atomic % S and thus have less S than the ideal $M_3S_4$ composition. The Ni contents vary from 41.5 (Fe-bearing polydymite) to 15 atomic %; violarites with more Fe than the ideal $FeNi_2S_4$ composition are associated with pyrrhotite. Smythite compositions vary from 53.5 to 55 atomic % S and from 1.5 to 3.5 atomic % Ni. The compositions of the associated pentlandite vary more or less systematically with the violarite compositions.

For assemblages involving Fe-rich phases the textural evidence indicates violarite has developed by alteration of pentlandite. Single crystal *x*-ray diffraction studies on partly altered pentlandite grains have shown that violarite has the same crystallographic orientation as the pentlandite. The crystal structures of the two phases are both based on cubic close packed S substructures with metal atoms distributed between octahedral and tetrahedral interstices, and the alteration can be accommodated largely by removal of excess metal atoms.

It seems likely that the stability field of violarite in the Fe-Ni system enlarges to more Fe-rich compositions, toward the Fe-S join, as the temperature decreases. However, in Fe sulphide-bearing assemblages violarite appears largely because of the ease with which it can form from pentlandite. Formation of violarite from other phases in the ternary assemblages requires extensive structural rearrangements and is inhibited by the limited thermal energy available at these low temperatures.

## PETROLOGY OF THE NEMEIBEN LAKE ULTRAMAFIC BODY (SASKATCHEWAN) AND ASSOCIATED NICKEL-SULPHIDE DEPOSITS

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The Nemeiben Lake ultramafic body is located within the Churchill Province of the Canadian Shield, 16 miles north of the town of Lac La Ronge in central Saskatchewan between 55° 15′ and 55° 30′ north latitude and 105° 00′ and 105° 15′ west longitude. The ultramafic rocks consist of serpentinites, partly serpentinized and uralitized pyroxenite, and unaltered pyroxenite. Associated sulphide mineralization is of disseminated, net texture, and fracture filling types. The ore minerals present are pyrrhotite, pentlandite, chalcopyrite, pyrite, marcasite, violarite, bravoite and native copper. The sulphides are considered to be initially of magmatic origin, formed from a sulphide melt separated during a late stage of crystallization of the ultramafic rocks. Subsequent serpentinization has locally redistributed the ores.

Serpentinization in the Nemeiben Lake ultramafic rocks was accompanied by introduction of water with no apparent changes of $SiO_2$ and MgO contents. A minor removal of CaO and possible addition of sulphur during serpentinization is the only other apparent chemical change.

## SILVER-GOLD RATIOS RELATED TO COPPER MINERALIZATION AT THE ANGLO-ROUYN MINE, SASKATCHEWAN

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From 1966 to August, 1972, the Anglo-Rouyn copper mine at La Ronge, Saskatchewan produced 309,600 oz silver and 67,652 oz gold. The ratio of Ag to Au changed from 5.51:1 at the start to 3.5:1 near the end of operations. With time, copper grade decreased, gold grade increased, and the Cu:Ag ratio was nearly constant. Electron microprobe study of the concentrate showed most of the silver to be present in chalcopyrite. Only half the gold is so associated, the rest being in iron sulphides, sphalerite, and silicates.

Silver-gold assays from ore samples give ratios from 1.2:1 to 300:1. Samples rich in quartz, chlorite, or iron sulphides show lower Ag:Au ratios than those rich in chalcopyrite. Ore with a high proportion of chalcopyrite gives ratios of 10-16:1.

Metal contents and ratios are spatially distributed in the shallow, elongate, NE-SW trending ore body. The centre of the body shows banded chalcopyrite ore with few apparent metamorphic effects and a relatively high Ag:Au ratio. Lower Ag:Au ratios occur in quartz-rich, non-banded ore toward the ends of the orebody where relative proportions of chalcopyrite, pyrrhotite, and pyrite vary and metamorphism is more apparent. Irregular distribution of gold may be due to original deposition with copper, later deposition, or selective redistribution through metamorphism.

## METAMORPHIC AMPHIBOLES FROM THE CHLORITE ZONE OF CENTRAL AND WESTERN OTAGO, NEW ZEALAND

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Most of the analyzed amphiboles come from a 100 meter square area in a deformed and thoroughly metamorphosed basic to ultrabasic sill and its enclosing metavolcanic rocks. The remainder come from impure marble and metachert up to 9 km distant. Each amphibole analysis combines Si, Al, Ti, total Fe, Mg, Mn, Ca, K, and Na determinations by electron microprobre and a standard wet chemical analysis for ferrous iron. The amphiboles range in composition from calciferous hornblende and actinolite to subcalciferous and sodic hornblendes. The 70 analyses indicate a compositional gap in $Al^{iv}$ content between actinolite and calciferous hornblende in the range $Al^{iv}=0.6$ to 0.9 ions per 23 oxygens at $M(4)=2.0$ Ca. The gap in $Al^{iv}$ content narrows towards and disappears at $Al^{iv}=0.7$ at $M(4)=1.6$ Ca; subcalciferous amphiboles with $M(4)<1.6$ Ca are compositionally continuous for all contents of $Al^{iv}<1.6$. All of the nearly 1,300 published analyses of calciferous amphiboles show this compositional gap for metamorphic amphiboles up to and including the garnet zone. Analyses of diffusely zoned calciferous to sodic hornblendes indicate a continuous compositional variation from $M(4)=1.75$ Ca to 0.9 Ca at $Al^{iv}=0.75$. The following comparison of amphibole compositions from different facies or zones shows the widespread compositional range of amphiboles from transitional blueschist-greenschist facies:

| Metamorphic facies or zone | Na in $M(4)$ | | $Al^{iv}$ |
|---|---|---|---|
| Barrovian chlorite | $<$ 0.2 | | $<0.4$ |
| Blueschist | $\leqq$ 2.0 | except miscibility gap | $<0.6$ |
| Transitional blueschist-greenschist | $\leqq$ 2.0 | | $<1.6$ |

Amphiboles of transitional blueschist-greenschist rocks commonly have Na in $M(4)$ compensated by $Fe^{3+}$ in $M(1)$, $M(2)$, and $M(3)$. Amphiboles from the chlorite zone of Central and Western Otago have up to 1.1 Na in $M(4)$ compensated by $Fe^{3+}$ in $M(1)$, $M(2)$, and $M(3)$ and up to 1.5 $Al^{iv}$. Based on amphibole compositions and paleotemperature determinations in the range 510 to 550°C, the chlorite zone of Central and Western Otago is similar to the transitional blueschist-greenschist facies of New Caledonia and the Outer Metamorphic Belt of Japan and unlike the Barrovian greenschist facies.

## DETERMINATION OF THE PRINCIPAL REFRACTIVE INDICES OF BIAXIAL MINERALS FROM ANY RANDOMLY ORIENTED GRAIN

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The $\beta$ index of a biaxial mineral can be rapidly determined from any randomly oriented grain in thin section or from any randomly oriented fragment. The orientations of the principal vibration directions ($X$, $Y$, $Z$), and of the optic axes, are first determined by use of the universal stage and are plotted on a Wulff net. Then, the circular sections are drawn and points where the circular sections intersect the primitive circle of projection are marked P. The vibration directions $X'$ and $Z'$ for this particular grain are halfway between these points. The angle between $Z'$ and the closest point P is read on the projection and is designated as $\psi$.

The cover glass of the thin section and balsam are removed in order to allow contact of the grain with the immersion liquids. The values of $\alpha'$ and $\gamma'$ are determined in the usual way (without a universal stage).

The β index is determined graphically from a modification of Mertie's diagram using the measured values of α′ and γ′ and the angle ψ.

While the thin section is still on the universal stage, the maximum birefringence (γ-α) or partial birefringence (β-α or γ-β) may be determined by use of an appropriate compensator. This value together with 2*V* and β enables α and γ to be calculated in the usual way.

## SHORTITE IN KIMBERLITE FROM THE UPPER CANADA GOLD MINE, ONTARIO

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Shortite, $Na_2Ca_2(CO_3)_3$, occurs in the groundmass of micaceous, hypabyssal-facies, kimberlite dikes in the Upper Canada Gold Mine, Ontario. Electron microprobe analytical, optical and *x*-ray data are virtually identical to those of shortite from saline dolomitic marl of the Green River Formation, the only other known occurrence. Shortite grains range up to 2.2 mm across and constitute about 8 volume percent of the kimberlite groundmass. Shortite is associated with calcite, aggregates of serpentine and fresh olivine ($Fo_{83-88}$). Grains of the former three minerals have about equal dimensions and all poikilitically enclose small grains of phlogopite, magnetite, apatite and perovskite. Round megacrysts, as large as 2 cm, of olivine ($Fo_{93-94}$) are concentrated in central portions of the dikes by flow differentiation. Minor megacrysts of phlogopite, chromite, partially kelyphitized pyrope, and chrome-diopside are also present. The shortite, serpentine and associated minerals are interpreted to be primary, late-stage precipitates from kimberlitic magma at low temperature. This implies that a sodic, carbonatic, residual magma might be generated by fractionation of kimberlitic magma.

## MONAZITE FROM THE KULYK LAKE AREA, NORTHERN SASKATCHEWAN

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Monazite occurs in a roughly zoned, narrow vein-pegmatite system intrusive into gneisses near Kulyk Lake, Saskatchewan. The gneisses are assemblages of quartz-two feldspars-ilmeno-hematite-apatite ± clinopyroxene, hornblende, biotite, and chlorite; chlorite is retrograde after other mafic minerals. Pegmatitic graphic and aplitic granite encloses the vein and is bleached adjacent to some portions of it. The vein measures about 15 m by 30 cm and is dominantly composed of monazite and Fe-Ti oxides. Irregular lobes in the vein exhibit rough zones of oxide-, monazite-, and apatite-rich assemblages from their margins to their cores. The oxides are ilmeno-hematite, hematite and goethite. Electron microprobe analyses indicate that the former was $ILM_{34}$-$HEM_{66}$ before exsolution. Apatite is essentially rare-earth free. Monazite is unzoned but varies slightly in La/Ce within the vein; the preferred average analysis is $La_2O_3$-16.1%, $Ce_2O_3$-36.8%, $Pr_2O_3$-4.2%, $Nd_2O_3$-10.6%, $ThO_2$-4.3%, $P_2O_5$-27.4%; sum — 99.4 weight %. Minor Al, Ca, F, Fe, Mn, Y were detected whereas U was not. We interpret that the monazite vein precipitated from an aqueous phase released during the late-stage crystallization of the enclosing pegmatite and aplite, all of which was possibly generated by partial melting of the regional gneisses.