ABSTRACTS OF PAPERS PRESENTED AT THE THIRTEENTH ANNUAL MEETING

DISCOVERY OF VANADIUM IN CHIBOUGAMAU, QUEBEC

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One of North America's largest vanadium concentrations was recently discovered in the Dore Lake complex, a metamorphosed stratiform complex of the Bushveld type. The complex is divided into three major zones. They are, in ascending order, the following: Anorthosite, Ultramafic rocks, and Tonalite. The Ultramafic zone has been tentatively subdivided into several metapyroxenite and metaanorthosite members. The vanadium occurs as vanadiferous magnetite and ilmenite in the lowest metapyroxenite member. This member varies from 200 to 300 feet in thickness and consists of alternating layers of magnetite-bearing metagabbro and metapyroxenite, and vanadium-bearing titaniferous magnetite; the individual layers of magnetite range from a few millimeters to over a meter in thickness. The magnetite-rich zone dips from 75 degrees southeast to vertical and forms the axis of a 6-mile-long ridge with a relief of 200 to 400 feet. Although the complex has been subjected to greenschist facies metamorphism, the original textures and structures are remarkably preserved.

Aeromagnetic anomalies first attracted the attention of exploration companies to the magnetite-rich member of the Dore Lake complex. Subsequent drilling indicated a large tonnage of titaniferous magnetite; however, the titanium content of the derived concentrate (8–10% TiO_2) was considered excessive for an iron ore product and the property was abandoned. The vanadiferous nature of the magnetite-ilmenite in Rinfret township was determined in 1966 in the course of a detailed geological study of the area by the senior author for the Quebec Department of Natural Resources. The V_2O_5 content of the Fe–Ti member varies from 0.3% to over 1.0%; cores from one drill hole average 0.5% over a core length of 500 feet. Magnetic concentrates from this deposit, with an ore-to-concentrate ratio of 3 to 1, vary from 1.0% to 2.5% V_2O_5, averaging 1.4% over a 500-foot section, indicating an overall recovery of 85–90% of the V_2O_5 in the magnetic concentrate, which, in turn, contains 6 times more vanadium than the ilmenite concentrate.

The deposit lies within a short distance of existing road and rail facilities.

THE SYSTEM $NaAlSiO_4$-$NaOH$-H_2O

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A study was made of the phase relationships in the system $NaAlSiO_4$-$NaOH$-H_2O, at 15,000 psi and at 450°C, 520°C, 600°C, and 700°C. The following phases were found and characterized: hydroxyl varieties of nosean, sodalite and cancrinite, with formulae approximating $3NaAlSiO_4.NaOH._xH_2O$, $1 \leqslant x \leqslant 1.5$, sodic nepheline and phase X, apparently a previous unreported phase, with a composition approaching $Na_4Al_2Si_2O_9$. Approximate phase diagrams were deduced for the four temperatures.

THE DIFFERENT CRYSTAL STRUCTURES OF GERSDORFFITE (NiAsS)

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Gersdorffite has three related crystal structures. A high-temperature structure has the pyrite space group $Pa3$ with arsenic and sulphur equally distributed over $8(c)$ with $x = 0.3787$ and nickel in $4(a)$ with $x = 0.00$. An intermediate-temperature structure has the ullmannite space group $P2_13$ with arsenic in $4(a)$ with $x = 0.6164$, sulphur in $4(a)$ with $x = 0.3825$ and nickel in $4(a)$ with $x = -0.0065$. A low-temperature structure with a geometrically cubic cell has a distorted pyrite-type structure and space group $P1$ with nickel in pseudo $4(a)$ with $x = 0$, and arsenic and sulphur equally distributed over pseudo $8(c)$ with $x = \frac{3}{8}$; however, all symmetry is destroyed by small random position shifts.

These three structures may be distinguished in x-ray diffraction powder patterns, because the structure with disordered non-metal atoms ($Pa3$) has neither 001 nor 011 reflections present, the structure with ordered non-metal atoms ($P2_13$) has 001 reflection absent and 011 reflection present, and the distorted structure ($P1$) has both 001 and 011 reflections present. The intensity of the optical anisotropism is proportional to the intensity of the 001 reflection and hence related to the amount of distortion. The stability of the distorted structure increases with cobalt substitution for nickel.

SOME GEOCHEMICAL FACTORS IN THE FORMATION OF NICKEL SULPHIDES IN ULTRAMAFIC ROCKS

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Sulphur, not nickel, is the key element in the formation of non-lateritic nickel orebodies associated with ultramafic rocks. High sulphur and high H_2O pressures combine to act as favourable controls on the abundance, grade and localization of magmatic sulphides. Evidence for high sulphur pressures is found in the presence of pyrite in sulphide assemblages, and in high nickel : copper ratios in the sulphide fraction. Field criteria such as the existence of sulphur-rich country rocks may also be useful. High water pressures in the magma are indicated by reaction rims of hornblende around olivine and pyroxene, and by zones of amphibolite generally.

Magmatic sulphides may undergo redistribution at low temperature as a result of serpentinization or other metamorphic events, including weathering. If sulphurization (or desulphurization) has taken place, this should be recognizable in polished section studies. In cases of desulphurization of primary sulphides during serpentinization, secondary sulphides should be looked for at the margins of the most intensely serpentinized zones.

METAMORPHISM IN THE HALIBURTON HIGLANDS OF ONTARIO

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Metamorphic assemblages from Grenville Province rocks of the Haliburton Highlands show resemblances to those of the almandine-amphibolite facies of the Scottish Highlands and to amphibolite facies assemblages from the Abukuma plateau. This would indicate low-pressure intermediate-type metamorphism (Miyashiro 1962).

In accordance with the Haliburton assemblages, a metamorphic grid (Wylie 1964) can be constructed for the restriction Pf = Ps. It gives the following limits to metamorphic conditions in this region.

T = 550 to 650°C.
Ps = 3.5 to 6.5 kilobars.

ORIGIN OF THE SIDERITE COPROLITE-LIKE BODIES OF THE WILKES FORMATION, LATE MIOCENE OF SOUTHWESTERN WASHINGTON

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Over the years, thousands of coprolite-like bodies composed of siderite have been found in stream beds in the Late Miocene Wilkes formation of southwestern Washington. They have been variously described as excrement, algae nodules, air-current-shaped stalactitic growths, pseudomorphs after bryozoa and as masses squeezed through reeds or roots. They are found in a clay believed by Roberts (1958) to have been originally a waterlain volcanic ash. He reports the bed to contain the remains of aquatic reed-like plants and shrubs, generally in an upright position, suggesting rapid burial by volcanic ash fall with intervening periods of slow deposition that permitted plant growth.

Siderite bodies range from tiny irregular and elongate masses an inch or less in length and $\frac{1}{8}$ to $\frac{1}{2}$ inch in diameter up to masses a foot or more in length and 2 to 3 inches in diameter. Masses up to 30 pounds in weight have been reported. They appear confined to one member of the Wilkes formation and occur in outcrop on both limbs of the Napavine syncline for a distance of 5 miles east–west. Shape and size vary from place to place, with more botryoidal and disc-shaped forms on the east limb of the syncline and mostly "coprolite"-like masses on the west limb. Over 500 specimens have been examined and none contain visible remains of seeds, plant fibres, hair or bones, as might be expected in a true excrement. There is no evidence of replacement of previously deposited material. They appear to be formed as plastic primary masses of iron carbonate.

NEPHELINE K-FELDSPAR INTERGROWTH FROM KAMINAK LAKE, N.W.T

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A small alkalic pluton at Kaminak Lake, 95 miles west-southwest of Rankin Inlet, N.W.T., contains a suite of unusual rocks with compositions ranging from melteigite to syenite that usually carry major amounts of black melanite garnet. A common member of this suite is similar to ledmorite described by Shand from Loch Borolan, Scotland, and is composed of euhedral aegirine-augite, melanite, and nepheline, surrounded by interstitial, vermiform intergrowth, in places showing radiating or pinnate structure, of nepheline and K-feldspar. This intergrowth makes up as much as 40% of some rocks, and is commonly unaltered. Similar intergrowths have been referred to as pseudoleucite. The proportion of the two intergrowth phases is remarkably uniform at between 35 and 40% nepheline rods in a feldspar groundmass. Calculations from partial, quantitative electron microprobe analyses indicate that, by weight, the nepheline phase is $Ne_{71.3}Ks_{26.4}Q_{2.3}$, that the feldspar phase is $Or_{93.2}Ab_{6.8}$, and that the intergrowth as a whole has a molecular ratio K_2O:Na_2O of 59:41. Although the analysis of the intergrowth as a unit can be calculated almost exactly as leucite with 39 weight per cent $NaAlSi_2O_6$, it seems unlikely that the intergrowth is pseudoleucite in the sense that it formed from an originally homogeneous leucite phase. As an alternative, it is suggested that the intergrowth formed directly by cotectic crystallization of nepheline and K-feldspar from a final magmatic liquid phase.

CHEMISTRY OF SOME TERTIARY BASALTS FROM EAST GREENLAND

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Tertiary flood basalts in the Scoresby Sund area of East Greenland were sampled at over ninety localities during the Oxford University Expedition of 1965. The rocks are largely aphyric, with some flows showing plagioclase phenocrysts, and groundmass minerals are augite, pigeonite, plagioclase, magnetite-ilmenite and some olivine. The pyroxenes are invariably fresh, but the rare olivines are frequently pseudomorphed by serpentine.

Whole-rock analyses are usually quartz normative, but this may be due to the relatively high percentages of Fe_2O_3 (3.8–5.4). One sample that does not appear to have suffered oxidation (1.9% Fe_2O_3) is olivine normative. The parent magma for each of these lavas could be classified as an olivine tholeiite.

Plagioclase feldspar phenocrysts that show very striking progressive and oscillatory zoning in thin section display only moderate compositional ranges under probe analysis (An_{70}–An_{45}); groundmass plagioclase varies from An_{68} to An_{47}. The most interesting result is the wide range of the Mg/Fe ratio in the pyroxenes. Within a single polished thin section, Ca-rich pyroxenes varied from $Ca_{45}Mg_{40}Fe_{15}$ to $Ca_{42}Mg_{24}Fe_{36}$. This covers about 80% of the entire range of Ca-rich pyroxene compositions in the Skaergaard intrusion. Olivine compositions vary from Fo_{69} to Fo_{55} and pigeonites from $Ca_{10}Mg_{55}Fe_{35}$ to $Ca_{10}Mg_{45}Fe_{45}$. Differentiation trends of basic magmas can thus be followed in some detail by probe analyses of individual minerals. Further studies involving opaque phases are now in progress.

TRIDYMITE IN MINERALIZED ZONE AT DUNBRACK, MUSQUODOBOIT RIVER, NOVA SCOTIA

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Tridymite has been ascertained in the gangue of the Dunbrack occurrence. The Dunbrack occurrence is located approximately 3½ miles NNW of Musquodoboit Harbour, Halifax County, Nova Scotia. (44°49′10″ N, 63°11′30″ W). The mineralization consists essentially of argentiferous galena and sphalerite with some chalcopyrite, chalcocite and pyrite. There are colourful oxidation products such as malachite and azurite. The gangue mineral is reported to be mainly quartz, but closer examination reveals tridymite, or quartz paramorphs after tridymite, to be fairly widespread. In the tridymite, twinning in a sectorial pattern, dividing the pseudo-hexagonal basal sections in six parts, is a widely occurring feature. Around a central twinned part, there is frequently a rim of radial, fibrous material: this "chalcedony" does not differ in refractive index from the tridymite core as does adjoining quartz. In random orientation and in sections with maximum birefringence, a divergence of a few degrees in the direction of the *c*-axis of sub-parallel neighbouring lamellae is reminiscent of the lamellar growth of quartz. In contact with quartz, this material shows lower refraction. The tridymite of the Dunbrack occurrence contains plentiful minute inclusions. Growth–dissolution alternation has in some places produced distinct zonar layers reminiscent of sceptre quartz. The question arises whether the Dunbrack tridymite owes its formation to exceptional circumstances.

A REFINEMENT OF THE CRYSTAL STRUCTURE OF BORAX
$Na_2B_4O_5(OH)_4 \cdot 8H_2O$

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Because of the unusual borate polyanion in borax and the low degree of accuracy in the original work, the structure has been re-examined. Borax is monoclinic, space group $C2/c$ with $a = 11.8790$, $b = 10.6440$, $c = 12.2012$ Å all ± .0002 Å and $\beta = 106.617 \pm .001°$ (at 25°C). Approximately 1500 x-ray diffraction intensities were measured with a single crystal diffractometer (copper radiation) and converted to structure factors in the usual manner. These were placed on an absolute scale by comparison with the calculated values. Block diagonal least squares refinement (isotropic temperature factors) lowered the residual, R, to 0.10. Anisotropic temperature factor refinement converged at $R = 0.06$ and a difference electron density map revealed the positions of the ten hydrogen atoms (in the asymmetric part of the unit cell) so that the hydrogen bonding scheme proposed by Morimoto (1956) could be directly verified. The hydrogen bonding is of principal interest as these bonds link the borate polyanions into infinite chains and these chains to the hydrated sodium ion chains. The oxygen-oxygen distances in these bonds are between 2.736 and 3.148 Å. All seem normal in that the oxygen-hydrogen-oxygen angles are close to 180°, the variation being 155° to 174°, with the exception of one bond which has an angle of 144°. This bond is noteworthy because it is the longest—3.148 Å. In addition, the oxygen bonded directly to the hydrogen is fairly close to two other oxygens (3.351 and 3.481 Å) and the O–H–O angles are 119° and 124°. This may indicate that this bond is partially trifurcated.

THE SCANNING ELECTRON MICROSCOPE IN FABRIC INVESTIGATIONS

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The scanning electron microscope produces a magnified image of the sample surface by a reflection technique. An electron beam, focussed to a fine point of the order of 100 Å, is scanned over the surface of the sample, stimulating the emission of secondary electrons which are collected and amplified. The output is fed to a cathode ray tube, the spot of which is deflected in synchronism with the scan of the initial electron beam on the specimen surface. The image formed has a magnification which depends upon the ratio of the lengths of the final and initial scanning movements. The resolution is limited to about 100 Å and is not as good as that of transmission electron microscopes. The surface is examined directly, so neither replication nor ultra-thin sectioning is required. A thin layer of metal, such as evaporated gold, has to be deposited on the surface of non-conducting materials like rocks and soils to prevent an electric charge building up, which otherwise causes a serious loss of resolution. Because of the reflection geometry, the large depth of focus of the electron optical system may be exploited to the full.

The instrument has many potential petrological applications, particularly in studies in which the very high resolution of the electron microscope is not required but in which the resolving power or depth of focus of the optical microscope is insufficient. Its use in fabric investigations of fine-grained rocks, particularly limestones and clay soils will be illustrated.

AN OCCURRENCE OF SODALITE AT THE PRINCESS QUARRY, BANCROFT, ONTARIO

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Sodalite occurs in the Princess Quarry in veins up to 2 feet in width; the distribution of the veins is controlled without exception by the joint pattern in the nepheline syenite country rock. Nepheline, microcline, microcline perthite, biotite, calcite, magnetite, and apatite are also present in the veins together with trace amounts of cancrinite, pyrite and pyrrhotite. In parts of the Quarry, sodalite and nepheline have been severely altered to a mixture of zeolites.

The nepheline syenite wall rock is conspicuously altered in some areas; alkali feldspar, sodalite, and a mixture of zeolite minerals characterize this zone of alteration.

It is envisaged that the veins formed in two stages. Initially a pegmatite assemblage characterized by nepheline and oligoclase formed along tension fractures in the nepheline syenite host rock. Subsequently, this assemblage was partially replaced to form sodalite and microcline by a reaction similar to that given below:

$$\underset{\text{Albite}}{NaAlSi_3O_8} + 3\underset{\text{Nepheline}}{(Na_{.75}K_{.25})AlSiO_4} + Na\,Cl_{aq}$$

$$= \underset{\text{Microcline}}{(Na_{.25}K_{.75})AlSi_3O_8} + \underset{\text{Sodalite}}{3NaAlSiO_4 \cdot NaCl}$$

The source of the chlorine-bearing solutions is considered to be an undersaturated nepheline normative magma such as that proposed by Gittins (1961) to explain the origin of the nepheline rocks in the Bancroft region of the Grenville Province.

PARTITION COEFFICIENTS AS METAMORPHIC INDICATORS IN ROCKS FROM SUDBURY, ONTARIO

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The use of distribution coefficients as metamorphic indicators has been tested for minerals separated from fourteen representative pelitic schist samples. The samples were collected from an almandine amphibolite sequence near Sudbury, Ontario, along a 10 kilometer traverse which progressively intersected the mapped isograds of sillimanite first occurrence, staurolite breakdown, kyanite breakdown, K-feldspar first occurrence, and muscovite breakdown. Chemical analysis was done by "rapid" methods.

The distribution coefficients of Mg and Fe^{+2} for biotite/garnet show a linear decrease with metamorphic grade, whereas those for Ca and Mn increase. Similar relations have been found for muscovite/garnet and muscovite/biotite.

Deviations of some samples from the idealized linear trends are ascribed, from electron microprobe studies, to partial re-equilibration of ions between the minerals in response to changing metamorphic conditions.

The inferred temperature interval across the traverse is approximately 475° to 725°C and 5 to 7 kilobars total pressure. P_{H_2O}, f_{O_2} and f_{H_2} were calculated on the basis of biotite compositions.

PETROGRAPHY OF THE WARK–COLQUITZ COMPLEX, SOUTHERN VANCOUVER ISLAND, BRITISH COLUMBIA

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The sequence of thermal and tectonic events recorded by the crystalline rocks of southern Vancouver Island is important in establishing whether these rocks correlate with the pre-Devonian crystalline basement on the Gulf Islands, 20 miles to the east.

The rock mapped previously with the Wark gabbro-diorite (gneiss) unit at Tenmile Point is an igneous labradorite-orthopyroxene-clino-pyroxene-green hornblende-biotite-quartz gabbro. Most of the Wark-type rocks are more altered than this relatively fresh rock, but the rock type can usually be recognized with confidence through relict textures. Nearly-continuous gradation from essentially fresh rock to a saussurite-actinolite-prehnite rock can be recognized.

The Colquitz quartz diorite (gneiss) map unit is more variable than the Wark map unit. The Colquitz rocks are correlated less confidently and range from igneous quartz diorite to finely laminated crystalloblastic gneiss with exceptional calc-silicate and marble layers. It is questionable whether all rocks of the Colquitz map unit shared the same history.

Petrographic evidence and cross-cutting relationships currently suggest the following partial sequence: sedimentation, metamorphism to give finely laminated gneisses, intrusion of the gneissic complex by Wark-type gabbro-diorite, possible intrusion by quartz diorite, static metamorphism, cataclasis without significant recrystallization and, finally vein filling and minor replacement by prehnite and associated minerals. Emplacement of the Saanich granodiorite predated the latest prehnitization but otherwise has not been fitted into the above sequence.

NEW DATA ON THE OPTICAL PROPERTIES AND THE CHEMICAL COMPOSITION OF THE PYROXENES OF S.E. MADAGASCAR

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Twenty-nine samples of pyroxenes (diopside-hedenbergite series) were separated from the pyroxenites of Southeast Madagascar and studied mineralogically and chemically. The optical and physical properties were determined by an analysis of the indices of refraction, birefringence, extinction angles, optic axial angles, pleochroism and specific gravity. For the indices of refraction, it was found that α varies from 1.670 to 1.724 and γ from 1.690 to 1.743. Birefringence varies from 0.013 to 0.029. Extinction angles vary from 37.5 to 46 degrees. Optic axial angles vary from 57 to 61 degrees (with a positive optic sign). Specific gravity varies from 3.285 to 3.682, with the samples having the darker colour and higher Fe content being the more dense.

The most remarkable characteristic of these pyroxenes is their notable high content of Al_2O_3, varying from 7.00 to 10.00%. The number of Ca atoms is equal to the sum of Fe and Mg atoms. Also, the weight percentages of CaO, 24–26%, correspond to those which exist in true diopside having the formula $Ca(Mg, Fe)Si_2O_6$. On the contrary, however, the SiO_2 content in these pyroxenes is low, between 40 and 47% by weight, when it normally would be expected to fall between 49 and 55% according to the formula. In other words, compared to true diopside-hedenbergite, these pyroxenes seem to have aluminum substituted for silicon.

SIGNIFICANCE OF TWO CONTRASTING DEVONIAN BATHOLITHIC ASSOCIATIONS FROM NEW BRUNSWICK

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The Devonian granitic rocks of New Brunswick occur in two distinct belts: one, a series of elongate batholiths, trends north-easterly across the province, a distance of 175 miles, along the axis of the Lower Paleozoic folded belt; the other, here called the St. George batholith, is exposed in the southwestern portion of the province, adjacent to the Bay of Fundy. Presumed to be of essentially the same age, rocks from these two belts differ markedly in their mineralogy, major and minor element chemistry, texture, field relationships and lithologic associations. These differences are thought to reflect the physical environment of crystallization as well as the volatile content of the crystallizing magma. Many features of the mesosolvus-subsolvus type of granitic rocks from the axis of the folded belt indicate mesozonal emplacement of a magma relatively rich in volatiles. On the other hand, the granites of the St. George batholith seem to have crystallized in the epizone, from a relatively dry melt; this suggestion is supported by occurrences of volcanic and hypabyssal associations, such as hypersolvus granite-granophyre-rholite, and rapakivi granite – rapakivi rhyolite.

If these inferences are sound, major hydrothermal ore deposits should not be expected adjacent to plutons of the St. George type. In fact, the major ore deposits of New Brunswick are located along the 'axial' batholith belt: the host rocks of the St. George batholith are notably devoid of extensive mineralization that may be related to the emplacement of that pluton.

PETROLOGY OF RODINGITES IN ULTRAMAFITES, KLAMATH MOUNTAINS, CALIFORNIA

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Rodingite has been extensively developed within a layered portion of an ultramafic body in the eastern Klamath Mountains, California. Serpentinized peridotite and dunite occur in alternating layers, each about one hundred feet thick, along Parks Creek, six miles northwest of Weed, California.

There are two varieties of rodingite in the area. The first type is found as fine-grained veins that are almost pure hydrogrossularite rock. The veins lie along the boundary between peridotite and diorite dykes and within serpentinized peridotite. The other type of rodingite is found as garnetized, pegmatitic gabbro dykes. Textural relationships in the dykes provide evidence to suggest that garnet has replaced feldspar. Some dykes contain blocks of serpentinite up to one half meter in diameter.

The garnet has a unit-cell of 11.87 ± 0.01 Å, a refractive index of 1.727 ± 0.003, and a specific gravity of 3.74. It is mainly hydrogrossularite with 1.5 to 2.5% water, but probably contains some andradite and spessartine molecule. X-ray fluorescence tests show both iron and manganese peaks.

Ca-rich solutions probably deposited veins along fracture zones and altered the gabbro dykes. These solutions may be related to serpentinization of the peridotite and dunite.

PETROLOGY OF THE COPPER MOUNTAIN INTRUSIONS NEAR PRINCETON, B.C.

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The Copper Mountain intrusions, which include the Voigt and Smelter Lake dioritic stocks, the Armstrong Bluffs monzonite-syenite complex and the differentiated Copper Mountain stock are part of a continuous alkali-calcic rock series ranging in composition from pyroxenite to perthosite pegmatite. The series is believed to be derived from a single parent magma of basic diorite composition and to have formed through crystallization differentiation. The age of the series, determined by potassium–argon methods is about 195 m.y.

Parent magma was intruded into Nicola Group (Upper Triassic) rocks by forceful injection, with structural readjustment of the country rock. The Voigt and Smelter Lake stocks (diorite) crystallized without apparent differentiation. The Armstrong Bluffs monzonite-syenite complex is believed to have formed by repeated tapping of a differentiating magma which was emplaced at intervals after the crystallization of diorite in Voigt and Smelter Lake stocks. In the Copper Mountain stock, after crystallization of a dioritic roof and outer zone, magma differentiated to form a continuous series from pyroxenite to perthosite pegmatite.

Differentiation resulted from a combination of thermal convection, chemical diffusion, crystal armoring and crystal settling. Differentiation began with the formation of gabbro and was initiated by convection currents which were formed as a result of temperature gradients in a mobile, volatile-charged magma. When the composition of the magma approached the Ab–Or side of the Ab–Or–An ternary system, subsolvus crystallization was succeeded by hypersolvus crystallization and the development of perthosite pegmatite.

Feldspars from the Copper Mountain intrusions, studied by x-ray powder techniques, exhibit a range of thermal states from the intermediate to the low-temperature types. Feldspar geothermometry suggests a range of crystallization from above 820°C to about 500°C.

GEOCHEMICAL PATTERNS AND THEIR ECONOMIC SIGNIFICANCE IN THE NORTH-CENTRAL DISTRICT OF MACKENZIE, N.W.T.

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Eight hundred rock samples from the north–central District of Mackenzie, N.W.T. were analyzed spectrographically for nineteen elements and the concentrations compared with various rock units and with aerial geophysical surveys. Yellowknife and Snare volcanics and associated phyllites contain the highest concentrations of Ni, Cu, Co, Ti, Sn, Mo, V, Mn, Zn, and Cr. Spatially related schists and gneisses, on the other hand, are distinctly low in these elements. Except for local departures, Echo Bay volcanics contain trace elements in amounts close to regional averages. The content of Y, Sc, Ga, Pb, Mn, Ba and Be is higher in the granite rocks from the younger Bear Province than in the granite rocks from the older Slave Province, in spite of the great mineralogical similarities between these two Provinces. Individual granitic bodies from the Slave Province also show much greater variation in the trace element content.

Both aphanitic and crystalline acidic porphyries show a similar content of trace elements, except for higher amounts of Y, Se, Ga, Sr, Pb, Mn and Ba in crystalline varieties. When compared to granitic rocks from the Bear Province, the porphyries show striking similarities in trace element concentrations. Sedimentary rocks from the Epworth formation give the lowest concentrations of trace elements in the region.

Analysis of the geochemical data reveals that the background values can be predicted on the basis of mineralogy and that the residual values coincide fairly closely with anomalous magnetic highs.

ELECTRON MICROPROBE STUDIES OF MINERALS ACROSS A SECTION OF THE SUDBURY NICKEL IRRUPTIVE

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In the Levack-Strathcona area of the north range of the Sudbury Nickel Irruptive, 1500 feet of felsic norite is overlain by 600 feet of oxide-rich gabbro and 4300 feet of a granophyre known as the micropegmatite. Plagioclase, hypersthene and augite are cumulus minerals in the felsic norite; plagioclase, augite, magnetite and apatite are cumulus minerals in the oxide-rich gabbro. Phase layering in this portion of the Irruptive parallels the base of the Intrusion.

The anorthite content of cores of plagioclase grains falls from 68 molecular per cent at the base to 55% at the top of the felsic norite and continues to fall to 50% in the centre of the overlying oxide-rich gabbro. No fresh plagioclase was found in samples from the upper part of the gabbro except at the very top where the plagioclase composition is An_5. Throughout the micropegmatite plagioclase contains 1–3% of the anorthite and less than 1% of the orthoclase molecules. The abrupt drop in the anorthite content of plagioclase within the oxide-rich gabbro, and the albitic composition of plagioclase in the micropegmatite are attributed to a reaction involving the formation of epidote.

The Fe : Mg atomic ratio of augite increases from 0.35 near the base of the felsic norite to 0.58 at the top and continues to increase through the oxide-rich gabbro to reach 0.73, 200 feet above the base of the micropegmatite. No unaltered augite was found in samples higher in the micropegmatite than this. The Fe : Mg atomic ratio of hypersthene increases from 0.49 at the base to 0.69, 400 feet below the top of the felsic norite. Horizons in which plagioclase, augite and hypersthene have a constant composition are parallel to the base of the Irruptive.

The cryptic variation shown by plagioclase, augite, and hypersthene support the hypothesis that the felsic norite, oxide-rich gabbro, and lower part of the micropegmatite are the result of the fractional crystallization of a single intrusion of silicate magma. The parallelism between both the cryptic variation and phase layering and the base of the intrusion is at variance with palaeomagnetic data which indicate that rocks of the Irruptive cooled through their Curie points at a time when the base along the north range was dipping at 42° south.

CRYSTAL CHEMISTRY OF THE SKUTTERUDITE MINERALS

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The stabilities of the skutterudite minerals are attributed to the tendency of the metal atoms to achieve a state in which there is complete spin pairing of the non-bonding *d*-electrons in the t_{2g} orbitals. In $CoAs_3$, complete spin pairing can be attained if it is assumed that cobalt is trivalent, thereby leaving the atom with six non-bonding, spin-paired *d*-electrons in the three t_{2g} orbitals. In $(Fe_{0.5}Ni_{0.5})As_3$, a similar situation is attained by the replacement of $2Co^{+3}$ by $(Fe^{+2} + Ni^{+4})$, so that the average number of electrons per atom remains the same. This explains the complete solid–solution range between $CoAs_3$ and $(Fe_{0.5}Ni_{0.5})As_3$. $FeAs_3$ and $NiAs_3$ do not exist as stable compounds, because Fe^{+3} and Ni^{+3} (the valencies required to fulfil the bonding requirements) both have odd numbers of non-bonding *d*-electrons so that complete spin pairing is impossible. The tendency of skutterudites to be deficient in arsenic can be explained by the presence of some divalent cobalt and nickel, presumably in equilibrium with their higher valence states.

MINNESOTAITE FROM THE BLUEBELL MINE, RIONDEL, B.C.

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Minnesotaite from the Bluebell Mine, Riondel, B.C. gave the following chemical analysis: SiO_2 51.47%, FeO 30.50%, Fe_2O_3 3.23%, Al_2O_3 1.57%, CaO 0.00%, MgO 5.10%, H_2O+ 5.88%, H_2O- 0.16%, MnO 1.83%, total: 99.74%. This chemical composition is nearly identical with that of minnesotaite from the type locality (Mesabi Range,* Gruner 1944); differences are a higher alumina content (1.57 vs. 0.64%) the presence of MnO and a slightly lower magnesia content (5.10 vs. 6.36%) in the Bluebell material compared with the Mesabi Range material.

Minnesotaite from the Bluebell mine is extremely fine-grained; *x*-ray power diffraction photographs show considerable line broadening due to crystallite size.

*Gruner, J. W. (1944): "The composition and structure of minnesotaite, a common iron silicate in iron formations". *Am. Mineral.*, **29**, 363–372.

CHEMISTRY OF SAFFLORITE–LOELLINGITE

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One hundred microprobe analyses of the orthorhombic minerals safflorite-loellingite have been obtained on eighty specimens from world-wide localities. These show that there is a continuous solid-solution series between $CoAs_2$ and $FeAs_2$. The distribution of the concentration of data suggests that the term loellingite may be conveniently restricted to $FeAs_2$ with less than 3 mole per cent metal impurity and safflorite to the (Co, Fe, Ni)As_2 series. This is in approximate accord with previous usage.

Most safflorite compositions have Co/Fe ratios varying from 20 to 80 mole, per cent and generally with less than 20 mole per cent $NiAs_2$. The *x*-ray diffraction patterns of nickel-free safflorite-loellingite vary systematically with composition. However, the addition of 5–20 mole per cent $NiAs_2$ has a strong effect on the structure and gives an *x*-ray pattern essentially similar to $CoAs_2$ even in iron-rich safflorite. This may be due to the available valency electrons of Ni (4) and Fe (2), which have the same mean number as Co (3). Two cobalt-rich safflorites (and synthetic $CoAs_2$) exhibit monoclinic symmetry.

Twenty-one microprobe analyses of loellingite were obtained and are all essentially nickel-free. This discredits the previous identification of nickelian loellingite. Most loellingite samples show less than 2 mole per cent $CoAs_2$, and up to 5 mole per cent sulphur replaces arsenic.

The stoichiometry of six safflorites and five loellingites was determined in which the metal : arsenic ratio varied from 1.89 to 2.08. Eight samples show arsenic lattice vacancies, but these are almost always completely filled by metals in excess of a 1:2 metal : arsenic ratio.

MICAS AND ASSOCIATED MINERALS FROM TWO Li-PEGMATITES

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Micas from Li-pegmatites were chosen for the study of the distribution of certain elements between the micas and their host minerals and inclusions in order to learn about the chemical evolution of the pegmatites and the genesis of micas.

Microcline, cleavelandite, spodumene and beryl are the hosts of muscovite and lepidolite in the Val d'Or pegmatite of the Superior Province. Three principal types of mica occur in this pegmatite: phlogopite along the margins, and muscovite and lepidolite in the centre. Micas overgrowing spodumenes are different: green spodumene is host to a greenish muscovite that contains four cations in the octahedral coordination $(K_{1.8}\cdot Na_{0.1})(Al_{3.5}, Fe'''_{0.3}\cdot Fe''_{0.1}, Li_{0.2})$ $(Si_{6.1}, Al_{1.9})O_{20}(OH_{3.49}, F_{.05})$, whereas pink spodumene is host to a pink Li-mica that contains five cations in the octahedral coordination $(K_{1.7}, Rb_{0.1}, Na, Ca, Cs_{0.1})(Al_{2.9}\cdot Fe'''_{0.1}\cdot Mn_{0.1}, Li_{1.9})(Si_{6.7}, Al_{1.3})O_{20}(OH_{2.4}, F_{1.7})$. Micas enclosed in beryl and in fractures of cleavelandite resemble Li-micas from the pink spodumene in chemical composition, but contain different quantities of Zn and Ni.

On the basis of increasing quantities of fluorine, lithium, rubidium, manganese and silica, the following sequence of crystallization of micas is suggested: (1) phlogopite, (2) coarse muscovite, (3) muscovite overgrowing green spodumene, (4) Li-mica overgrowing pink spodumene and lepidolite in cleavelandite fractures and (5) Li-mica overgrowing beryl. Three modes of occurrence of micas were observed from micas in a Li-pegmatite in the Leduc Mine, in the Grenville Province: (1) fine-grained biotite in surrounding gneisses, (2) biotite sheets along the fractures of pink peristerite from the pegmatite margins and (3) Li-mica enclosed in amazonite containing inclusions of tourmaline. The biotites are similar in chemical composition, but the biotite from the peristerite fractures contains more silica, fluorine and lithium. The Li-mica contains the highest quantities of manganese, lithium, fluorine and silica, much adsorbed water, and almost six cations in the octahedral coordination. $(K_{1.8}, Na, Rb_{0.1})(Al_{2.0}Fe''_{0.2}, Mn_{0.5}, Li_{3.1})(Si_{7.1}\cdot Al_{0.9})O_{19.5}(OH_{1.7}, F_{3.2})$.

Micas contain higher concentrations of the following elements than their hosts: K (except microcline), Li (except spodumene), Rb, Cs, Fe, Mn, Ni and Zn.

ELECTRON PROBE DATA FOR SOME CANADIAN PLATINUM METAL MINERALS

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Minute grains of minerals containing significant concentrations of the platinum metals Pd, Pt, Rh and Ir have been found associated with nickel ores from Werner Lake, Falconbridge, and Strathcona, Ontario. These grains have been analysed by electron probe methods and three species with the formulae $(Pd, Ni, Pt)(Te, Bi)_2$, RhAsS and IrAsS have been identified. The presence of major amounts of Ni in the first appears to distinguish it from the moncheite–merenskyite series $(Pd, Pt)(Te, Bi)_2$. The latter two phases may be identified as hollingworthite and irasite, both of which have only recently been described from South Africa. Most of the Pt metals are found to some degree in one or other of the intergrown sulpharsenide phases, but the bismuthotelluride contains only Pd and Pt, and Ni. In the absence of *x*-ray diffraction data the identification of a new species is unjustified, but the complexity of platinum metal mineral chemistry is seen to increase with each new microanalysis. The presence of Ni in the platinoid bismuthotellurides may have genetic implications.

REGIONAL VARIATIONS OF MINOR ELEMENTS IN SULPHIDES, SLOCAN DISTRICT, B.C.

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Second-order trend surface and residual maps have been obtained for geographically distributed values of numerous minor elements in galena, sphalerite and pyrite from the Slocan mining camp, British Columbia. Quadratic surfaces for many of these variables (Ag in galena, Sn in sphalerite, and As, Cr, Sn and Co/Ni ratios in pyrite) have similar patterns and coincident major axes with a northwest trend. Surfaces, except for that of Co/Ni ratios, are dome-shaped with a high central zone near the Sandon camp and values decreasing outward. The trend for Co/Ni ratios is basin-shaped, with values increasing outward. Each of the surfaces has a low coefficient of determination, but the similarity of patterns and correlation with known geological features in the camp suggest that they represent real but generalized trends. The data suggest that trend surface analysis is a useful technique for examining regional variations of certain minor elements in common sulphides.

A NEW IRON-TITANIUM OXIDE MINERAL FROM HEARST, ONTARIO

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Discovery of an iron-titanium oxide mineral occurring near Hearst, Ontario, was first discussed by the writer at the September 1966 meeting of the M.A.C. in Halifax, N.S. Since then, new data have been obtained which demonstrate unmistakably that this is a distinct, new mineral.

The Hearst mineral is black, submetallic, weakly magnetic, and occurs in sharp, angular, lustrous grains in an unconsolidated quartz-kaolinite deposit. Chemical analysis indicates an ideal composition $Fe_2O_3 \cdot 3TiO_2 \cdot 0.6\ H_2O$. Specific gravity is 4.03 ± 0.02. Single crystal *x*-ray and electron diffraction studies show that the mineral is hexagonal, $a_0 = 2.892 \pm 0.002$ Å, $c_0 = 4.604 \pm 0.002$ Å, $V = 33.53$ Å^3. Space group is unequivocally identified as $P6_322$. From the above data, $Z = 0.203$. Odd layer lines along $(c)^*$ show extra reflections and prominent arcs and streaks indicating disorder and possible existence of a super structure. This, combined with the fractional cell contents, suggests a tendency to statistical distribution of Fe and Ti in the cation sites, with a small cell content of $(Fe_{0.4}Ti_{0.6}O_{1.8})$. Work is continuing on this problem. All of the Debye Scherer arcs can be readily indexed from the single crystal data or matched with the extra reflections and diffuse streaks.

Electron microscopy and diffraction confirm the single-phase nature of the mineral grains. Infrared spectra of the mineral are distinct from ilmenite, hematite, anatase and rutile, though fairly similar to the last of these. The *x*-ray powder pattern is similar to, but distinct from mixtures of hematite, ilmenite and rutile. A DTA profile shows no prominent thermal effects up to 1100°C.

The mineral is believed to have formed syngenetically, late in the sequence of crystallization of a highly leucocratic igneous intrusive which was later kaolinitized. Attempts to synthesize the mineral hydrothermally will be made in the future.

The chemical composition and unit cell parameters of this mineral are almost identical with those of "pseudorutile" (Teufer & Temple, *Nature*, **211**, 179–181 (July 9, 1966) and "proarizonite" (Bykov, Dokl. Akad. Nauk *SSSR* **156**, 567–570, 1964); the problem of an acceptable name for the mineral has been referred to the Commission on New Minerals and Mineral Names, IMA.

WICKENBURGITE, A NEW MINERAL FROM ARIZONA

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Wickenburgite, $Pb_3Al_2CaSi_{10}O_{24}(OH)_6$, is a new mineral found in abundance at several prospects near Wickenburg, Arizona. It is an oxide zone mineral derived from lead ores and occurs with phoenicochroite, mimetite, cerussite, and willemite.

The mineral is well crystallized to granular; white, colourless, or rarely pink, and has a vitreous lustre. The hardness is 5, $G = 3.85$ (meas.); 3.876 (calc.). Fluoresces dull orange in short wave U.V.

Crystals show dihexagonal dipyramidal symmetry, are tabular, and dominated by $\{0001\}$ and $\{10\bar{1}1\}$. The axial ratio is $a{:}c = 1{:}2.354$ (morph.) and $a{:}c = 1{:}2.363$ with $a = 8.531$ Å and $c = 20.160$ Å derived from the refined powder data. $Z = 2$. Morphological and Weissenberg data establish the space group as $P6_3/mmc$. The strongest lines are 10.085 Å (10), 5.962 (3), 5.043 (3), 3.392 (6), 3.355 (4), 3.257 (8), 2.791 (3), and 2.639 (4).

Crystals are uniaxial (−) with $n_E(D) = 1.6480$, $n_O(D) = 1.6918$. Dispersion of the indices ($v > r$) is moderate.

No previously established species are likely to be confused with wickenburgite with the possible exception of belmontite (?).

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