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**ECONOMIC GEOLOGY SERIES No. 18**

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**NIOBIUM (COLUMBIUM) DEPOSITS  
OF CANADA**

**BY**

**ROBERT B. ROWE**

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DEPARTMENT OF MINES AND TECHNICAL SURVEYS

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GEOLOGICAL SURVEY OF CANADA

Economic Geology Series No. 18

# NIOBIUM (COLUMBIUM) DEPOSITS OF CANADA

By

Robert B. Rowe

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## PREFACE

The element discussed in this report is by international agreement now officially called niobium, but it is also widely known as columbium. Niobium is used mainly for making stainless, high-temperature steels which are in particular demand for components of jet aircraft. During the last few years there has been an increased demand for niobium, causing much interest in deposits containing the metal. The principal sources are in Africa, where large deposits are known, but Canadian deposits have attracted much attention because of their proximity to North American markets.

The author began a comprehensive study of Canadian niobium deposits in 1951, and two preliminary reports dealing with deposits near North Bay, Ontario, and Oka, Quebec have been published. The results of other investigations are presented here for the first time. This report describes the principal known Canadian deposits and lists other Canadian occurrences, gives brief accounts of foreign occurrences, presents generalizations on the mode of occurrence of niobium in Canada and elsewhere, and includes condensed information on uses, markets, and other economic matters. Because of the characteristic geological environments in which niobium is known to occur, the report should be of particular interest to advanced prospectors and to geologists directing prospecting for niobium deposits or appraising and exploring them.

GEORGE HANSON,  
*Director, Geological Survey of Canada*

OTTAWA, July 16, 1956





# NIOBIUM (COLUMBIUM) DEPOSITS OF CANADA

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## PART I

### INTRODUCTION

The element niobium (also called columbium) was of little use until the advent of the jet aircraft with the resultant need for high-temperature alloys. It is generally regarded by industry as a "new metal", although it was discovered more than 150 years ago, and further research is necessary before the entire role of niobium in modern metallurgy is known.

Several large deposits of the niobium mineral pyrochlore and other complex niobates have been found in Canada, and it is probable that Canada will become a producer of niobium in the near future. The principal source of niobium is the mineral columbite which is obtained mainly from Nigeria but reserves of this mineral are low, and industry is looking to other minerals, particularly pyrochlore, as future sources. Although pyrochlore deposits occur in several countries, the Canadian deposits are the most strategically located with respect to North American markets.

Field work was conducted during parts of 1951, 1952, and 1953, and in 1954 and 1955, and more than five hundred thin sections were examined.

The report should be regarded as an introductory one, because more information is necessary before a thorough understanding of the deposits and their economic possibilities can be attained.

### Acknowledgments

The Geological Survey of Canada, and the writer personally, thank the mining companies holding niobium properties in Canada for making information available, and for many courtesies.

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Capable assistance in the field was rendered by R. W. Hutchinson in 1951, J. Nixon in 1952, H. Rasian and L. Berman in 1953, and C. M. Wright in 1954.

## Terminology

Many of the terms in this report are not in common usage, and these are defined as follows:

*Alkaline rock.* Alkaline rocks proper are rocks that are relatively rich in sodium or potassium, or both; or that contain essential amounts of minerals that are relatively rich in sodium or potassium, such as nepheline and leucite. The alkaline rocks of complexes that contain niobium deposits are rich in sodium minerals and sodium-bearing varieties of other minerals. Rocks that are comagmatic with alkaline rocks proper are generally referred to the alkaline group of rocks.

*Alnoite.* Feldspar-free, melilite-bearing lamprophyre.

*Carbonate rock.* Rock that consists of 50 per cent or more carbonate.

*Carbonatite.* Rock that consists of 50 per cent or more carbonate, and is not of sedimentary or biogenic origin. The term is commonly used by African geologists to refer to carbonate rocks of volcanic origin. Some geologists use the term to refer to carbonate rock in an alkaline rock complex regardless of its origin.

*Essexite.* Nepheline-bearing gabbro, or gabbro that contains alkali feldspar.

*Fenite.* Rock that is metasomatically altered by emanations from an alkaline magma.

*Fenitization.* The metasomatic process that causes the formation of fenites. Soda pyroxenes and soda amphiboles are common products of fenitization.

*Fourchite.* Feldspar-free lamprophyres that are devoid of olivine and that commonly contain titanian augite.

*Ijolite.* Medium coloured rock that consists essentially of nepheline and soda pyroxene.

*Jacupirangite.* Rock that consists essentially of titanian augite. Accessory minerals include nepheline, zeolites, magnetite, ilmenite, and apatite.

*Juvite.* Nepheline syenite rich in potash feldspar.

*Lamprophyre.* Dark coloured dyke rock that is generally porphyritic and of unusual composition. Feldspar is usually restricted to the ground-mass or is lacking.

*Lujavrite.* Coarse-grained, eudialyte-bearing nepheline syenite with trachytoid texture.

*Malignite.* Rock that consists essentially of pyroxene, commonly soda pyroxene, nepheline, and alkali feldspar.

*Melteigite.* Dark coloured rock that is composed essentially of soda pyroxene and nepheline.

*Microijolite*. Medium coloured, very fine- to fine-grained rock that consists essentially of nepheline and soda pyroxene. It occurs as small bodies, dykes and sills.

*Monchiquite*. Feldspar-free lamprophyre that contains pyroxene, usually titanian augite, and olivine.

*Nephelinite*. A rock commonly extrusive in origin and porphyritic in texture, containing nepheline and pyroxene as essential constituents. The pyroxene is often soda pyroxene.

*Okaite*. A massive, coarse-grained rock that is composed essentially of melilite with nepheline, biotite, and calcite as varietal minerals.

*Sovite*. Carbonatite that is composed essentially of calcite. Some geologists use the term to refer to calcite rock in an alkaline rock complex regardless of its origin.

*Tephrite*. Plagioclase-bearing, basic volcanic rock with more than 10 per cent feldspathoids, and little or no olivine.

*Tinguaite*. Granular to porphyritic dyke rock that consists essentially of nepheline, alkali feldspar, and acicular soda pyroxene.

## PART II

### GENERAL INFORMATION

#### History

Element 41 was discovered by C. Hackett, an English chemist, in 1801 while analysing a mineral from New London, Connecticut. He named the element columbium. In 1844, H. Rose believed that he had found a new element in the mineral tantalite, and gave it the name of niobium in 1846. Blomstrand first prepared the pure metal in 1866 by reducing its chloride with hydrogen. Both names were used for many years. In 1949, at the fifteenth meeting of the International Union of Pure and Applied Chemistry, it was agreed to use niobium rather than columbium for element 41. It is best known as columbium in North America by geologists, mineralogists, and mining and metallurgical engineers.

The first discovery of a niobium mineral in Canada was made by Hoffman in 1882. He described and analysed samarskite from granitic pegmatite in Maisonneuve township, Berthier county, Quebec (Hoffman, 1882, and Ellsworth, 1932, pp. 248-249)<sup>1</sup>.

Other occurrences of niobium minerals in granitic pegmatites were found subsequently, but there has been no significant production of niobium minerals from these deposits. Many of them were first described by Ellsworth (1932).

In 1951 and 1952 several radioactive deposits of niobium minerals associated with complexes of alkaline and carbonate rocks were found in British Columbia, Ontario, and Quebec. These deposits have merited exploratory work in the form of stripping, trenching, and drilling; and underground exploration has been done on two of them. Some of the deposits are potential large-tonnage sources of niobium.

#### Properties and Uses

Some of the properties of niobium are as follows: colour steel-grey, atomic weight 92.91, specific gravity 8.4, valence 3 or 5, melting point 2,500 degrees centigrade, boiling point 3,300 degrees centigrade, and hardness almost equal to that of wrought iron (Hodgman, Weast, and Selby, 1955).

The estimated distribution of niobium by use in 1953 was as follows: ferrocolumbium and ferrotantalum-columbium in steel, 73 per cent; specialized nonferrous alloys, 18 per cent; cemented carbides, 4 per cent; welding rods, niobium metal and miscellaneous, 5 per cent (Griffith, 1953). Niobium is used mainly in the manufacture of stainless, high-temperature steels. Added as ferrocolumbium and ferrotantalum-columbium, it acts as a stabilizer of carbon and inhibits intergranular corrosion, and increases stability and high-temperature strength. The use of niobium in special, high-temperature alloys for jet engines has decreased since 1951, because

<sup>1</sup> Names and dates in parentheses refer to bibliography at end of this report.

drastic measures taken by the United States government for the procurement, allocation, and conservation of, and substitution for niobium encouraged engineers to specify substitutes (Griffith, 1952, and United States Senate, 1954). Perhaps the growing realization that niobium is not rare, and that niobium deposits are abundant, will encourage industry to expand the use of niobium. According to Reno (1956), current research could result in a demand far in excess of the 1955 supply.

### Production of Niobium Mineral Concentrates

The principal sources of niobium at present are the mineral columbite and intermediate members of the columbite-tantalite mineral series. In 1953, the estimated world production of columbite concentrates was 5,550,000 pounds (Griffith, 1953). Nigeria (4,388,160 pounds), Belgian Congo (623,902 pounds), Portugal (213,846 pounds), and the Federation of Malaya (116,480 pounds) were the principal producers. According to Banfield (1956), the Nigerian production of columbite concentrates in 1954 was 6,023,360 pounds. The 1953 production of Portugal was apparently abnormal, because production in 1952 was estimated as *nil* (Griffith, 1952), and 1954 estimates do not include Portugal as a leading producer (Banfield, 1956).

The mineral pyrochlore is a growing source of niobium. In 1952, pyrochlore-bearing carbonate rock was shipped from Kaiserstuhl, Germany, to France for processing (Griffith, 1952), and pyrochlore concentrates were produced at Sove, Norway, in 1953 (Griffith, 1953). According to Bjorlykke (1955), production at Sove in 1955 was 30,000 pounds of niobium oxide concentrate per month, and expansion to give a monthly production of 60,000 pounds was under way.

If the niobium market should expand greatly, reserves of columbite and columbite-tantalite appear to be too limited to meet such an expansion, and industry is looking to the very large deposits of pyrochlore and similar minerals as the major future sources of niobium. Several problems of concentration and extraction must be solved before niobium is readily available from many of these deposits; however, both government and industrial agencies are conducting research on these problems and considerable progress has been made.

### Specifications and Prices

The present market quotation for columbite (E and M J Metals and Mineral Markets, May 17, 1956) is \$1.15 to \$1.35 per pound of pentoxide on the basis of 65 per cent niobium-tantalum pentoxides. No quotations for other niobium minerals, ores, or concentrates are given.

During the period August 1952 to May 1955, market quotations for niobium ores and concentrates were governed largely by the niobium-tantalum purchase program of the United States Government that was announced by the Defence Materials Procurement Agency. Under the program the government agreed to purchase 15 million pounds of contained niobium-tantalum pentoxide. Specifications and prices quoted in the schedule were as follows:

- (1) For niobium ores and concentrates containing not less than 35 per cent combined niobium oxide and tantalum oxide and having



a niobium oxide to tantalum oxide ratio of not less than 1 to 1, c.i.f. Atlantic ports for material of foreign origin or f.o.b. depot of purchasing agent for material of domestic origin, \$1.40 per pound of combined contained pentoxides, plus \$0.02 per pound for each additional per cent above 35 per cent, plus a 100 per cent bonus to the producer. Impurities not to exceed the following maximum limits: titanium oxide, 8 per cent; tin oxide, 8 per cent; iron oxide, 25 per cent; and manganese oxide, 13 per cent.

(2) For niobium-tantalum ores and concentrates containing 20 per cent or more niobium oxide and 25 per cent or more tantalum oxide, \$1.60 per pound of combined contained pentoxides, plus \$0.02 per pound for each additional per cent above 45 per cent, plus a 100 per cent incentive bonus to the producer. Impurities not to exceed the following maximum limits: titanium oxide, 4 per cent; tin oxide, 4 per cent.

The purchase program was stopped in May 1955 when receipts and forward commitments filled the quota, and the world price was affected immediately. No price was quoted until August 1955, when a nominal quotation of \$2.25 to \$2.50 per pound of contained pentoxides was given for columbite. Since then the price has dropped gradually to the present level.

### Buyers and Consumers

The following companies are the principal buyers and consumers of niobium ores and concentrates (Griffith, 1953):

Electro Metallurgical Division, Union Carbide and Carbon Company,  
Niagara Falls, New York.

Fansteel Metallurgical Corporation, North Chicago, Illinois.

Kennametal, Incorporated, Latrobe, Pennsylvania.

Wah Chang Corporation, New York.

Beryl Ores Company, Arvada, Colorado.

Frankel Company, Incorporated, Detroit, Michigan.

Ayrton Metal Company, New York.

Alfred D. Brown Associates, Incorporated, New York.

Derby and Company, Incorporated, New York.

Mercantile Metal and Ore Corporation, New York.

Metal Traders, Incorporated, New York.

Miles Metal Corporation, New York.

Phillip Brothers, Incorporated, New York.

J. A. Samuel and Company, Incorporated, New York.

David Taylor Company, New York.

Transatlantic Metal and Ore Corporation, New York.

Foote Mineral Company, Philadelphia, Pennsylvania.

Hyman Viener, and Sons, Richmond, Virginia.

H. F. Pollock and Company, Limited, Montreal, Quebec.

Electro Metallurgical Company of Canada, Limited, Welland,  
Ontario.

Murex Company, Rainham, Essex, England.

Hoboken Works of the Union Miniere du Haut-Katanga near Antwerp,  
Belgium.

Societa per Aziona Silta, Milan, Italy.

## PART III

## GENERAL GEOLOGICAL INFORMATION

## Geochemical Data

Although much geochemical data are available concerning niobium, more work is necessary before its geochemistry is fully understood. Most of the information given has been taken from a textbook on geochemistry by Rankama and Sahama (1950).

*General occurrence.* Niobium has been detected in the rocks and sediments of the earth's crust, in sea water, and in the atmosphere of the sun.

*Geochemical character.* Niobium and tantalum have almost identical atomic radii ( $\text{Nb}^{5+} = 0.69 \text{ \AA}$ ;  $\text{Ta}^{5+} = 0.68 \text{ \AA}$ ), and carry the same charge. These similarities are believed to account for the fact that niobium and tantalum commonly occur together in nature, although the niobium to tantalum ratio varies. Niobium is known to substitute for titanium ( $\text{Ti}^{4+} = 0.68 \text{ \AA}$ ) in certain titanium minerals, and for zirconium ( $\text{Zr}^{4+} = 0.78 \text{ \AA}$ ), tin ( $\text{Sn}^{4+} = 0.71 \text{ \AA}$ ), and tungsten ( $\text{W}^{6+} = 0.62 \text{ \AA}$ ) in some of their minerals.

*Occurrence in igneous rocks.* The average niobium content of igneous rocks is 0.0024 per cent. Niobium occurs in greater abundance in acidic rocks than in basic rocks. In normal igneous rocks, the niobium content is generally too low to permit the formation of niobium minerals and the niobium occurs mainly in titanium and zirconium minerals. However, niobium is greatly concentrated in some zoned granitic pegmatites and independent niobium minerals have resulted. Recent discoveries of niobium deposits, particularly in Africa and Canada, and studies by Fleischer and others (1952) have confirmed previous work that indicated unusual enrichments of niobium in complexes of alkaline and carbonate rocks. The generally accepted figure for the niobium content of nepheline syenites and related rocks is 0.031 per cent. Recent work by Borodin (1956) shows that nepheline syenites and related rocks contain rather variable amounts of niobium. He found that massive nepheline syenites contain between 0.007 and 0.008 per cent niobium oxide, poikilitic nepheline syenites contain between 0.008 and 0.009 per cent niobium oxide, foyaites contain between 0.018 and 0.021 per cent niobium oxide, and ijolite-urtites contain between 0.025 and 0.031 per cent niobium oxide.

*Occurrence in sediments.* Weathering solutions are believed to carry niobium as soluble alkali niobates. Because the salts of niobium are readily hydrolyzed, niobium is concentrated at an early stage during the sedimentary cycle in sediments that consist of finely ground rock powder and insoluble matter. Clays, bauxites, and laterites carry more niobium than other sediments. Bauxites derived from alkaline rocks contain more niobium than bauxites derived from basaltic rocks. Low concentrations of niobium occur in sea water, and niobium is found in marine carbonate sediments and in some evaporites. Some deep-sea manganese nodules are

enriched several times over the average content in igneous rocks. Many niobium minerals and niobium-bearing varieties of other minerals have a high specific gravity, are resistant to chemical weathering, and are found in residual sediments and in placer deposits.

## Mineralogy

Mineralogical information is necessary for an understanding of niobium deposits and for studies concerning the extraction of niobium from minerals and rocks.

Knowledge of niobium minerals has increased greatly since the widespread use of X-ray powder pictures and spectrographic methods of analysis, and it is probable that the growing industrial interest in niobium will provide the stimulus for further investigations. Future work may necessitate revision of some of the information given.

Niobium minerals are difficult to study because they are chemically complex and because they are commonly metamict. Metamict minerals are noncrystalline pseudomorphs of the original minerals that presumably revert to the original structures when heated. They are identified by X-ray powder pictures that are taken after heating.

Niobium minerals and niobium-bearing varieties of other minerals that have been found in Canada are described in detail; others are listed. Most of the information given is taken from a recent textbook on mineralogy by Palache, Berman, and Frondel (1944).

## NIOBIUM MINERALS

### BETAFITE SERIES

*Composition.*  $A B_3 O_9 \cdot H_2O?$ , with  $A = U, Ca, Th, Pb, Ce, Y$ , and  $B = Ti, Nb, Ta, Fe, Al$ . Strongly radioactive. Betafite is commonly more or less altered to a yellowish material of high water content and diminished radioactivity. The  $Nb_2O_5$  content ranges from 8.51 to 45.80 per cent, and the  $Ta_2O_5$  content from trace to 28.50 per cent. The chemistry of the betafite series and its relationship to the pyrochlore-microlite series require further investigation.

*Physical properties.* Occurs as masses, grains, and octahedral crystals. Fracture conchoidal. Brittle. Hardness 4 to  $5\frac{1}{2}$ . Specific gravity 3.7 to 5, with low values probably due to alteration. Generally metamict.

*Optical properties.* Colour yellow, brown, greenish brown, reddish brown, black. Lustre waxy to vitreous to submetallic. Transmits light in thin fragments. Colour in thin section colourless, brown, reddish brown. Isotropic. High relief.

### COLUMBITE

*Composition.* Niobium-rich members of the columbite-tantalite series are called columbite. The general formula for columbite is  $(Fe, Mn)(Cb, Ta)_2 O_6$ . The  $Nb_2O_5$  content of columbite ranges from 47.22 to 78.88 per cent.

*Physical properties.* Columbite-tantalite occurs as grains, subhedral crystals, and orthorhombic crystals ranging from short prismatic to thin tabular. May occur in groups of parallel, subparallel, or radiating crystals. Heart-shaped contact twins and penetration twins occur, and may be repeated giving pseudo-hexagonal trillings. Brittle. Cleavage (010) distinct, (100) less distinct. Fracture subconchoidal to uneven. Hardness 6 to 7. Specific gravity of members of the series ranges from 5.12 to 8.20, increasing with increasing Ta content.

*Optical properties.* Colour black to greyish black to brownish black, with reddish brown internal reflections (especially in the manganian varieties). Commonly tarnished iridescent. Streak dark red to black. Colour in thin section red, reddish yellow, reddish brown, some varieties are strongly pleochroic; in polished section grey-white with brownish tint, red or reddish brown internal reflections.

*Varieties.* Ferroan. Manganian. Tungstenian? Uranian (toddite).

#### ESCHYNITE-PRIORITE SERIES

*Composition.*  $A B_2O_6$ , with  $A = Ce, Y, Er, Ca, Fe^2, Th$ ; and  $B = Ti, Cb$ . Eschynite contains Ce, priorite contains Y and Er.  $Nb_2O_5$  content ranges from 15.08 to 36.68 per cent. Ta low or absent.

*Physical properties.* Occurs as grains, masses, and prismatic to tabular orthorhombic crystals. Cleavage, (100)? Fracture conchoidal. Brittle. Hardness 5 to 6. Specific gravity 4.95 to 5.19. Commonly radioactive.

*Optical properties.* Colour yellow, brown, black. Streak reddish yellow to brown to almost black. Lustre resinous to waxy to submetallic, commonly dulled by alteration. Colour in thin section light brown to reddish brown. Isotropic (metamict).

#### EUXENITE-POLYCRASE SERIES

*Composition.* The formula is  $A B_2O_6$ , with  $A = Y, Ce, Ca, U, Th$ ;  $B = Ti, Cb, Ta, Fe^3$ . The predominant constituents are Y, Ca, Ti, Cb, and Ta. Euxenite is high Nb + Ta member; polycrase is high Ti member. The  $Nb_2O_5$  content ranges from 3.83 to 41.43 per cent, and the  $Ta_2O_5$  content ranges from 1.01 to 47.31 per cent. Commonly altered to yellowish material rich in water.

*Physical properties.* Occurs as grains, masses, stout prismatic and flattened orthorhombic crystals, and parallel, subparallel and radial aggregates of crystals. Twinning common on (201), rare on (101) and (013). Fracture subconchoidal to conchoidal. Hardness  $5\frac{1}{2}$  to  $6\frac{1}{2}$ . Specific gravity 4.9 to 5.9. Generally radioactive.

*Optical properties.* Colour black, commonly with a greenish or brownish tint, amber, mottled amber and black. Streak yellowish, greyish, reddish brown. Transparent in thin splinters. Lustre, greasy to vitreous to submetallic. Colour in thin section brown, yellowish brown, reddish brown. Isotropic (metamict).

*Varieties.* Tantalian (tanteuxenite). Lyndochite (high in Ca and Th, low in U).

## FERGUSONITE

*Composition.* Niobium-rich members of the fergusonite-formanite series are called fergusonite. The formula of the series is  $A\text{BO}_4$ , with  $A = \text{Y, Er, Ce, La, Di, U}^4, \text{Zr, Th, Ca, Fe}^3$ .  $B = \text{Cb, Ta, Ti, Sn, W}$ . Fergusonite is considered to be essentially  $(\text{Y, Er, Ce, Fe}) (\text{Nb, Ta, Ti}) \text{O}_4$ .  $\text{Nb}_2\text{O}_5$  content of fergusonite ranges from 34.79 to 46.66 per cent.

*Physical properties.* Occurs as grains, prismatic to pyramidal tetragonal crystals, and irregular masses. Cleavage (111). Fracture subconchoidal. Brittle. Hardness of members of the series ranges from  $5\frac{1}{2}$  to  $6\frac{1}{2}$ . Specific gravity of members of the series ranges from 5.6 to 5.8, increasing with increasing Ta content. Commonly radioactive.

*Optical properties.* Colour grey, yellow, brown, dark brown. Streak greenish grey, yellowish brown, brown. Lustre vitreous to submetallic on fresh surface. Colour in thin section, light brown to dark brown. Uniaxial, negative. Metamict material is isotropic. Weak pleochroism.

*Varieties.* Titanian (Risortite). Uranian. Erbian.

## PYROCHLORE

*Composition.* Niobium-rich members of the pyrochlore-microlite series are called pyrochlore, whereas tantalum-rich members are designated as microlite. The formula of the series is regarded as  $A_2B_2O_6$  (O, OH, F), with  $A = \text{Na, Ca, K, My, Fe}^2, \text{Mn}^2, \text{Sb}^3, \text{Pb}^?$ ,  $\text{Ce, La, Di, Er, Y, Th, Zr, U}$ , and  $B = \text{Nb, Ta, Ti, Sn}^?, \text{Fe}^3?, \text{W}^?$ . Pyrochlore is essentially  $(\text{Na, Ca})_2\text{Nb}_2\text{O}_6$  F. The  $\text{Nb}_2\text{O}_5$  content of pyrochlore ranges from 26.22 to 63.64 per cent.

*Physical properties.* Occurs as grains, octahedral crystals, subhedral crystals, and irregular masses. Spinel-law twins, twin plane (111), are rare. Cleavage (or parting?) octahedral, usually not distinguishable but may be distinct in thin section. Fracture subconchoidal to uneven to splintery. Brittle. Specific gravity of members of the series ranges from 4.2 to 6.4, increasing with increasing Ta content. Hardness of members of the series ranges from 5 to  $5\frac{1}{2}$ . Commonly radioactive.

*Optical properties.* Colour white, grey, pale yellow, honey-yellow, pale brown, brown, reddish brown, black. Lustre vitreous, resinous, submetallic. Streak light brown, yellowish brown. Isotropic, but non-metamict material may have weak anomalous birefringence. Relief high. Colour in thin section colourless, grey, pale brown, brown, reddish brown, dark brown to opaque. Zonal structure common.

*Varieties.* Uranian (ellsworthite, hatchettolite, uranpyrochlor). Titanian,  $\text{TiO}_2$  found in amounts up to 13.5 per cent. Cerian (koppite). Ferroan, contains FeO in amounts up to 10.0 per cent. Ferrian, contains  $\text{Fe}_2\text{O}_3$  in amounts up to 9.7 per cent. Thorian.

## NIOCALITE

Niocalite was discovered and named recently by E. H. Nickel of the Mines Branch, Ottawa.



*Composition.* Niobium calcium silicate. A chemical analysis by J. A. Maxwell of the Geological Survey gave the following results:

	Per cent
CaO.....	46.8
Nb <sub>2</sub> O <sub>5</sub> .....	0.7
Nb <sub>2</sub> O <sub>5</sub> .....	16.8
Rare earths and Al <sub>2</sub> O <sub>3</sub> .....	2.0
SiO <sub>2</sub> .....	26.8
H <sub>2</sub> O.....	0.2
F.....	1.7

*Physical properties.* Occurs as grains and elongate orthorhombic crystals that are four-sided in section perpendicular to the C-axis. Specific gravity 3.3. Hardness 5 to 6.

*Optical properties.* Colour yellow. Lustre vitreous. Streak colourless. Colourless in thin section. Relief moderate. Under crossed nicols the mineral shows very complex twinning. Sections parallel or almost parallel to the long axis give lemon-yellow, grey, and blue-grey interference colours, and sections perpendicular to the long axis give red and blue colours.

#### SAMARSKITE

*Composition.* The formula is probably A B<sub>2</sub>O<sub>6</sub>, with A = Y, Er, Ce, La, U, Ca, Fe<sup>2</sup>, Pb, Th; and B = Nb, Ta, Ti, Sn, W, Zr? The Nb<sub>2</sub>O<sub>5</sub> content ranges from 27.77 to 46.44 per cent, Ta<sub>2</sub>O<sub>5</sub> content ranges from 1.81 to 27.03 per cent. Commonly altered by hydration to yellowish or brownish material.

*Physical properties.* Occurs as grains, masses, and prismatic to tabular orthorhombic crystals. Cleavage {010} indistinct? Fracture conchoidal. Brittle. Hardness 5 to 6. Specific gravity 5.69 to 6.2. Commonly radioactive.

*Optical properties.* Colour velvet black, commonly with a brownish tint; grain and crystal surfaces commonly brown to yellowish brown due to alteration. Lustre vitreous to resinous to submetallic to splendid; commonly dull on grain and crystal surfaces. Streak dark reddish brown to black; grey to yellowish brown on altered material. Transparent in thin splinters. Colour in thin section light brown to dark brown. Generally metamict and isotropic.

#### OTHER NIOBIUM MINERALS

Other niobium minerals are as follows: scheteligite (Ca, Y, Sb, Mn)<sub>2</sub> (Ti, Ta, Nb)<sub>2</sub> (O, OH)<sub>7</sub>; yttrantalite (Fe, Y, U, Ca, etc.) (Nb, Ta, Zr, Sn)<sub>4</sub>O<sub>4</sub>; polymignyte (Ca, Fe<sup>2</sup>, Y, etc., Zr, Th) (Nb, Ti, Ta)<sub>4</sub>O<sub>4</sub>; ishikawaite (U, Fe, Y, etc.) (Nb, Ta)<sub>4</sub>O<sub>4</sub>; stibiocolumbite Sb (Ta, Nb)<sub>4</sub>O<sub>4</sub>; bismutantalite Bi (Ta, Nb)<sub>4</sub>O<sub>4</sub>; calciosamarskite (Ca, Y, etc., U, Th, Zr)<sub>3</sub>(Nb, Ta, Fe, Ti, Sn)<sub>5</sub>O<sub>15</sub>; mossite Fe (Nb, Ta)<sub>2</sub>O<sub>6</sub>; ixiolite (Fe, Mn) (Nb, Ta)<sub>2</sub>O<sub>6</sub>; hjelmite (Y, Fe<sup>2</sup>, U<sup>4</sup>, Mn, Ca) (Nb, Ta, Sn, W)<sub>2</sub>O<sub>6</sub>; ampingabeite (Y, Er, U, Ca, Th)<sub>2</sub>(Nb, Ta, Fe, Ti)<sub>7</sub>O<sub>18</sub>?

## NIBIUM-BEARING VARIETIES OF OTHER MINERALS

### ILMENORUTILE

Ilmenorutile was proposed by Koksharov (1854) as a name for a new variety of rutile. Analyses show that ilmenorutile contains appreciable amounts of niobium and lesser amounts of tantalum. Palache, Berman, and Frondel (1944, p. 558) described ilmenorutile as niobian rutile that is black, and that has a specific gravity of 4.2 to 5.6. Three analyses show niobium oxide contents of 21.73, 23.48, and 32.15 per cent, and tantalum oxide contents of nil, 14.70 and 23.48 per cent. Hutchinson (1955, pp. 447-451) studied ilmenorutile crystals from M'ba, French Cameroons, and the Tonkolili District, Sierra Leone, using rotation properties and polarization figures on polished surfaces, and X-ray powder pictures. He found that these specimens consist of intergrowths of columbite and rutile.

### NIBIAN PEROVSKITE

*Composition.* The formula for perovskite can be regarded as (Ca Ce, etc.) (Ti, Nb)O<sub>3</sub>. Ordinary perovskite is Ca TiO<sub>3</sub>. Niobian perovskite or dysanlyte is the niobium-bearing variety, and loparite is the variety that contains niobium and rare earths. Analyses show that the Nb<sub>2</sub>O<sub>5</sub> content ranges up to 25.99 per cent. As much as 5.08 per cent Ta<sub>2</sub>O<sub>5</sub> has been reported.

*Physical properties.* Occurs as masses, grains, as cubic, octahedral and cubo-octahedral crystals. Pseudoisometric, possibly monoclinic. Twinning on {111} as penetration twins and complex lamellar twins. Cleavage {001} imperfect. Fracture uneven to subconchoidal. Brittle. Hardness 5½. Specific gravity 4.01 to 4.04.

*Optical properties.* Colour black, greyish black, brownish black, dark purple, dark purplish brown, reddish brown, yellowish brown. Streak colourless, greyish. Lustre adamantine to metallic, may be dull on crystal surfaces. Colour in thin section, colourless to reddish brown to dark brown. May be weakly pleochroic. Isotropic or weakly birefringent. Complex twinning common. In polish section dark bluish grey with brown internal reflections.

### OTHERS

Several titanium and zirconium minerals commonly contain niobium and these include anatase, brookite, ilmenite, sphene, zircon, and eudialyte.

### Types of Deposits

Niobium deposits, like other mineral deposits, can be classified in many ways, such as by their mode of origin, their mineralogy, and their form. The writer believes that the following classification is practical for prospecting purposes. From a geological viewpoint, a genetic classification is most desirable, and this classification is based primarily on genetic considerations because niobium deposits of commercial interest are

derived from granitic magmas and sub-silicic alkaline magmas. Perhaps a completely genetic classification will be devised when more information is available. The classification is mineralogical to some extent because columbite, columbite-tantalite, euxenite-polycrase, samarskite, fergusonite, and eschynite-priorite usually occur in deposits of granitic origin, and pyrochlore, betafite, and niobian perovskite occur in deposits derived from alkaline magmas. Niobium minerals in bedrock deposits are invariably disseminated. The classification may not be complete; for instance, it is possible that placer deposits derived from alkaline rocks or carbonate rocks will be found.

### *Classification of Niobium Deposits*

- A. Deposits associated with or derived from granitic rocks
  - (1) Deposits in granite
  - (2) Granitic pegmatite deposits
  - (3) Eluvial deposits
  - (4) Placer deposits
- B. Deposits associated with or derived from alkaline rocks
  - (1) Deposits in alkaline silicate rocks
  - (2) Deposits in carbonate rocks
  - (3) Syenitic pegmatite deposits
  - (4) Deposits in fenites<sup>1</sup>
  - (5) Eluvial deposits

## DEPOSITS ASSOCIATED WITH GRANITIC ROCKS

*Deposits in granite.* Niobium minerals occur as accessory minerals in certain granites. Although the columbite content of albite-biotite granite in Nigeria is too low to be of commercial interest at present, this rock is the source of the cassiterite-columbite placer deposits which are the world's principal producers of niobium, and the important eluvial deposits of decomposed granite. Disseminated pyrochlore occurs in albite-riebeckite granite in Nigeria which is a potential large-tonnage source of niobium, uranium, and cryolite. The deposits of albite-riebeckite-pyrochlore granite are tentatively classified as granitic deposits, but they may be intermediate between deposits derived from granitic magmas and deposits derived from alkaline magmas.

*Granitic pegmatite deposits.* Although many textbooks rank granitic pegmatites the chief source of niobium minerals, they are actually of secondary importance. Columbite and columbite-tantalite concentrates are produced from pegmatites in many countries, and those of the Belgian Congo and Ruanda Urundi are probably the most important at present.

*Eluvial deposits.* The eluvial deposits of decomposed albite-biotite-columbite granite of Nigeria rank second only to the Nigerian cassiterite-columbite placer deposits as a source of niobium, and eluvial deposits of weathered, columbite-bearing granitic pegmatite in Belgian Congo and Ruanda Urundi are important.

<sup>1</sup>Fenite is defined in the section on terminology in Part I of this report.

*Placer deposits.* The cassiterite-columbite placer deposits of Nigeria, from which columbite is produced as a by-product or co-product of cassiterite mining, are the most important niobium deposits at present. Similar placer deposits in Malaya are also important producers of columbite concentrates. Placer deposits containing euxenite-polycrase and other complex niobium minerals, such as the Bugaboo deposits of British Columbia, and the deposits of Valley county, Idaho, are potential sources of niobium. Monazite placer deposits in the southeastern United States contain ilmenorutile.

## DEPOSITS ASSOCIATED WITH ALKALINE ROCKS

### NATURE OF ALKALINE ROCK COMPLEXES

Alkaline rock complexes that contain niobium minerals are characterized by the presence of silica-deficient, sodium-rich silicate rocks.

The structural features of these complexes are distinctive. They are more or less circular or elliptical in shape and small in size; the largest known complex is the Chibina complex, Kola Peninsula, which has an outcrop area of 650 square kilometres. The dips of the wall-rock contacts are usually steeply inward, steeply outward, or vertical. In general, the larger the complex, the more complicated the internal structure. The outer parts of large bodies are commonly composed of concentric, vertical bands, whereas the inner parts consist of horizontal or gently dipping layers. Vertical concentric bands usually predominate in small bodies or are the only structures present. Textures and structures of the various rock units are usually variable, and brecciation of one rock type by another is common. The structure of alkaline complexes may be further complicated by multiple intrusions of magma. Several geologists have pointed out that alkaline complexes occur in stable parts of the earth's crust outside of active orogenic zones.

Most alkaline rock complexes are characterized by a diversity of rock types. Rocks that occur in these complexes include: sodium-rich granites and syenites, nepheline syenites, foyaite, malignite, urtite, ijolite, melteigite, jacupirangite, pyroxenite, dunite, and carbonate rocks. In well-defined complexes, there is a gradual desilication of the rock suites inward from the wall-rock contacts and downward from the tops of the complexes.

The wall-rocks of many alkaline complexes are altered (finitized), and dykes of lamprophyre and other unusual rocks commonly cut the complex and the surrounding country rocks.

The origin of alkaline rock complexes is of great interest to petrologists. Many of them believe that alkaline rocks are produced by the desilication of normal magmas or subalkaline magmas due to the assimilation of limestones and, or, other saline sedimentary rocks. Others are of the opinion that alkaline rocks and the associated carbonate rocks are formed by magmatic differentiation. Unusual chemical conditions are generally postulated, but there is no general agreement concerning the composition of the parent magmas, and sodium-rich basic magmas, pyroxenitic magmas, ijolitic magmas, and carbonate magmas have been suggested as sources of the alkaline rock suite. In the case of carbonate magmas, it is believed

that alkaline rocks are produced by reaction between the magmas and the silicate wall-rocks. Some geologists believe that the carbonate rocks of these complexes are of sedimentary origin although recrystallized and metasomatized, whereas others believe them to be of hydrothermal or magmatic origin and refer to them as "carbonatites". Many of the alkaline complexes of Africa are in the necks of extinct volcanoes and are associated with tuffs, agglomerates, lavas, and volcanic structures. In places in Africa, only carbonate rocks are exposed, and it is probable that erosion has removed the alkaline silicate rocks, tuffs, agglomerates, and lavas. Most geologists who have studied alkaline rock complexes are impressed by the role of volatile materials.

For detailed descriptions of alkaline rock complexes and opinions regarding their origin, the reader is referred in particular to the reports of Backlund (1933), Brogger (1921), Daly (1910), Dixey, Smith, and Bisset (1937), Fawley and James (1955), Johannsen (1938), King (1948), Polanski (1948), Saether (1948), Ussing (1912), and von Eckermann (1948).

*Deposits in alkaline silicate rocks.* Deposits of loparite in lujavrite, urtite, and malignite of the Lovozero complex, Kola Peninsula, Russia, are reported to comprise the world's largest reserve of niobium. Niobian perovskite occurs in altered okaite and altered ijolitic rocks of the Oka complex, Quebec, and pyroxene-magnetite-perovskite-nepheline rock is part of the complex at Magnet Cove, Arkansas. Pyrochlore occurs in ijolite and malignite near Chapleau, Ontario, and betafite is found in biotitized microijolite of the Oka complex. Feldspar rock near Manson Creek, British Columbia, contains columbite and ilmenorutile.

*Deposits in carbonate rocks.* Deposits of pyrochlore in carbonate rocks of alkaline rock complexes are probably the most important potential future source of niobium. The pyrochlore carbonatites of Africa are included in this category. Examples are the carbonatites of Northern Rhodesia, Nyasaland, Tanganyika, and Uganda, and the carbonate rocks in the alkaline complexes of Brazil, Canada, and Sweden.

*Syenitic pegmatite deposits.* Although niobium minerals and niobium-bearing varieties of other minerals are reported to occur in nepheline syenite pegmatites, none are productive. Those of the Ilmensky Mountains, Russia, are well-known examples.

*Deposits in fenites.* These deposits may be subdivided as follows: (1) deposits in fenitized carbonate rocks, and (2) deposits in fenitized silicate rocks. Deposits of pyrochlore in fenitized carbonate rock in Norway and Germany are productive. The Newman pyrochlore deposit, Lake Nipissing, Ontario, is in fenitized silicate rocks and carbonate rocks.

*Eluvial deposits.* Several eluvial deposits of decomposed carbonatite occur in Africa. The deposit near Tororo, Uganda, has been investigated as a possible source of pyrochlore and other minerals. Bauxite and bauxitic clay in Arkansas contain niobium-bearing ilmenite.

## World Review of Deposits

There is less information available concerning niobium deposits than deposits of many other metals because niobium is a minor metal from a production standpoint, and because many deposits are in remote areas.

In general, there is more information about deposits associated with complexes of alkaline and carbonate rocks than other types of deposits, because alkaline rocks are of particular interest to petrologists and geochemists as well as economic geologists. It is beyond the scope of this report to present a complete review of the world's niobium deposits, however, the information given will enable the reader to compare Canadian deposits with those elsewhere.

## BELGIAN CONGO AND RUANDA URUNDI

*References:* Griffith, 1952; Griffith, 1953; United States Bur. Mines Mineral Trade Notes, 1953.

Belgian Congo and the Belgian protectorate of Ruanda Urundi together ranked second only to Nigeria as a source of columbite concentrates in 1953. The principal deposit in the Belgian Congo is at Manono, and it consists of granitic pegmatite that contains cassiterite and columbite, and eluvium derived from the weathering of the pegmatite. The M'Buye mine is the main deposit in Ruanda Urundi. Columbite occurs in a kaolinized, zoned granitic pegmatite, and in eluvial and alluvial material derived from the pegmatite.

## BRAZIL

*References:* Griffith, 1953; Melcher, 1954.

Small quantities of pyrochlore occur in the calcite rock core of the alkaline rock complex at Jacupiranga, state of Sao Paulo, Brazil. The calcite rock contains an average of 12 per cent apatite and 4 per cent magnetite plus mica, olivine, serpentine, pyrrhotite, baddeleyite, and pyrochlore. Weathering of the calcite rock has produced a residual deposit of 7 million tons averaging 23 per cent phosphorus pentoxide. Other rocks in the complex include peridotites, pyroxenites, jacupirangite, ijolitic rocks, nepheline syenites, and fenites. Dykes of essexite, ijolite, monchiquite, and tinguaita are common. The peridotite, pyroxenite, jacupirangite, and ijolite are believed to have formed by gravitative settling during the cooling of the magma conduit. The leucocratic alkaline rocks are assumed to be fenites, in part rheomorphic; and the calcite rock is believed to be intrusive.

In 1953, high-grade columbite deposits were reported in the Araxa region of Minas Gerais.

## GERMANY

*References:* Fischer, 1945; Griffith, 1953; Leibbrand, 1948; Schneiderhohn, 1948.

Carbonate rock containing pyrochlore has been mined near the village of Schelingen in the Kaiserstuhl, Germany. Limestone was intruded by an essexite-tephrite complex, and pyrochlore occurs at the contact in marblized limestone and in marble-tephrite breccia. Niobian perovskite occurs in marble veins. The pyrochlore contains from 50 to 62 per cent niobium oxide, and the niobian perovskite contains up to 26.5 per cent niobium oxide. Reserves are estimated to be 500,000 to 700,000 metric tons containing 0.5 per cent niobium oxide. The niobium minerals are believed to have formed due to the action of late pneumatolytic and hydrothermal solutions.

## MALAYA

*Reference:* Griffith, 1953.

Malaya is one of the principal producers of columbite concentrates which are obtained as a by-product from placer deposits of tin in the State of Kedah. Niobium-tantalum-bearing tin slags have been investigated as a possible source.

## NIGERIA

*References:* Banfield, 1956; Deans, 1952; Jacobson and others, 1951; John and Paulo, 1954; Mackay and others, 1949; Mackay and others, 1952; Williams, 1956.

Four types of niobium deposits occur in Nigeria: (1) cassiterite-columbite placer deposits; (2) eluvial deposits of decomposed columbite-bearing granite; (3) deposits of columbite-bearing granite; and (4) deposits of pyrochlore-bearing granite. Types (1) and (2) are productive.

The cassiterite-columbite placer deposits of Nigeria are the world's principal source of niobium at present. Most of the columbite is produced from recent placer deposits derived from the weathering of columbite-bearing granite. Nearly two-thirds of the two thousand leases contain columbite, and about one-half of these have sufficient columbite to pay for its recovery. In fifteen to twenty leases, the ratio of columbite to cassiterite is 1 to 3. One concentration of columbite far exceeds any other, and has supplied a substantial proportion of the world's production. Here the columbite to cassiterite ratio ranges as high as 2 to 1. In 1948, the average tenor of columbite ore was 0.6 pound per cubic yard. Other heavy minerals in the placer deposits include: ilmenite, rutile, magnetite, cassiterite, monazite, zircon, thorite, and wolframite.

Significant amounts of columbite concentrates are obtained from the eluvial deposits of decomposed albite-biotite-columbite granite. The columbite content is commonly less than 0.5 pound per cubic yard, but several areas have been found in which the content is appreciably higher. In a rich area, the columbite content ranges up to 6.0 pounds per cubic yard, and averages over 2 pounds. Other heavy minerals associated with the columbite include: zircon, cassiterite, thorite-orangite, xenotime, and monazite. In general, the heavy mineral content and the radioactivity of a rich area vary directly as the columbite content.

The albite-biotite phase of the Younger Granite complex of the Jos Plateau is the source of the columbite that occurs in the placer and eluvial deposits. Other rocks belonging to the Younger Granite suite include granites, syenites, monzonites, gabbros, and porphyries. Columbite is believed to be a primary accessory mineral and generally occurs as minute acicular and platy crystals, singly or in small randomly oriented clusters. The columbite content is as much as 0.02 per cent.

Disseminated pyrochlore occurs as an accessory mineral in the albite-riebeckite granite phase of the Younger Granite complex. The pyrochlore occurs as golden-yellow grains and octahedra, most of which are less than 250 microns in size. An average of three chemical analyses gives a content of 3.1 per cent uranium oxide, 3.3 per cent thorium oxide, and 41.1 per

cent combined columbium and tantalum oxides. The deposit at Kaffo Valley is believed to be a potential source of niobium, uranium, and cryolite. The Kaffo granite is composed essentially of quartz, orthoclase perthite, plagioclase, and riebeckite, with accessory cryolite, pyrochlore, aegirine, topaz, zircon, thomsonelite, monazite, and thorite. A preliminary estimate sets the grade of the deposit at 0.26 per cent niobium oxide and the tonnage at 707,500 tons per vertical foot.

According to Banfield (1956), the 1954 production of columbite concentrates in Nigeria was 2,689 long tons, of which two-thirds were obtained from placer deposits, and one-third from eluvial deposits.

## NORTHERN RHODESIA

*References:* Griffith, 1952; Reeve and Deans, 1954.

A pyrochlore-bearing carbonate rock forms Nkumbwa Hill in the Isoka District, Northern Rhodesia. The rock consists of dolomite and ankerite or siderite, apatite and other phosphates, and various accessory minerals including pyrochlore, monazite, and sellaite ( $\text{MgF}_2$ ). The pyrochlore occurs as pale yellow octahedrons up to 1 mm. in size, and contains 73.46 per cent niobium oxide. Preliminary sampling suggested that large tonnages of rock and soil containing 0.25 per cent pyrochlore are present. Alkaline silicate rocks are absent, and the occurrence is believed to be a carbonatite plug.

A columbite deposit was reportedly discovered in Lusaka district in 1952.

## NORWAY

*Reference:* Bjorlykke, 1955.

Pyrochlore deposits occur in a complex of carbonate and alkaline rocks at Sove in the Fen District, southern Norway. The complex consists of a central part and an outer part. Calcite rock, called sovite, and inclusions of alkaline silicate rocks comprise the central part which has an average diameter of 1,200 metres. According to Adamson (1950), the alkaline rocks are mainly urtites, ijolites, and melteigites. Syenitic fenites and more or less lens-shaped bodies of calcite rock comprise the outer part of the complex.

The pyrochlore occurs in places in the alkaline silicate rocks, in breccia zones in calcite rock in the central part of the complex, and in calcite lenses in the outer part of the complex. Light grey, brown, and black varieties of pyrochlore have been found, and inclusions of other minerals, particularly apatite and calcite, are common. In places crystals of the black pyrochlore are pseudomorphically replaced by aggregates of submicroscopic columbite crystals. Six assays of the pyrochlore show that the niobium-tantalum pentoxide content ranges from 59.4 to 65.0 per cent and that the black variety is rich in iron. Pyrochlore-bearing calcite rock is more or less dolomitized and contains fluorapatite, magnetite, biotite, hornblende, pyrite, zircon, and barite.



Although the largest deposits occur in the breccia zones in the central part of the complex, they are undeveloped, and mining is limited at present to the "Cappelen dyke", one of the calcite lenses in the outer part of the complex. About  $1\frac{1}{2}$  million tons of ore with an average grade of 0.2 to 0.5 per cent niobium oxide have been outlined in the Cappelen dyke. A nearby calcite lens contains 1 million tons of ore.

According to Bjorlykke (personal communication) the sovite must be regarded as unmelted contact residue from a melting process which produced a series of alkaline rocks. The pyrochlore is believed to have formed by pneumatolytic and hydrothermal activity.

Production in April 1955 was about 50 tons of 50 per cent niobium oxide concentrate per month (H. Bjorlykke, A/S Norsk Bergverk, personal communication).

## NYASALAND

*References:* Deans, 1952; Dixey, Smith, and Bisset, 1937; Garson 1952.

Pyrochlore occurs as an accessory mineral in carbonate rock in a complex of carbonate and alkaline rocks on Chilwa Island, southern Nyasaland. The complex belongs to the Chilwa series which comprise a group of vents that are filled with carbonate rocks; plutonic rocks, mainly syenites and nepheline syenites; and dykes of a variety of igneous rocks. Dixey, Smith, and Bisset believe that the carbonate rocks are of magmatic origin.

A complex ring structure was formed at Chilwa Island. Migmatites, gneisses, and schists of the basement complex were intruded by porphyritic hornblende syenite. The next event was the intrusion of a small mass of ijolite. This was followed by the development of the inner rings of breccia and various carbonate rocks. A few small masses of nepheline-syenite cut the carbonate rocks and breccias, and dolomite cone sheets cut the gneisses, syenites, and breccias of the outer rings. Fluorite and quartz occur in late, radial faults. Garson notes that the basement rocks and hornblende syenite are fenitized.

The pyrochlore-bearing carbonate rock consists chiefly of white, sugary calcite. Accessory minerals include pyrochlore, apatite, rutile, soda pyroxene, biotite, sphene, melanite, nepheline, magnetite, and pyrite.

Pyrochlore occurs as octahedra and dodecahedra from a few microns to 2 or 3 mm. in size. It varies from colourless to yellow, brown, red, and black. Magnetic and non-magnetic varieties are present. The composition is as follows: niobium and tantalum oxides, 64.9 per cent; ferric oxide, 1.4 per cent; titanium oxide, 1.8 per cent; rare earths and thorium oxide, 2.6 per cent; and calcium oxide, 16.6 per cent.

Preliminary sampling suggests that the carbonate rock has an average content of 0.2 per cent pyrochlore, and that an accumulation of several million tons of eluvial and alluvial material contains an average of about 0.3 per cent pyrochlore. Residual soils on the plateau summit of the vent contain as much as 2 per cent pyrochlore, but the tonnage of this material is apparently limited.

## RUSSIA

*References:* Eliseev and Nefedov, 1943; Gerasimovsky, 1940; Panteleyev, 1938.

Niobium deposits in the Lovozero alkaline rock complex, Lovozero tundras, Kola Peninsula, Russia, are reported to comprise the world's largest reserve of niobium, and it is probable that they are productive. The complex is horizontally layered and consists mainly of lujavrite, foyaite, juvite, malignite, and urtite. It outcrops over an area of 650 square kilometres.

The principal niobium mineral is loparite, which is perovskite that contains rare earths and niobium, and has the following composition.

	Per cent
TiO <sub>2</sub> .....	37.82 - 39.24
Nb <sub>2</sub> O <sub>5</sub> .....	9.49 - 9.90
Ta <sub>2</sub> O <sub>5</sub> .....	1.13 - 1.22
Rare earths.....	31.22 - 32.44
ThO <sub>2</sub> .....	0.67
CaO.....	5.26 - 6.21
SrO.....	0.62 - 0.85
Na <sub>2</sub> O.....	7.77 - 9.06

Although loparite occurs in all of the rock types in the complex, the best concentrations occur in lujavrite, urtite, and malignite. Zones of maximum enrichment generally occur near the hanging-wall or foot-wall of the layers. Alteration is represented by the replacement of nepheline by sodalite and zeolites, albitization of potash feldspar, and replacement of soda pyroxene by amphibole. The average content of loparite in these rocks is as follows: lujavrite, 1.8 per cent; urtite, 8 to 11 per cent; and malignite, about 14 per cent.

The loparite is believed to have formed due to autopenmatolytic and pneumatolytic processes.

Niobium minerals also occur in syenites and nepheline syenite pegmatites in the Ural and Ilmensky Mountains, but the occurrences are not of economic importance.

## SWEDEN

*References:* Høgbom, 1909; von Eckermann, 1948.

The occurrence of pyrochlore and cerian perovskite in the carbonate rocks of Alno Island, Sweden, has been known for many years.

According to Høgbom, the differentiation of a magma that intruded gneiss produced a series of rocks ranging from nepheline syenites through nepheline-melanite and nepheline-aegirine rocks to jacupirangites and olivine-magnetite rocks. Large bodies of carbonate rock, that contain the minerals of these rocks, perovskite, and pyrochlore, occur within the alkaline area, and are believed by Høgbom to have formed from the magma

that produced the alkaline rock series. He observed that the gneiss was resorbed and metamorphosed by the nepheline syenite magma, and that a border of syenite was produced containing alkali feldspars rather than nepheline. All of these rocks are cut by dykes of alnoite, monchiquite, nephelinite, and tinguaita.

Von Eckermann has recently described the alkaline area of Alno Island as consisting chiefly of a core of intrusive carbonate rock, mainly calcite rock or sovite, and an outer part of alkaline rocks and fenites that are cut by concentric dykes of sovite breccia. He notes that pyrochlore has been found in the sovite of the core and in one of the sovite breccia dykes. According to von Eckermann, the alkaline rocks formed due to the activity of a magmatic liquid core consisting mainly of carbonates predominantly potassic, and lesser amounts of lime, magnesia, alumina, iron, titanium phosphorus, free carbon dioxide, fluorine, and water. The fenites were produced from the wall-rocks, which consist of granites, gneisses, and biotite schists injected by granite, by the addition of carbon dioxide, water, potash, and lime from the core, and the loss of silica and some soda to the core. Soda orthoclase, aegirine-augite, and nepheline were the principal minerals formed by the fenitization process. Other minerals of the fenites include calcite, apatite, biotite, pyrite, sphene, and magnetite. The addition of silica to the core permitted the crystallization of alkaline rocks such as urtite, juvite, ijolite, foyaite, melteigite, malignite, jacupirangite, and the more undersaturated sovite. Calcite in amounts up to more than 90 per cent is the chief mineral of the sovites, and other minerals include biotite, aegirine-augite, apatite, titanian magnetite, fluorite, pyrite, serpentine after olivine, pyrite, hedenbergitic augite, natrolite after nepheline, sericite-natrolite after nepheline, sphene, ilmenite, cerian perovskite, and pyrochlore.

## TANGANYIKA

*Reference:* Fawley and James, 1955.

Carbonate rocks that contain pyrochlore occur near Panda Hill in Southern Tanganyika, and the occurrence is known as the Mbeya carbonatite. The carbonate rocks fill the neck of an extinct volcano and form an outer ring that surrounds the plug. They consist mainly of calcite or dolomite, and the most abundant accessory minerals are: magnetite and other iron oxides, apatite, amphibole, mica, pyrochlore, fluorite, zircon, pyrite, and pyrrhotite. Tuff, agglomerate, and Precambrian garnet gneiss that enclose the carbonate rocks are brecciated and metasomatized. The gneisses are desilicated, carbonatized, and feldspathized. Dolomite dykes, carbonatized alnoite(?) dykes, and small dykes and subcircular vents of explosion-vent breccia occur in places.

Pyrochlore occurs as pale yellow to olive-green to black cubo-octahedra, and some of the crystals are coated with columbite. In general, the crystals are about 1 mm. or less in size, but crystals up to more than 5 mm. in size have been found. The niobium oxide content ranges from 55 to 66 per cent, the tantalum oxide content from 0.5 to 2.2 per cent, and the equivalent thorium oxide content from 0.05 to 2.45 per cent.

Diamond drilling of a small part of the occurrence has indicated  $9\frac{1}{2}$  million tons of carbonate rock averaging 0.3 per cent niobium oxide. About  $1\frac{1}{2}$  million tons of residual soil and rubble contain an average of 0.6 per cent niobium oxide.

## UGANDA

*References:* Deans, 1952; Carlson and others, 1954;  
Indian Minerals, 1955.

Eluvial material associated with the Sukulu carbonatite plug near Tororo, Uganda, has been investigated as a possible source of pyrochlore, apatite, magnetite, zirconium minerals, and material for cement. Several million tons of alluvial soil are believed to be available.

Pyrochlore occurs in several other carbonatite plugs in Uganda.

Columbite-tantalite concentrates are produced in the Ankole-Kigezi area.

## UNITED STATES

*References:* Fleischer and others, 1952; Fryklund, Harner, and Kaiser, 1954; Griffith, 1952; Griffith, 1953; Kaiser, 1953; Kaiser, 1954; Kaiser, 1956; Page and others, 1953.

Several types of niobium deposits occur in the United States, but production is relatively small.

Columbite and columbite-tantalite are the main source of niobium, and are recovered mainly as by-products of spodumene pegmatite mining in South Dakota and North Carolina.

Deposits associated with the complex of alkaline and carbonate rocks at Magnet Cove, Arkansas, have been investigated as possible sources of niobium. Carbonate-feldspar-rutile veins cut aegirine-nepheline syenite and other types of syenite. Analyses indicate that the average niobium content of rutile concentrates is  $1.2 \pm 0.2$  per cent. Pyroxene-magnetite-perovskite-nepheline rock contains 0.03 to 0.04 per cent niobium. Calcite rock with accessory apatite, monticellite, biotite, magnetite, pyrite, and perovskite contains as much as 0.01 per cent niobium. Single perovskite crystals assay from 5.1 to 8.8 per cent niobium. Near the margin of the complex, novaculite contains niobium-bearing brookite and rutile, and the average niobium content of brookite concentrates is about 2 per cent.

Niobian rutile that contains about 5 per cent niobium occurs as streaks in silicified volcanic tuff in the Medley district of Texas. Stocks of nepheline syenite occur nearby.

Marble beds in the Mineral Hill district of Idaho contain niobian rutile. The beds are from 1 foot to 10 feet thick, and niobian rutile, monazite, ilmenite, hematite, and allanite are apparently localized mainly in the noses of drag-folds in the beds. Neither pegmatites nor alkaline rocks are associated with the deposits, and it is suggested by Kaiser that titanium, niobium, rare earths and other elements, present in the terrain, were mobilized during regional metamorphism and redeposited in the drag-folds in the marble beds.

Placer deposits containing niobium minerals have been found. Deposits in Valley county, Idaho, contain columbite, euxenite, samarskite, and fergusonite; columbite occurs in deposits in Elmore county, Idaho; and monazite deposits in the southeastern States contain ilmenorutile.

Studies at Potash Sulphur Springs, Arkansas, show that the soil overlying the complex of nepheline syenites and carbonate rocks contains as much as 0.24 per cent niobium. The niobium mineral is yellow pyrochlore.

Bauxite and bauxitic clay in Arkansas have been investigated as possible sources of niobium, which occurs mainly in ilmenite that is now discarded in black sand and brown mud. The ilmenite fraction contains as much as 0.86 per cent niobium.

## OTHER COUNTRIES

*References:* Carlson and others, 1954; Griffith, 1952; Griffith, 1953.

*Angola.* In 1951, large deposits of columbite-tantalite were reported to have been discovered in the Lobito area.

*Bolivia.* Columbite production was reported from the province of Nuflo de Charez in 1952, and deposits of columbite associated with monazite and fluorite in the districts of Santa Cruz and Cockabama were investigated in 1953.

*British Guiana.* Columbite placer deposits in the Mazaruni River area were investigated in 1952 and 1953, and a small production was reported.

*French Cameroons.* The possibility of recovering columbite-tantalite as a by-product of tin mining was investigated.

*Kenya.* A deposit of pyrochlore has been discovered at Mrima.

*Korea.* Pegmatites and placer deposits are reported to contain appreciable concentrations of columbite and tantalite.

*Mozambique.* Columbite was produced in conjunction with beryl in 1953. Beach sands derived from the Alto Lingonka pegmatite belt contain columbite, samarskite, and euxenite.

*Southern Rhodesia.* Columbite and tantalite are recovered from pegmatites in the Fort Victoria district.

*South-West Africa.* Columbite-tantalite concentrates were produced in 1951. In 1952, it was reported that columbite-tantalite had been found in tin pegmatite deposits.

*Union of South Africa.* Columbite-tantalite mining and prospecting operations were conducted in 1953.

## PART IV

## GENERALIZATIONS REGARDING CANADIAN DEPOSITS

## Types of Deposits and Occurrences

All known types of niobium deposits have not been found in Canada; for a complete classification the reader is referred to Part III of this report. The Canadian deposits that so far have shown greatest economic possibilities are placer deposits derived from granitic rocks, and bedrock deposits associated with alkaline rock complexes.

## PLACER DEPOSITS DERIVED FROM GRANITIC ROCKS

The Bugaboo group of eight placer deposits in southeastern British Columbia are the only known niobium placers in Canada. These deposits are radioactive and contain euxenite-polycrase and pyrochlore. They consist of recent alluvium and are derived from granitic stocks.

Placer deposits are generally inexpensive to mine, and the possibility of finding other placers derived from granitic rocks and placers derived from alkaline rock complexes should not be ignored, particularly in the Cordilleran region.

## DEPOSITS ASSOCIATED WITH ALKALINE ROCK COMPLEXES

The largest reserves of niobium minerals and niobium-bearing varieties of other minerals in Canada occur in deposits associated with alkaline rock complexes. These complexes are more or less circular to elliptical or lenticular in shape, and are up to a few square miles in area. Very little is known about the details of the internal structure of most of the complexes because of the lack of outcrops. Rock types that occur in these complexes include sodium-rich syenites, nepheline syenites, malignites, ijolitic rocks, okaite, jacupirangitic rocks, lamprophyres, carbonate rocks, and rocks produced by the metasomatism of carbonate rocks. The wall-rocks of some of the complexes are fenitized—that is, altered by emanations from the complexes.

The deposits are in the complexes proper, and in the fenitized wall-rocks. Niobium minerals and niobium-bearing varieties of other minerals occur in silicate rocks and carbonate rocks, and include betafite, columbite and uranian columbite, ilmenorutile, niobian perovskite, niocalite, and pyrochlore and uranian pyrochlore. Pyrochlore and uranian pyrochlore are the most abundant. These minerals occur as disseminated grains and crystals that are generally very fine grained to fine grained. The deposits are radioactive due to the presence of uranium or thorium or both in the niobium minerals. Accessory minerals that are most commonly associated with the niobium minerals and niobium-bearing varieties of other minerals are apatite, magnetite, biotite, soda pyroxene, soda hornblende, pyrite, and

pyrrhotite. In some cases, the minerals of the host rocks are highly altered, whereas in others they are quite fresh. Several of the deposits contain shoots that are richer in niobium. Some of the shoots cut across rock types, and these contain more than one niobium mineral in some cases. The writer believes that the deposits are formed due to the action of hydrothermal or pneumatolytic solutions from alkaline magmas. These solutions may be generated at various stages during the differentiation of these magmas—a process that is very complex and variable.

## OTHER OCCURRENCES

Occurrences of niobium minerals that at present appear to be mainly of geological and mineralogical interest are found in fracture-fillings and chloritic shear zones in granitic rocks; in a syenitic pegmatite; in nepheline syenite; in calcite rocks and veins; and in a gossan capping. About 70 per cent of the occurrences are in granitic pegmatites, most of which, if not all, are zoned<sup>1</sup>.

## Distribution and Age

Niobium mineral deposits and occurrences have been found in British Columbia, Saskatchewan, Manitoba, Ontario, Quebec, Nova Scotia, and the Northwest Territories. Over 90 per cent of them are in the Canadian Shield and the outlier of the Shield that forms the Oka Hills, and the others are in the Western Cordilleran Region, the St. Lawrence Lowlands, and the Acadian-Appalachian Region. The large number in the Shield is probably due to the large area of the Shield, the fact that pegmatites are especially abundant in the Grenville sub-province, and the association of alkaline rock complexes with stable regions of the earth's crust.

The placer deposits are Recent in age, and the bedrock deposits and occurrences range from Precambrian to Cenozoic. Most of the pegmatite occurrences are Precambrian. The alkaline complexes probably range from Precambrian to Cenozoic. On the basis of structural and petrological evidence, the Oka complex is believed by the writer to be Palæozoic or younger. The Manitou Island complex is pre-Ordovician. The other complexes are the youngest rocks in the areas in which they occur, and cannot be dated by structural methods.

## Grade

Bedrock niobium deposits in Canada are divided into four classifications by the writer as follows:

	Per cent niobium oxide
Very low grade.....	less than 0.30
Low grade.....	0.30 to 0.60
Medium grade.....	0.60 to 0.90
High grade.....	more than 0.90

<sup>1</sup> A zoned pegmatite consists of one or more zones and a core. Zones are shells, complete or incomplete, that reflect the shape or structure of a pegmatite body and, where ideally developed, are concentric about an innermost zone or core (Cameron, Jahns, McNair, and Page, 1949).

These ratings are tentative, and modifications may be necessary when all of the economic factors regarding the processing of niobium-bearing rocks are known.

### **Future Outlook**

Although there is no production of niobium concentrates in Canada at present, it is probable that Canada will become a producer should the demand for concentrates increase. In other countries, niobium is recovered chiefly from columbite, but reserves of columbite are low, and deposits of other niobium minerals, particularly pyrochlore, are being investigated as possible large-tonnage sources. Canada is well endowed with pyrochlore deposits that are strategically located with respect to North American markets, and the writer believes that there are deposits that remain to be found.

### **Suggestions for Prospecting**

There are probably many niobium deposits in Canada yet to be discovered, and information gained from the study of known deposits in Canada and elsewhere should be of use in prospecting.

All of the Canadian deposits of economic interest that are described in this report are abnormally radioactive and were discovered because of this. The prospector is advised to use a sensitive radioactivity detection device such as a 'beta-gamma' Geiger counter or a scintillation counter, as an aid in prospecting both bedrock and placer terrains, and to carefully evaluate all anomalies regardless of their strength. It is possible that non-radioactive niobium deposits of economic interest will be found in Canada, and the prospector is cautioned not to rely entirely on his radioactivity detector.

In prospecting for niobium in Canada, efforts should be concentrated towards finding placer deposits and bedrock deposits associated with alkaline rock complexes. Bedrock deposits in granitic rocks, granitic pegmatites, and syenitic pegmatites are likely to be of very low grade and unworkable under economic conditions. It is not likely that sizable eluvial deposits occur in Canada, but the possibility should be kept in mind.

The writer believes that insufficient attention has been paid to placer deposits in Canada, not only with regard to niobium but other materials as well. Careful mineralogical work should be done on heavy mineral concentrates from all sizable placer deposits, especially if the deposits or the concentrates are radioactive. Although values in placer deposits are commonly low as compared to those in bedrock deposits, the constituent minerals are free or relatively free.



All alkaline complexes and their vicinities should be carefully prospected, not only for niobium, but also for tantalum, uranium, thorium, beryllium, rare earths, zirconium, apatite, and barite. It is therefore desirable for prospectors to be aware of the characteristics of these complexes so that unmapped ones will not be missed. Alkaline complexes generally occur in stable areas of the earth's crust, particularly areas of Precambrian rocks. Circular structures are common and it is reported that many of the African complexes were discovered by studying aerial photographs. Alkaline complexes commonly occur in belts, and the existence of such a belt extending northwestward from the Monteregian Hills in Quebec, to Heron Bay, Lake Superior, Ontario, is strongly suggested. Many alkaline complexes that contain niobium minerals also contain magnetite that causes pronounced magnetic anomalies (*see* Figures 6, 15, and 29). In general, alkaline rocks are difficult to recognize in the field, but some contain distinctive minerals such as sodalite, and coarse-grained nepheline rocks are pitted on weathered surfaces. Lamprophyre dykes commonly occur in alkaline rock complexes and as satellites, and many varieties are easily recognized by their dark colour and porphyritic nature. There is a strong suggestion that the greater the degree of differentiation in the complex, that is, the greater the variety of rock types, the greater the chance of finding niobium deposits of economic interest. In general, niobium minerals tend to occur in the carbonate rocks of alkaline complexes if such rocks are present, but important deposits also occur in silicate rocks.

## PART V

## DESCRIPTIONS OF DEPOSITS AND OCCURRENCES IN CANADA

This part of the report includes detailed descriptions of Canadian niobium deposits that have been explored extensively by stripping, trenching, diamond drilling, or underground work. Other deposits and occurrences are treated briefly in a table. Almost all known deposits and occurrences are included, but a few are omitted because of lack of permission to publish information. The listing of known occurrences has been aided by the fact that many niobium minerals are radioactive, and the regulations of the Atomic Energy Control Board stipulate that any radioactive discovery from which assays showing 0.05 per cent or more of uranium or thorium have been obtained must be reported to the Geological Survey of Canada. There may, however, be some known occurrences of non-radioactive niobium minerals of which the Geological Survey is unaware.

**Bugaboo Placer Deposits, Southeastern British Columbia**

The Bugaboo group of eight radioactive placer deposits that contain niobium minerals are in the valleys of Bugaboo, Vowell, and Forster Creeks, about 45 miles south of the town of Golden in southeastern British Columbia (see Figure 1). Twelve placer leases, held by Quebec Metallurgical Industries Limited, Ottawa, cover the deposits.

Churn drilling has been done on several of the leases, and a small mill has been erected on the Bugaboo lease to provide black sand concentrates for extraction tests which are being conducted in the laboratories of the company.

G. O. Reid discovered uranium-bearing black sand at the head of Bugaboo Creek in 1949 (Lang, 1952).

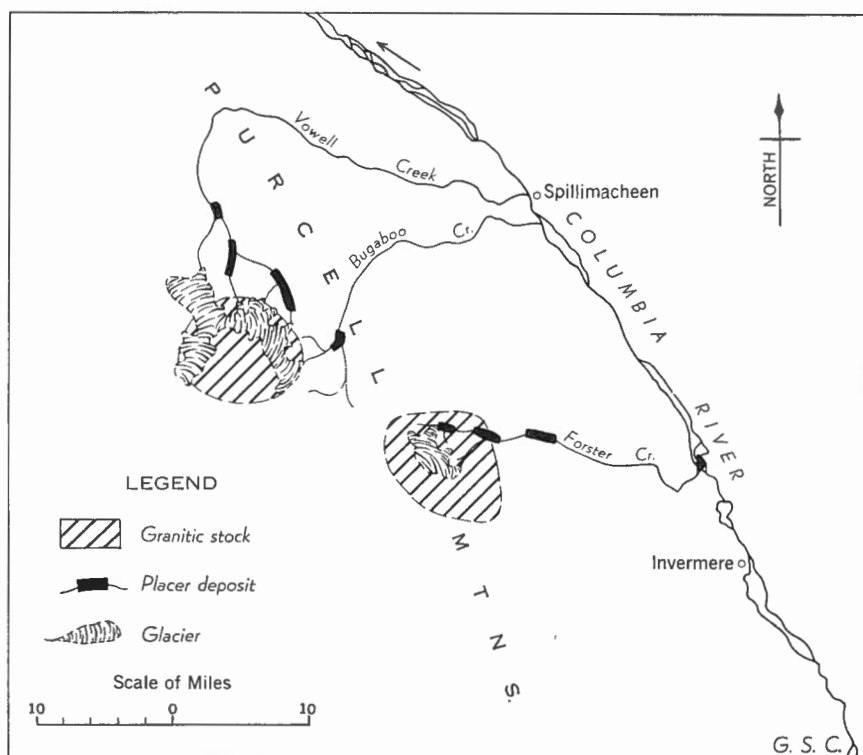
The placer deposit now held by Quebec Metallurgical Industries Limited at Bugaboo Creek was discovered by F. T. Russel and A. Archer in August 1953, by means of a fluorescent stain technique for uranium made on radioactive black sand pan concentrate. Subsequent prospecting led to the discovery of similar deposits in the beds of Vowell and Forster Creeks.

The deposits (see Figure 1) are composed of recent alluvium that is derived chiefly from the Bugaboo and Horsethief granitic stocks, two of a series of similar stocks in the Purcell Range (Reesor, 1954, and Walker, 1926). These stocks are presently being studied by J. E. Reesor of the Geological Survey. Some of the alluvium is probably derived from the aureoles of contact metamorphic rocks that are associated with the stocks. Glaciers and glacial streams are the agents of erosion.

Preliminary mineralogical studies have been made of samples of black sand concentrates from these deposits in the laboratories of the Geological Survey, and two niobium minerals, a member of the euxenite-polycrase series and pyrochlore, have been identified. Euxenite-polycrase occurs as grains and octahedra. The grains are very fresh, have a vitreous lustre and a conchoidal fracture, and are reddish brown to amber-coloured

or mottled in colours of light brown, reddish brown and dark brown. The crystal surfaces are dull and almost black. Pyrochlore occurs as fresh, vitreous, amber-coloured grains. Uraninite has been found in all of the samples, and occurs as fresh, dark steel-grey grains and subhedral crystals. Other minerals in the concentrates include: allanite, andalusite, apatite, epidote, fluorite, garnet, hematite, ilmenite, magnetite, pyrite, sphene, and zircon. According to W. D. Hubler of Quebec Metallurgical Industries Limited (personal communication), uranothorite has been identified in concentrates from these deposits.

The company reports that the estimated reserve of placer material available for dredging consists of a minimum of 65 million cubic yards. Grade has not been announced.



**Figure 1.** Sketch-map showing the Bugaboo placer deposits, southeastern British Columbia, and their relationship to granitic stocks, glaciers, and glacial streams. (From map by H. D. Hughes, Quebec Metallurgical Industries Limited, 1955.)

### Lonnie Deposit, Manson Creek Region, Central British Columbia

*Reference:* Holland, 1955.

The Lonnie deposit is a complex of carbonate rocks and feldspar rock that contains disseminated columbite, ilmenorutile, and uranian pyrochlore. It is on the Lonnie group of eight mining claims, about five miles east of

the settlement of Manson Creek, central British Columbia. Northwestern Explorations Limited, Vancouver, holds the property. Work done consists of stripping, and trenching.

Niobium was discovered by spectrographic analyses in samples sent to the British Columbia Department of Mines by E. A. Floyd and J. C. Kay in the autumn of 1953. The Lonnie group was staked to cover the occurrence by A. Almond of Vanderhoof, E. A. Floyd of Manson Creek, J. C. Kay of Victoria, and C. S. Powney of Fort St. James. Northwestern Explorations Limited acquired the claims in December 1954.

The deposit has been described by Holland (1955), and it was examined by the writer in August 1955. Twenty-six thin sections were studied.

The country rocks are schists and gneisses of the Wolverine complex (Armstrong, 1949, pp. 26-31). Figure 2 is a geological map of the vicinity of the Lonnie deposit. Adjacent to the Lonnie complex, the schists and gneisses are fenitized and contain abundant soda pyroxene and soda hornblende.

The Lonnie complex is more than 2,000 feet in length and 300 feet in maximum width, and consists of bands of feldspar rock, calcite-soda pyroxene rock, massive calcite-biotite rock, and foliated calcite-biotite rock (see Figure 2). Columbite and ilmenorutile occur in the feldspar rock, and uranian pyrochlore occurs in the calcite-soda pyroxene rock.

The feldspar rock consists mainly of plagioclase with lesser amounts of calcite, white mica, microcline, zircon, black opaque minerals, and biotite. Streaks, patches, and veinlets of calcite rock occur in places. The rock is generally white, fine grained, granular, and massive, but in places it is foliated due to blue-grey lenticles. In thin section it can be seen that some specimens are inequigranular, and exhibit mortar structure and bent plagioclase twin-lamellae.

The calcite-soda pyroxene rock consists chiefly of white calcite and green soda pyroxene with lesser amounts of plagioclase, soda hornblende, apatite, and greyish brown octahedra of uranian pyrochlore. Lenses of calcite-soda pyroxene rock and calcite rock occur in places in the wall-rock gneisses and schists, and the wall-rock contacts are commonly sheared. The grains of soda pyroxene range up to over 1 inch in length, and occur as disseminated grains and in lenses and patches. Boudinage structure occurs in places, and the boudins are rich in soda pyroxene. In thin section it can be seen that the soda pyroxene grains are pleochroic in shades of yellowish green and green, and that they generally contain rounded grains of calcite. Many of the plagioclase grains have bent twin-lamellae. Soda hornblende occurs as grains and as shreds and veinlets in soda pyroxene. It is markedly pleochroic in shades of pale yellow, sky blue, and violet. One crystal of pyrochlore was observed in thin section: it is zoned in shades of grey and amber.

The massive calcite-biotite rock is generally coarse grained, and the calcite is white. Only one thin section of this rock was examined and it was found to contain abundant plagioclase.

The foliated calcite-biotite rock is bluish grey, and very fine to coarse grained. Under the microscope it is seen that plagioclase and apatite are abundant, and a few grains of microcline were observed. Calcite twin lamellae are usually bent.

A narrow band composed of green hornblende crystals in a fine-grained, brown matrix occurs in calcite-soda pyroxene rock in one of the trenches. In thin section, it can be seen that the crystals are soda hornblende, and the matrix consists of ragged soda pyroxene grains and feldspar with lesser amounts of calcite.

The sheared contacts, the boudinage and mortar structures, and the deformation of the calcite and plagioclase lamellae suggest that the Lonnie complex was forcefully intruded. However, crystalline limestones occur in the Wolverine complex (Armstrong, 1949, pp. 26-31), and it is possible that the carbonate rocks are metasomatized marble, and that the feldspar rock and porphyritic rock represent the magma that was responsible for the activity. Whatever the origin of the complex, the alkaline nature is apparent.

A zone that is 1,620 feet in length and 50 feet in average width contains an average of 0.21 per cent niobium oxide. The zone consists of calcite-soda pyroxene rock with an average content of 0.16 per cent niobium oxide, and feldspar rock with an average content of 0.23 per cent niobium oxide.

### **Verity Deposits, Blue River Region, Southeastern British Columbia**

*References:* McCammon, 1953; McCammon, 1955; Smith, 1954.

The Verity deposits consist of bands and lenses of carbonate rock that contain uranian pyrochlore and uranian columbite in places. They are located near mile 109, Albreda subdivision, Canadian National Railways, 23 miles north of the village of Blue River (*see* Figure 3). A mining property of eighty mining claims, owned principally by the O. E. French family, Blue River Post Office, covers the deposits. The property consists of several groups of claims, and both the deposits and the property are named after the Verity group which contains the original and principal showings.

Radioactive carbonate rocks were discovered by the French family in 1951 on claims that were originally staked for vermiculite. Uranian pyrochlore was identified in specimens sent to the British Columbia Department of Mines, and uranian columbite was identified in specimens sent to the Geological Survey. Additional claims were staked, and the property was optioned in 1952 to St. Eugene Mining Corporation Limited, Vancouver. Several outcrops of carbonate rock were discovered and the number of claims was enlarged to eighty. Work done in 1953 consisted of stripping and trenching, mainly on the Verity No. 1 and No. 2 claims. St. Eugene Mining Corporation Limited retains a 20 per cent interest in the property.

The Blue River region has not been mapped geologically, and is very difficult to prospect because of the heavy growth of timber and underbrush and the rugged nature of the topography. McCammon (1953 and 1955), and Smith (1954) have described these deposits, and most of the information presented here has been taken from their reports. The writer visited the property in August 1955, and seven thin sections were studied.

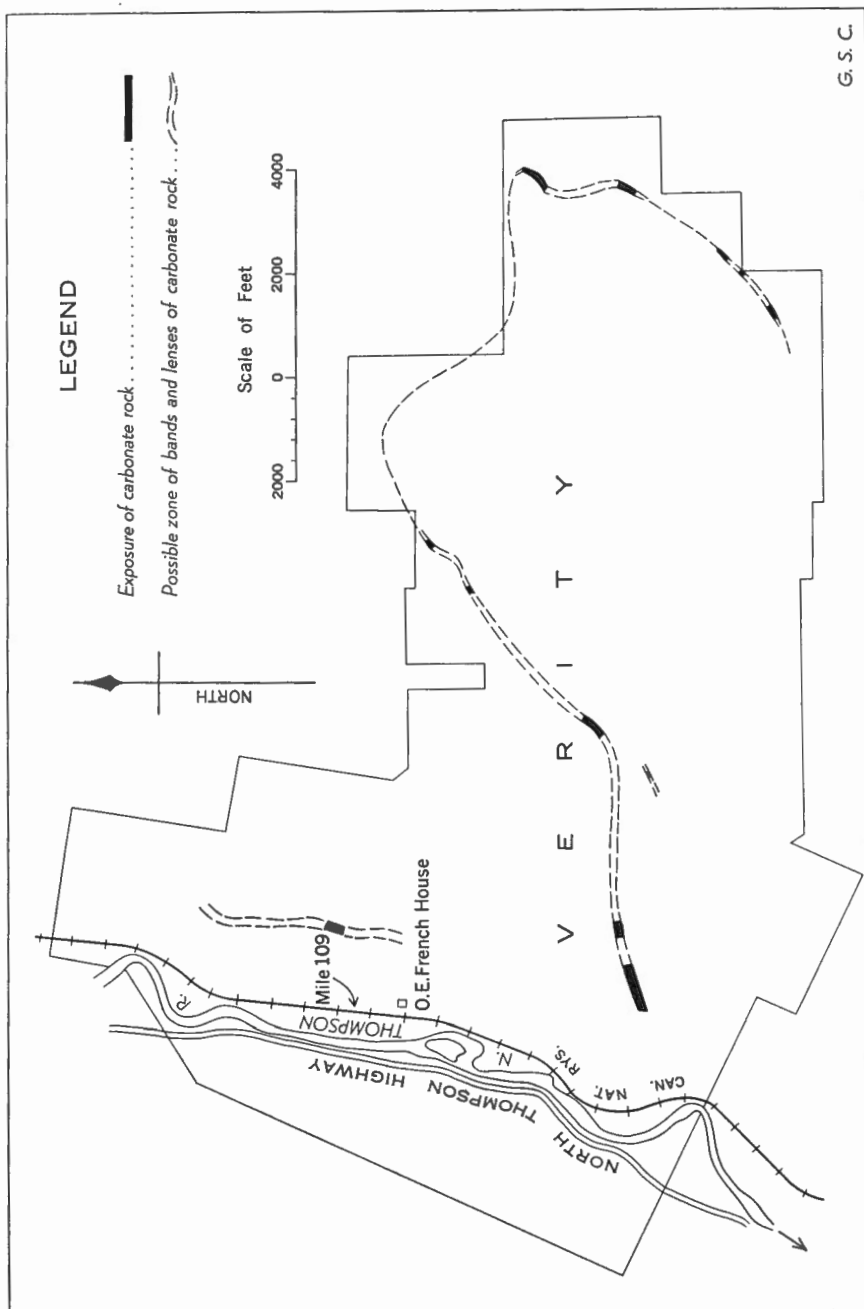


Figure 3. Sketch map of the Verity property, southeastern British Columbia, showing occurrences of carbonate rocks. [From map by H. D. Hughes, 1952.]

The bands and lenses of carbonate rock range up to 150 feet in thickness and are apparently conformable with the enclosing quartz-mica and hornblende gneisses. According to Smith (1954), these bands and lenses probably belong to zones that are rich in carbonate rocks (*see* Figure 3). Dykes and sills, that consist mainly of plagioclase, cut the gneisses and the carbonate rock in places. An outcrop of sodalite syenite occurs just north of the northeast corner of the property. Figure 4 is a geological sketch-map of the main showing on the Verity No. 1 and No. 2 claims.

The carbonate rock is fine to coarse grained and is composed mainly of dolomite. One specimen collected by the writer was found to consist chiefly of calcite. Variable amounts of accessory minerals occur in places, and these include: vermiculite, magnetite, olivine, ilmenite, green amphibole, zircon, biotite, white mica, pyrrhotite, pyrite, uranian pyrochlore, and uranian columbite. Amphibole and mica grains commonly parallel the foliation of the wall-rock gneisses. The carbonate rock is generally weathered to a depth of about 10 feet, and fresh specimens are difficult to obtain.

Uranian pyrochlore occurs as disseminated crystals and gneiss that range up to  $1\frac{3}{4}$  inches in size. The colour varies from pale brown to brown to reddish brown to very dark brown to almost black. Some of the smaller grains have a reddish halo. A partial analysis of a specimen of the uranian pyrochlore is given in Table I.

Uranian columbite was identified by the late H. V. Ellsworth of the Geological Survey in specimens of carbonate rock that were sent to him by O. E. French. It gives an X-ray powder picture like that of columbite-tantalite and occurs as small, black, metallic grains. Table I contains a partial analysis of this mineral.

TABLE I  
*Partial Analyses of Niobium Minerals,  
Verity Property, Southeastern British Columbia*

Uranian pyrochlore		Uranian columbite	
	Per cent		Per cent
Nb <sub>2</sub> O <sub>5</sub> .....	65	Nb <sub>2</sub> O <sub>5</sub> +Ta <sub>2</sub> O <sub>5</sub>	60 to 70
Ta <sub>2</sub> O <sub>5</sub> .....	10	U <sub>2</sub> O <sub>5</sub>	9 to 10
U <sub>3</sub> O <sub>8</sub> .....	6	(FeAl) <sub>2</sub> O <sub>3</sub>	10
ZrO <sub>2</sub> .....	0.03	TiO <sub>2</sub>	2 to 3
		Rare earths	2 to 3
		CaO	2 to 3
		MgO	2 to 3
Analyst: R. J. Traill, Geol. Surv., Canada.		Analyst: H. V. Ellsworth, Geol. Surv., Canada.	
Method: Semi-quantitative X-ray fluorescence.		Method: Chemical, described by Ellsworth as "a rough diagnostic analysis".	

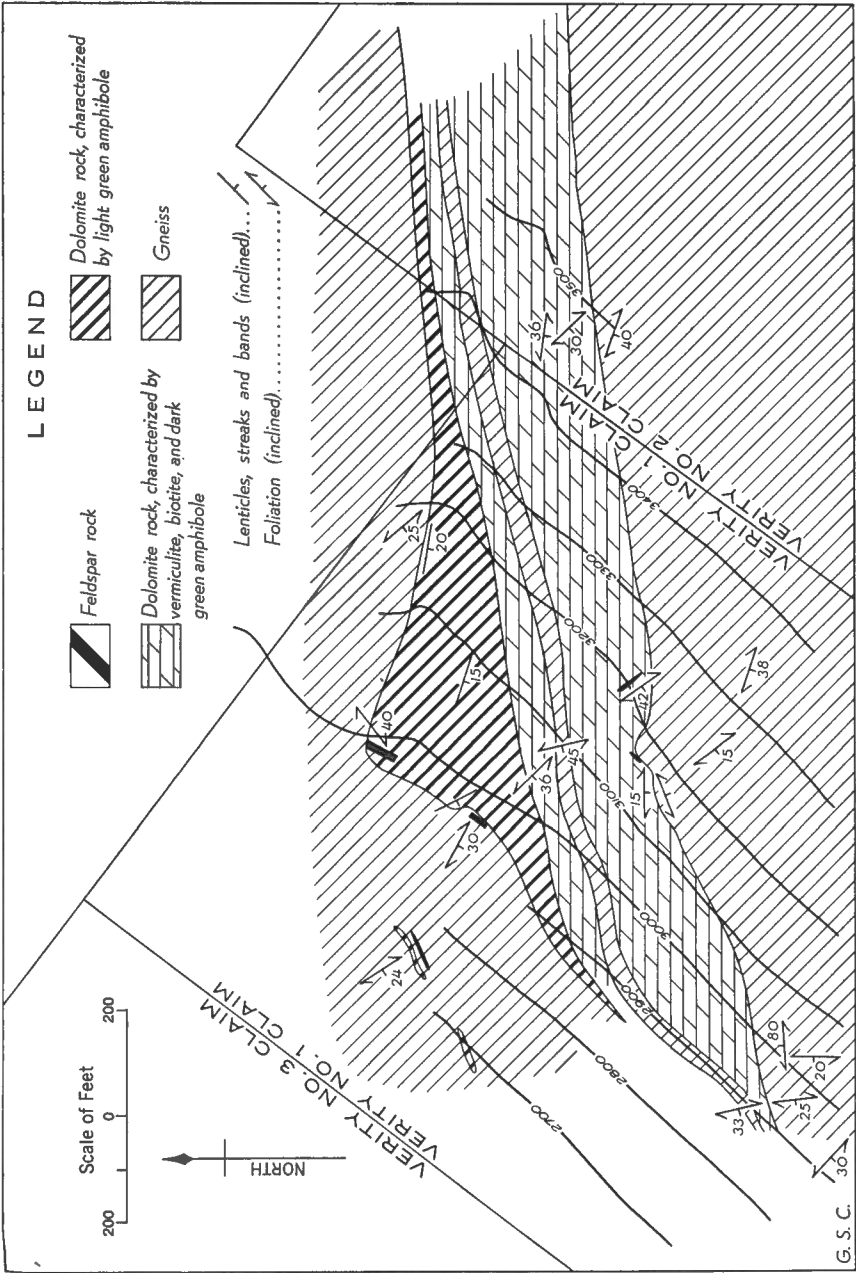


Figure 4. Geological sketch-map showing the general geology of the Verity No. 1 and No. 2 claims, Verity property, Blue River region, southeastern British Columbia. (From map by Dr. Alex Smith, 1952.)



Several samples of carbonate rock were collected by McCammon (1953 and 1955) and the results of the analyses are given in Table II.

TABLE II

*Analyses of Carbonate Rock, Verity Property,  
Southeastern British Columbia*

Width (inches)	Per cent				
	Nb <sub>2</sub> O <sub>5</sub>	U <sub>3</sub> O <sub>8</sub>	CaO	MgO	P <sub>2</sub> O <sub>5</sub>
A..... 5	0.38	0.039	—	—	—
B..... 60	0.37	<0.01	27.6	12.4	1.88
C..... 39	<0.1	<0.01	36.8	5.7	2.75
D..... 31	<0.1	0.33	42.4	4.7	2.02
E..... 54	<0.1	0.017	—	—	—
F..... 44	0.60	0.101	33.3	12.5	4.85
G.....	not detected	trace			
H.....	not detected	0.008			
I.....	0.086	0.04			

References: McCammon (1953 and 1955).

Analyst: British Columbia Department of Mines.

NOTES: A, B, C, D, E, and F were specimens that gave Geiger counter readings of 1½ to 2 times those generally recorded for the carbonate rock.

G, and H were specimens that were selected to indicate the grade of carbonate rock on the Mill group of claims.

I was a specimen from the Verity No. 1 claim that gave a high reading on a scintillation counter.

## Multi-Minerals Deposits, Chapleau Region, Northwestern Ontario

References: Haanel, 1910; Lang, 1952; Nickel, 1955; Nickel, 1956.

Disseminated pyrochlore occurs in places in an alkaline rock complex on the Multi-Minerals property, about 14 miles southeast of the village of Chapleau in northwestern Ontario. The property consists of seventy-eight mining claims in McNaught and Lackner townships, and is held by Multi-Minerals Limited, Toronto.

In May 1949, it was discovered that an iron occurrence in McNaught township was radioactive (Haanel, 1910, pp. 110-111, and Lang, 1952, p. 131). On the basis of this discovery, Nemegos Uranium Corporation was formed. Two patented claims covering the iron occurrence were acquired, and an additional seventy-two claims were staked. The company reported that 7,500 feet of diamond drilling was done in 1950. Northrim Exploration Company Limited took an option on the property in September 1953. The property was sold to Multi-Minerals Limited in December 1953, and an additional four claims were staked.

Work done by December 1954 included magnetic and geological surveys, and 41,246 feet of diamond drilling. Drilling was proceeding in June 1955.

The writer visited the property in June 1955, and fifty-three specimens were collected for thin-section study.

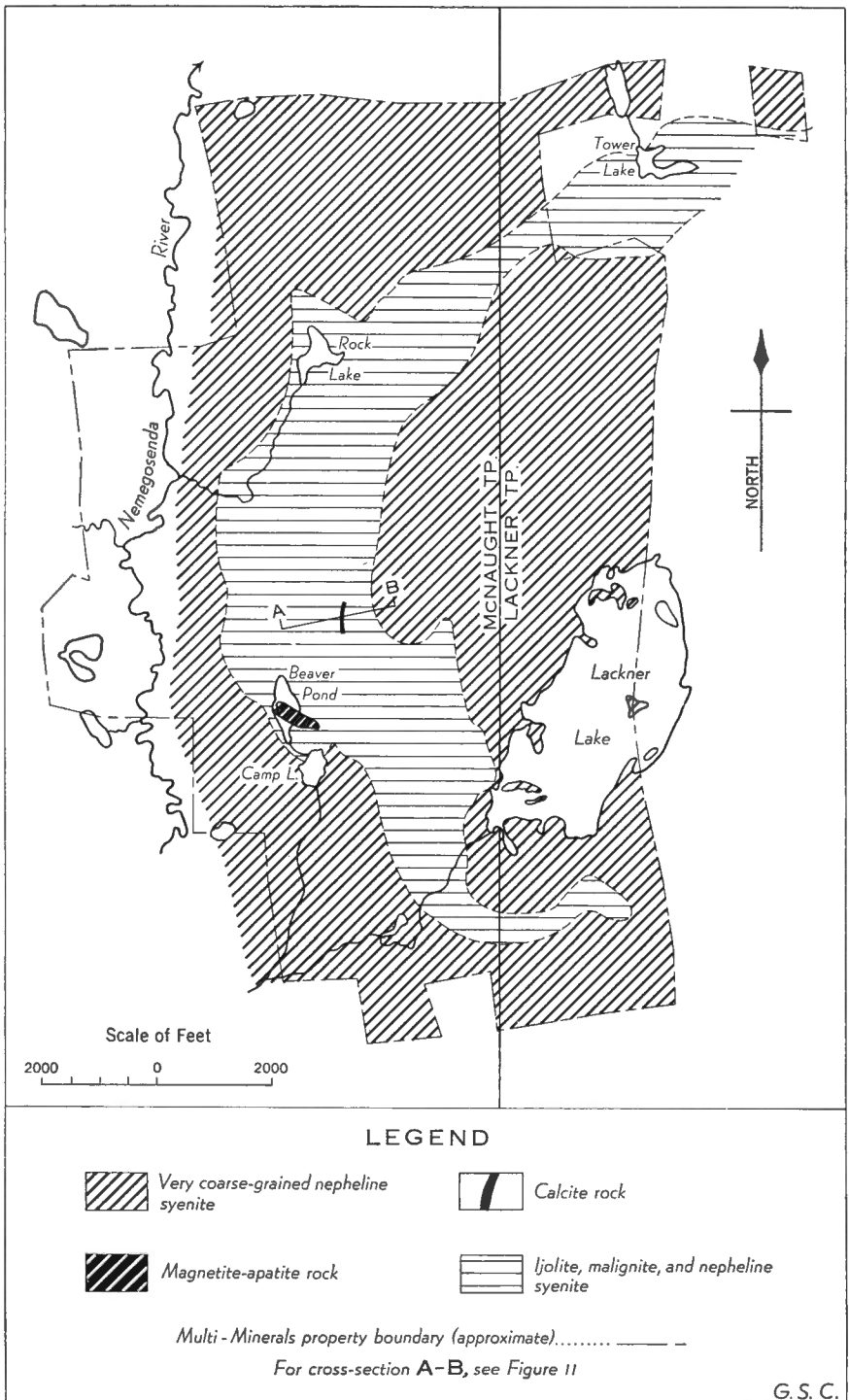
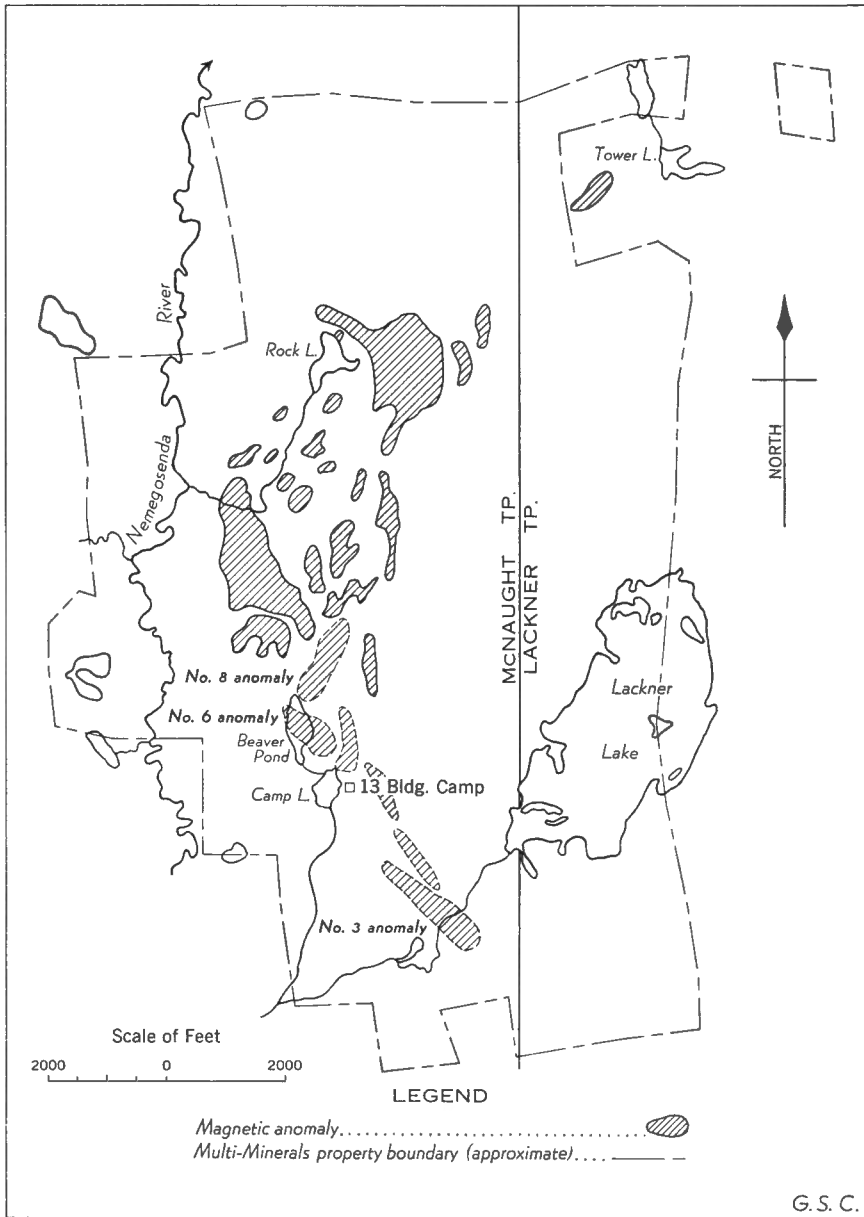


Figure 5. Geological sketch-map of Multi-Minerals property, Chapleau region, northwestern Ontario. (From maps by H. L. Garvie and E. Neczkar, Multi-Minerals Limited, 1954.)



**Figure 6.** Sketch-map showing location of magnetic anomalies, Multi-Minerals property, Chapleau region, northwestern Ontario.

## GENERAL GEOLOGY

The Chapleau region has not been mapped geologically.

The deposits on the Multi-Minerals property are in an alkaline rock complex that consists of an outer part and an inner part (*see* Figure 5). Very coarse-grained nepheline syenite comprises the outer part. The inner part is crescent-shaped and is composed of ijolite, malignite, medium- to coarse-grained nepheline syenite, magnetite-apatite rock, and lamprophyre dykes. The minerals of these rocks are remarkably fresh.

Several magnetic anomalies have been outlined (*see* Figure 6). Those explored were found to be caused by magnetite-apatite rock and magnetite-rich zones in the silicate rocks.

Pyrochlore occurs in places in the inner part of the complex in the silicate rocks in association with magnetite, apatite, and biotite, in magnetite-apatite rock, and in calcite rock.

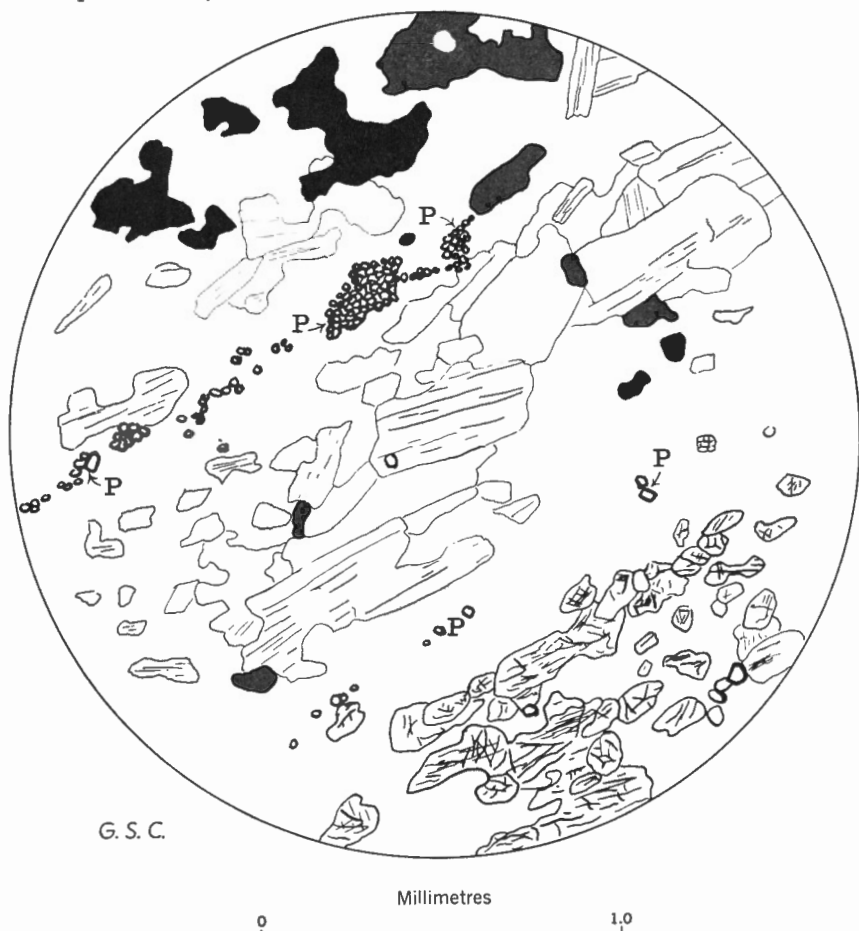


Figure 7. Camera-lucida drawing of ijolite, showing pyrochlore (P) in a lenticle that is rich in biotite and magnetite, Multi-Minerals property.

## DESCRIPTIONS OF PYROCHLORE-BEARING ROCKS

## IJOLITE

The ijolite of the complex is medium greenish grey, and is composed essentially of soda pyroxene and nepheline. Structurally and texturally, the ijolite is quite variable, and ranges from massive to foliated, fine to medium grained, and equigranular to inequigranular. Feldspar occurs in places, generally in aggregates and augen-like lenticles with nepheline. Perthite was noted in one thin section. Other minerals commonly present include magnetite, apatite, biotite, pyrrhotite, and ilmenite (intergrown with magnetite).

Pyrochlore occurs in places in ijolite as disseminated, yellow to yellowish brown grains and crystals up to 0.5 mm. in size, as clusters and streaks of minute grains and crystals, and as minute grains and crystals in nepheline veinlets. It is commonly associated with magnetite, apatite, and biotite. In thin section, the pyrochlore is reddish brown to grey to dark grey and almost opaque. It is lemon-yellow to orange under reflected light and more readily apparent. Figure 7 is a camera-lucida drawing of ijolite showing pyrochlore in a lenticle that is rich in biotite and magnetite. Figure 8 is a camera-lucida drawing of a nepheline-pyrochlore veinlet. An analysis of pyrochlore from ijolite is given in Table III.

TABLE III

*Analyses of Pyrochlore from Multi-Minerals Property,  
Chapleau Region, Northwestern Ontario*

	Per cent	
	A	B
Nb <sub>2</sub> O <sub>5</sub> .....	46.0	58.1
Ta <sub>2</sub> O <sub>5</sub> .....	1.4	2.8
U <sub>3</sub> O <sub>8</sub> .....	12.6	1.2
ThO <sub>2</sub> .....	4.7	—
CaO.....	27.0	16.9
MnO.....	0.2	0.30
Fe <sub>2</sub> O <sub>3</sub> .....	3.0	11.0
ZrO <sub>2</sub> .....	0.5	—
TiO <sub>2</sub> .....	2.5	9.1
MgO.....	0.4	0.28
Ce <sub>2</sub> O <sub>3</sub> .....	1.3	—
La <sub>2</sub> O <sub>3</sub> .....	0.3	0.32
Dy <sub>2</sub> O <sub>3</sub> .....	0.1	—

References: (A) Nickel (1955); (B) Nickel (1956).

Analyst: Mines Branch, Ottawa.

Method: Recalculated, semi-quantitative spectrographic analyses of pyrochlore concentrates.

Source rock: (A) ijolite; (B) malignite.



**Figure 8.** Camera-lucida drawing of pyrochlore grains and crystals in a nepheline veinlet in ijolite. Note fractures associated with the pyrochlore, Multi-Minerals property.

### MALIGNITE

The malignite is composed essentially of soda pyroxene, nepheline, and feldspar. Both potash feldspar and plagioclase are usually present. Accessory minerals include magnetite, apatite, biotite, ilmenite (as separate grains and intergrown with magnetite), pyrrhotite, pyrite, and zircon. The rock is medium greenish grey, fine to medium grained, massive to foliated, and is generally inequigranular. Lenticles rich in dark-coloured minerals, lenticles rich in light-coloured minerals, and feldspar and nepheline augen and augen-like lenticles are common.

The pyrochlore is similar in appearance to that of the ijolite, and occurs as disseminated grains and crystals up to 0.3 mm. in size and as

small clusters of grains and crystals. Figure 9 is a camera-lucida drawing of pyrochlore-bearing malignite.

An analysis of pyrochlore from malignite is given in Table III.



Figure 9. Camera-lucida drawing of malignite, Multi-Minerals property. Note pyrochlore (P), phenocrysts of plagioclase (Pl) and potash feldspar (F), and microphenocrysts of nepheline (Ne).

#### NEPHELINE SYENITE

The nepheline syenite of the inner part of the complex is medium to coarse grained, leucocratic, and is composed chiefly of plagioclase laths and grains, nepheline, and soda pyroxene. An untwinned feldspar, probably potash feldspar, was observed in several thin sections, and perthite was seen in one thin section. Minor amounts of magnetite, shred-like biotite, and calcite are commonly present.

Disseminated grains of brownish yellow to reddish orange pyrochlore up to 0.5 mm. in size were seen in two thin sections of altered nepheline syenite. The feldspar of this rock is cloudy in places and the nepheline is partly altered to zeolite and a micaceous mineral probably cancrinite. Biotite is more abundant than in the unaltered nepheline syenite, and has formed at the expense of soda pyroxene.

#### MAGNETITE-APATITE ROCK

Fine- to medium-grained magnetite-apatite rock occurs as bodies, and as lenticles, bands, and patches in ijolite and malignite. Minor amounts of soda pyroxene are commonly present. The lenticles, bands, and patches in the silicate rocks generally contain altered nepheline.

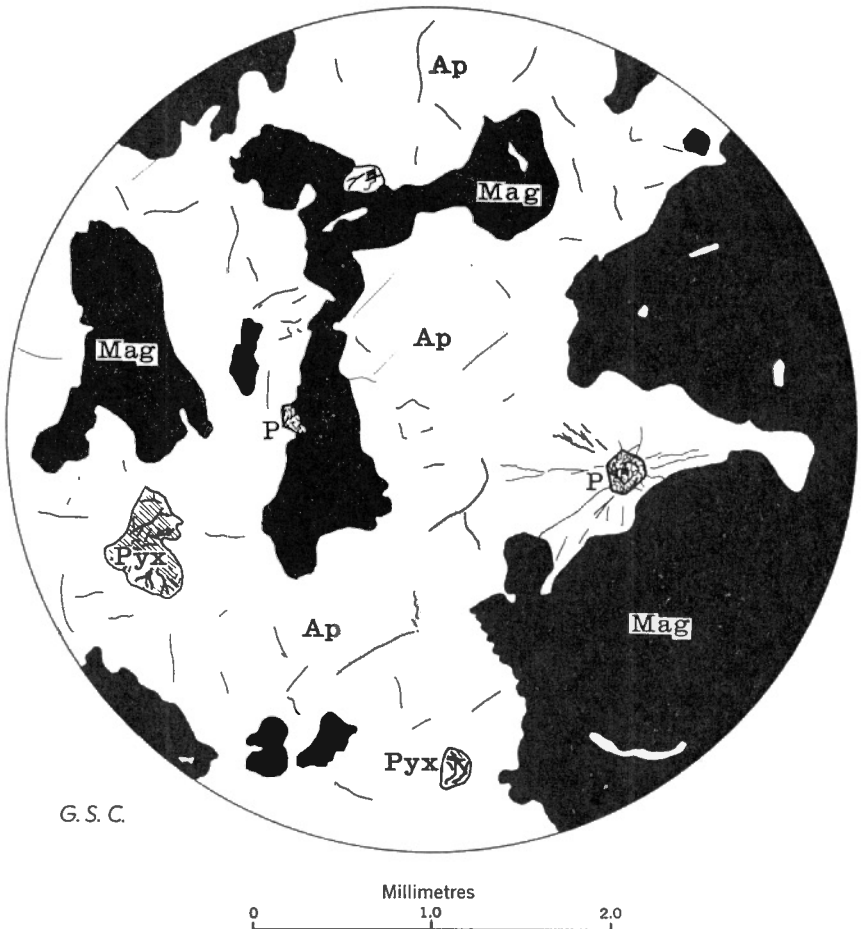
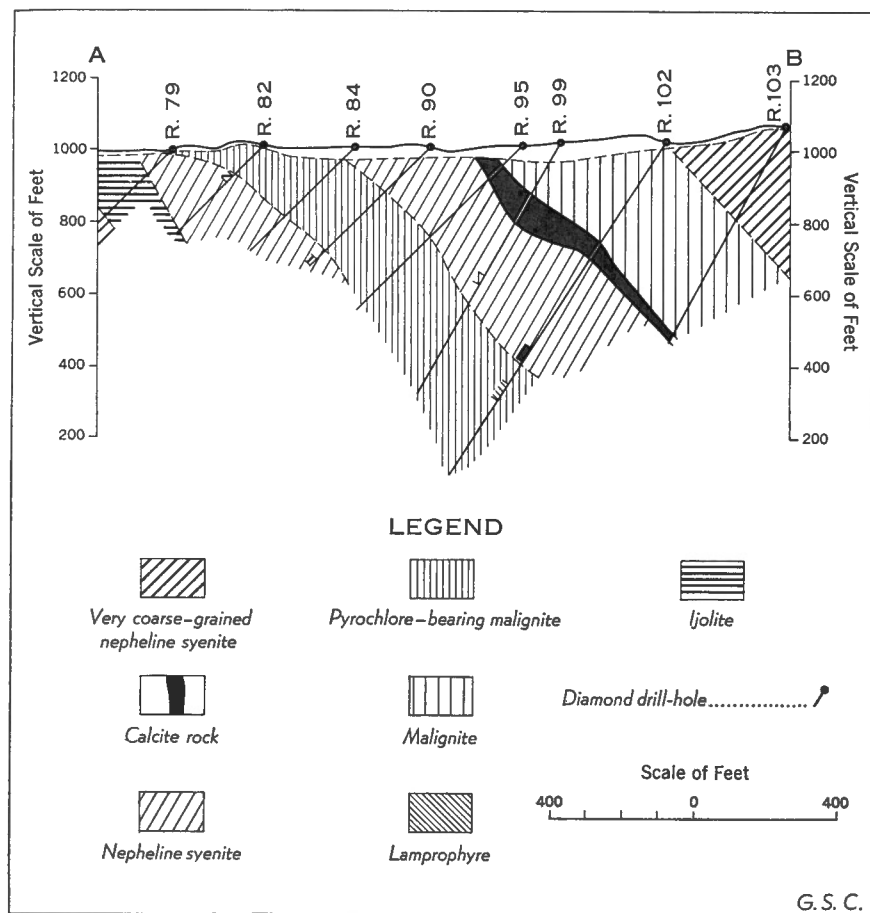


Figure 10. Camera-lucida drawing of magnetite-apatite rock, Multi-Minerals property, showing magnetite (Mag), apatite (Ap), soda pyroxene (Pyx), and pyrochlore (P). Note radial fractures associated with pyrochlore crystal.



Pyrochlore occurs in places in this rock and can be seen in thin section as disseminated, reddish brown grains and crystals up to 0.25 mm. in size. Most of the pyrochlore grains and crystals are in apatite. Figure 10 is a camera-lucida drawing of pyrochlore in magnetite-apatite rock.



**Figure 11.** Vertical cross-section along line A-B (see Figure 5) through No. 8 deposit and body of calcite rock, Multi-Minerals property, northwestern Ontario. (From section by H. L. Garvie, Multi-Minerals Limited, 1955.)

### CALCITE ROCK

A body of medium- to coarse-grained calcite rock has been encountered by several diamond drill-holes (see Figures 5 and 11). Accessory minerals occur in places and include soda pyroxene, apatite, magnetite, biotite, pyrrhotite, and reddish brown grains and octahedra of pyrochlore up to 1.0 mm. in size. In thin section, the pyrochlore is grey to brownish yellow to dark brown to almost opaque. Figure 12 is a camera-lucida of calcite rock that contains pyrochlore.

## DESCRIPTIONS OF DEPOSITS

## No. 6 DEPOSIT

This deposit consists of a body of magnetite-apatite rock that contains disseminated pyrochlore (see Figure 5), and is the cause of No. 6 magnetic anomaly (see Figure 6). In places the rock is massive, elsewhere it consists of vertical to steeply-dipping lenticles, streaks, and bands rich in magnetite or apatite.

The company announced that diamond drilling had indicated 5,024,250 tons of rock containing an average of 69.60 per cent magnetite, 21.88 per cent apatite, and 0.173 per cent niobium oxide.

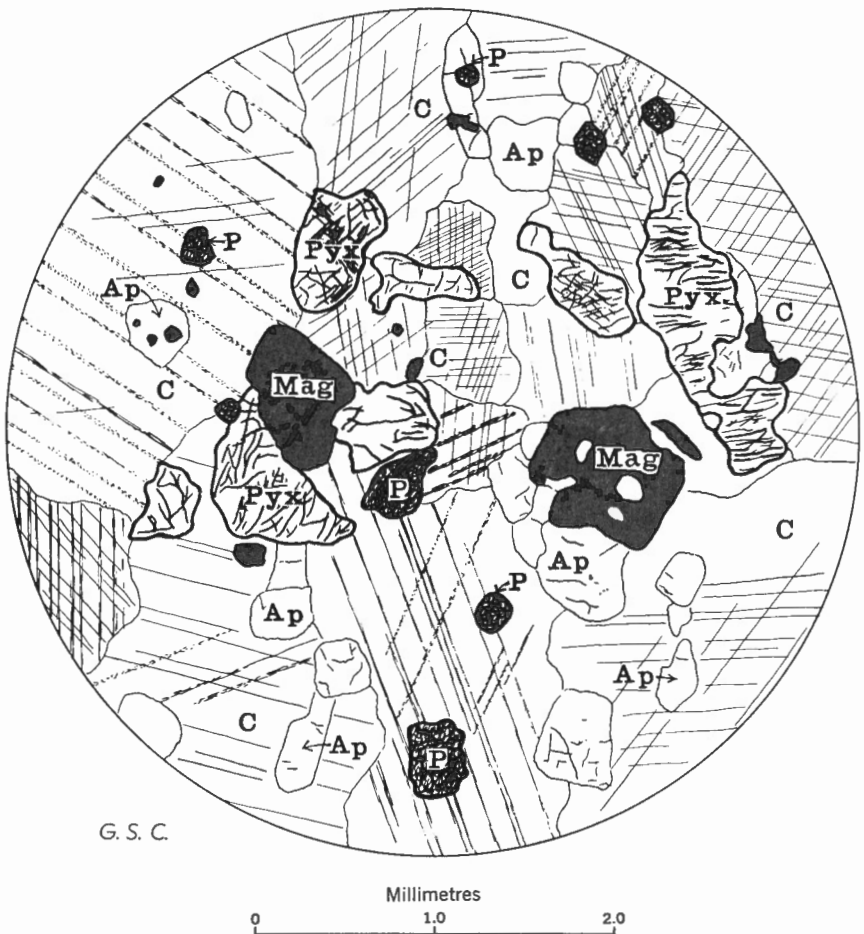


Figure 12. Camera-lucida drawing of calcite rock, Multi-Minerals property, showing calcite (C), apatite (Ap), soda pyroxene (Pyx), magnetite (Mag), and pyrochlore (P).

### No. 8 DEPOSIT

No. 8 deposit is a zone of pyrochlore-bearing malignite and ijolite. It corresponds in size and location to No. 8 magnetic anomaly (*see* Figures 5, 6, and 11).

The company announced that diamond drilling had indicated 20,620,000 tons of rock containing an average of 0.272 per cent niobium oxide.

### No. 3 DEPOSIT

This deposit is a zone that consists chiefly of ijolite with lenticles, bands, and patches of magnetite-apatite rock that contain pyrochlore. It corresponds in size and location to No. 3 magnetic anomaly (*see* Figure 6).

The company announced that diamond drilling had indicated 6,388,640 tons of rock containing 0.22 per cent niobium oxide.

## Newman Deposit, Lake Nipissing, Ontario

*Reference:* Rowe, 1954.

The Newman deposit of niobium and uranium is a potential large-tonnage source of niobium. It occurs in a complex of alkaline and carbonate rocks that outcrop in places on the Manitou Islands, a group of five islands in Lake Nipissing, Ontario, that are about 5 miles southwest of the city of North Bay (*see* Figure 13). Mining property covering the complex and vicinity is held by Beaucage Mines Limited, North Bay, Ontario. The property consists of 8,000 acres, of which 328.6 acres are occupied by the Manitou Islands.

Considerable work has been done on the Newman deposit. Preliminary work consisted of magnetic surveys and diamond drilling. A shaft was sunk on Newman Island and stations were established at the 275-foot and 400-foot levels. By mid-October 1955, a drift had been extended 900 feet east from the shaft on the 400-foot level; several crosscuts had been made both north and south of the drift to establish the width of the mineralized zone; over 12,000 feet of diamond drilling had been done from the 400-foot level; and over 9,000 tons of rock had been mined for extraction tests.

Construction of a pilot plant rated at 50 tons per day was commenced in June 1955. The plant is to be in two sections; a flotation section, and a chemical section. The flotation section was operating in December 1955, and construction of the chemical section began in October 1955.

The fact that certain outcrops on the Manitou Islands are radioactive was discovered by James Strohl, Tunkhannock, Pennsylvania, with the use of a Geiger counter. Mining property covering the occurrences was acquired by the late James J. Kenney and Martin van Clieaf, both of North Bay. A specimen was sent to the Mines Branch, Ottawa, and was found to contain 0.11 per cent uranium oxide equivalent. J. E. Thompson, Ontario Department of Mines, examined radioactive outcrops on the islands and collected eight specimens that assayed from 0.01 to 0.12 per cent uranium oxide equivalent. Mineralogical studies in the

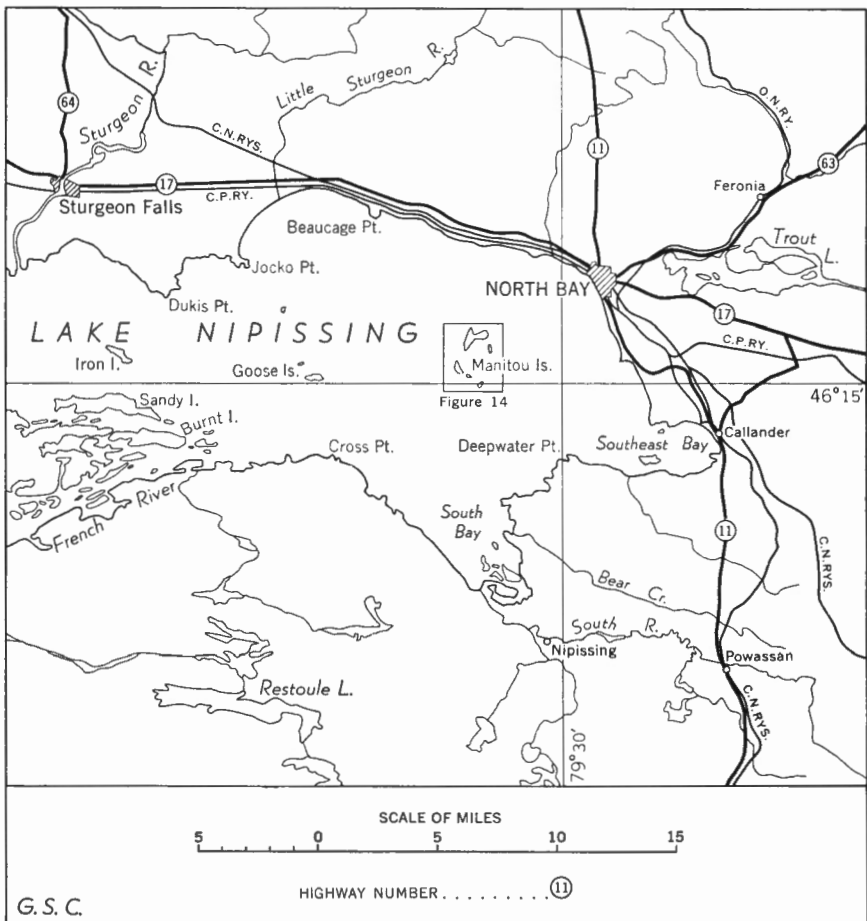


Figure 13. Index map showing location of Manitou Islands, Lake Nipissing, Ontario.

laboratories of the Geological Survey of Canada showed that a rock specimen from the Manitou Islands contained a member of the pyrochlore-microlite series, and, on December 26, 1952, the mineral was reported as uranian pyrochlore. Mr. Kenney then sent a specimen to Union Carbide and Carbon Company, Niagara Falls, New York, to be analysed, and the analysis showed 0.08 per cent uranium oxide and 1.00 per cent niobium-tantalum pentoxides. On February 17, 1953, Beaucage Mines Limited was formed to take over the Manitou Islands property held by Messrs. Kenney and Van Cleef. Inspiration Mining and Development Company Limited, North Bay, is the major shareholder in Beaucage Mines Limited.

Field studies were conducted by the writer in 1953, 1954, and 1955. One hundred and seventy-six specimens were collected, and one hundred and thirty-two thin sections were studied.

## GENERAL GEOLOGY

The Lake Nipissing region is in the Grenville sub-province of the Canadian Shield. Very little is known about the geology of the region: the only map and report that cover the area are the result of reconnaissance mapping by Barlow (1908).

The Manitou Island complex of alkaline and carbonate rocks is circular in shape, and is composed of an outer part and an inner part (*see* Figure 14). Two concentric bands comprise the outer part. Potash feldspar-soda pyroxene-quartz rock forms the first or outer band, and the second band consists of potash feldspar-soda pyroxene rock and lesser amounts of calcite rock. The silicate rocks of these bands are believed to be fenites, rocks that have been made alkaline by the addition of material from an alkaline magma. The origin of the calcite rock is not known; it could be sedimentary or magmatic or both.

Very little is known about the composition or structure of the inner part of the complex because it is not exposed. Altered pegmatitic soda pyroxene syenite bounds the inner west margin of the second concentric band. Two diamond drill-holes penetrated through the syenite and encountered altered rocks, chiefly altered, medium- to very coarse-grained, feldspathic rocks.

The rocks of the Manitou Island complex are more magnetic than the surrounding rocks, and the circular shape of the complex is reflected in the magnetic pattern (*see* Figure 15).

Trap, feldspar porphyry, and lamprophyre dykes cut the rocks of the concentric bands.

Ordovician conglomerate and limestone unconformably overlies the complex in places.

## PETROGRAPHY OF THE MANITOU ISLAND COMPLEX

## POTASH FELDSPAR-SODA PYROXENE-QUARTZ ROCK

This rock constitutes the outer band of the fenite aureole. It is medium grained, and foliated due to green lenticles and streaks. The lenticles occur in a granular groundmass composed chiefly of white to pink feldspar and lesser amounts of quartz. Purplish red hematite spots and streaks occur in places. Elongate feldspar grains occur in a few places and are parallel or subparallel to the long axes of the lenticles. Minor fractures are common and movement has taken place along some of these.

Microscopic examination shows that the lenticles are rich in soda pyroxene, or one of the following fine-grained minerals: chlorite, calcite, soda hornblende, fibrous soda pyroxene, or an untwinned feldspar-like mineral, or one of these together with soda pyroxene. Most of the feldspar grains of the rock are cloudy with dust that is greyish white in reflected light. They are usually structureless, but some are perthitic and others have plagioclase twinning. Less dusty plagioclase grains occur in most of the thin sections and these contain hematite around grain boundaries and along cleavages, fractures, and the contacts of twin lamellae. Some

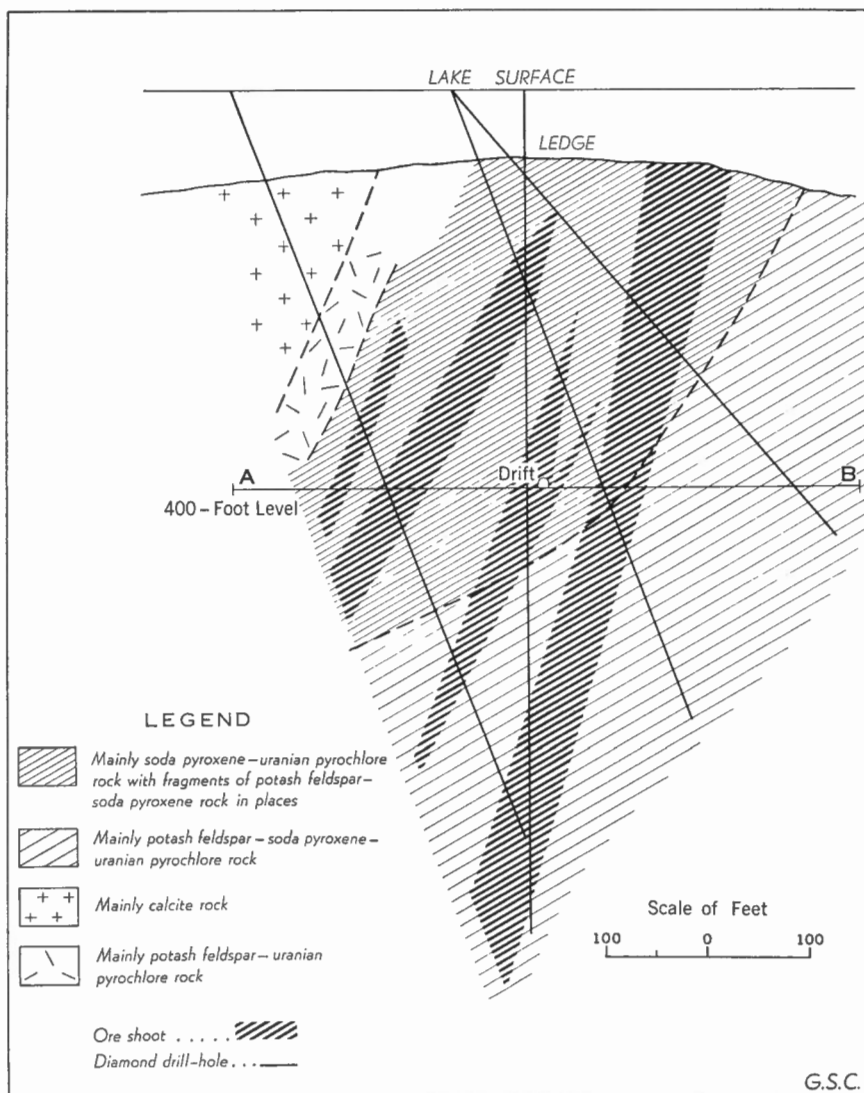
of the fractures and micro-faults are filled with soda pyroxene or soda hornblende or both. Veinlets up to  $\frac{3}{4}$  inch were observed and these consist of calcite, and calcite with one or more of soda pyroxene, soda hornblende, fluorite, pyrite, hematite, and apatite. Many of the calcite veinlets have narrow borders of biotite, soda pyroxene, fluorite, and soda hornblende, and the wall-rock adjacent to some of the veinlets is enriched in soda pyroxene or soda hornblende. The soda pyroxene associated with the veinlets is generally strongly pleochroic from greenish yellow to green, whereas that of the lenticles and streaks is usually ragged, somewhat fibrous, pale green, and slightly pleochroic. Both types have essentially parallel extinction. In hand specimen, the pyroxene of the streaks and lenticles is green, and the pyroxene of the fractures and veinlets is very dark green to black.

#### POTASH FELDSPAR-SODA PYROXENE ROCK

With the loss of quartz and purplish red hematite, and the appearance of more massive structure and coarser texture, the potash feldspar-soda pyroxene-quartz rock grades into potash feldspar-soda pyroxene rock which comprises most of the second concentric band. The rock is medium to coarse grained and composed mainly of pink feldspar and green soda pyroxene. Small, pegmatitic patches of calcite, soda pyroxene, soda hornblende, potash feldspar laths, and fluorite occur in places. Abrupt changes in structure and texture are common, and some of these are due to minor faults. In places, the rock is foliated due to lenticles that are rich in soda pyroxene. Elsewhere it is massive with patches, rosettes, or disseminated grains of soda pyroxene. An outstanding feature of the pegmatite dykes is the alignment of the elongate soda pyroxene crystals and feldspar laths perpendicular to the dyke walls. In general, the rock becomes more massive and coarser grained towards the contact with syenite. Patches and well-defined dykes of potash feldspar-soda pyroxene pegmatite apparently become more numerous as the contact is approached. Fracture fillings and veinlets similar to those in the potash feldspar-soda pyroxene-quartz rock also occur in this rock.

Under the microscope, it can be seen that the potash feldspar grains are cloudy with greyish white and orange-red dust. They are commonly sutured, or are surrounded by very fine-grained feldspar suggesting mortar structure. Perthitic potash feldspar occurs in many thin sections, and a few grains with microcline structure were seen in some sections. Rosettes of potash feldspar laths that have wavy extinction occur in association with rosettes of soda pyroxene. Plagioclase grains occur in places, and both these and the plagioclase of the perthite are relatively free from dust. Much of the soda pyroxene contains very fine-grained calcite, and is ragged, somewhat fibrous, only slightly pleochroic and cloudy with opaque dust. Fresh soda pyroxene grains and prismatic crystals occur in places and are strongly pleochroic. Soda hornblende, pleochroic in shades of greenish yellow, lavender, and blue, partly or entirely replace some of the soda pyroxene. Chlorite formed by the replacement of soda pyroxene was seen in a few thin sections. Very fine-grained calcite is a common constituent of the rock. Micro-veinlets of quartz and calcite, and biotite and chlorite were observed in a few thin sections. Very fine-grained

brown mica is present in places at the expense of soda pyroxene. Apatite occurs as disseminated grains, aggregates, and in micro-veinlets. Very minor amounts of pyrite, magnetite, monazite, and uranian pyrochlore are present in places. Aggregates of very fine-grained, white mica were seen in two thin sections, and these probably formed by the replacement of nepheline.



**Figure 16.** Generalized vertical cross-section, Newman deposit, on line A-B, looking west, (Figure 17). (From section by O. E. Owens, Beaucage Mines Limited, 1955.)

## CALCITE ROCK

Calcite rock occurs with potash feldspar-soda pyroxene rock in the second concentric band of the complex. Most of the calcite rock is conformable with the potash feldspar-soda pyroxene rock. The calcite rock varies from very fine to coarse grained, and from massive to finely foliated. In places, it is composed entirely of white to grey calcite, elsewhere, it contains streaks and lenticles rich in soda pyroxene, soda hornblende, biotite, apatite, magnetite, and iron sulphides. A few crystals and skeletal crystals of uranian pyrochlore are present in places, and usually occur in the lenticles and streaks. Contacts between calcite rock and potash feldspar-soda pyroxene rock are exposed on Calder Island. Some are sharp, others are represented by contact zones. In these zones, the potash feldspar-soda pyroxene rock is more massive and is commonly enriched in calcite and soda pyroxene, and the calcite rock is more massive and enriched in coarser grained, black, soda pyroxene. In places, fragments of potash feldspar-soda pyroxene rock have broken away and have become engulfed by calcite rock showing flowage structure. In places, calcite rock has flowed into fractures in potash feldspar-soda pyroxene rock to form veins and veinlets. Some of these contain fragments of potash feldspar-soda pyroxene rock.

In thin section, the biotite is normally brown to olive-green. However, biotite close to uranian pyrochlore commonly has patches that are pleochroic from pale brown or olive-green parallel with the north-south cross-hair to bright orange-red with the cleavage parallel with the east-west cross-hair. Both clear and dusty calcite grains were observed. The soda pyroxene is generally somewhat fibrous and pale green in thin section, but in the contact zones it is usually fresh in appearance and strongly pleochroic from greenish yellow to grass-green.

## ALTERED PEGMATITIC SODA PYROXENE SYENITE

The altered pegmatitic soda pyroxene syenite does not outcrop on the islands, but has been intersected by many diamond drill-holes, and apparently bounds the inner west margin of the fenite aureole. Two diamond drill-holes penetrated through the syenite. It is very coarse grained, massive, and granitoid, and is composed chiefly of white to grey to pink laths and grains of potash feldspar and prismatic grains of green soda pyroxene and altered soda pyroxene that range up to about an inch in length. Minor amounts of disseminated, fine-grained pyrite and magnetite are commonly present. Veinlets of very coarse-grained, pink to white potash feldspar occur in places, and many of these have narrow cores of calcite. Red spots occur in the syenite adjacent to some of these veinlets.

In thin section, the potash feldspar is generally structureless, and more or less cloudy with grey dust. Many of the grains are perthitic or have Carlsbad twins. In some of the thin sections, fine-grained potash feldspar and plagioclase occur interstitial to the larger potash feldspar grains and laths. The soda pyroxene grains are strongly pleochroic from greenish yellow to dark green, and many of them are altered to very fine-grained carbonate, white mica, and chlorite, or have a ragged, fibrous appearance.



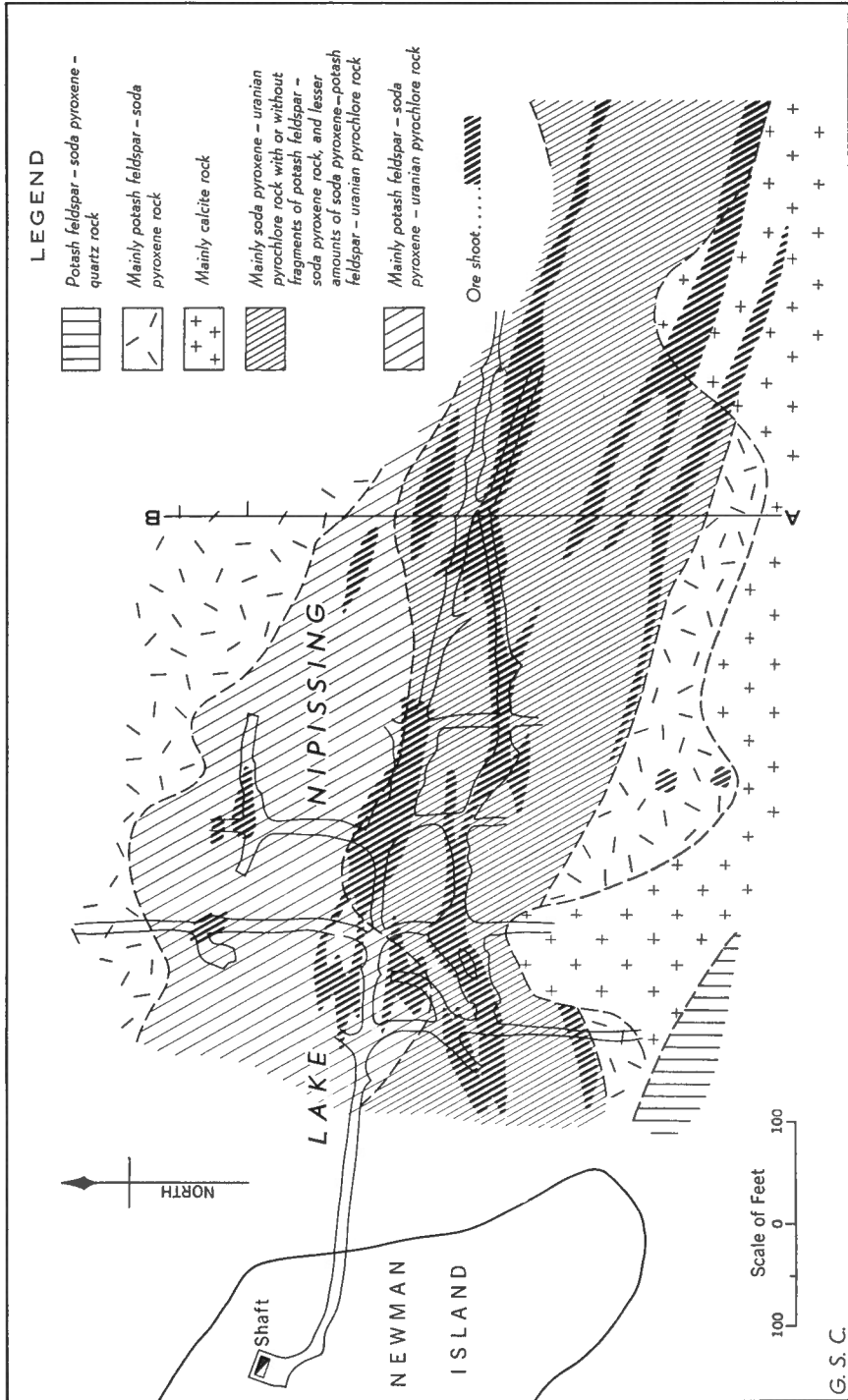


Figure 17. Generalized geological plan, 400-foot level, Newman deposit, Lake Nipissing, Ontario. (From plan by O. E. Owens, Beaucage Mines Limited, 1955.)

Matted aggregates of very fine-grained white mica, thomsonite, and analcime are seen in many of the thin sections, and some are four- or six-sided in outline suggesting that they probably represent altered nepheline. Very minor amounts of apatite, biotite, and fluorite are present in places. Monazite is a common accessory mineral. The red spots adjacent to the carbonate-potash feldspar veinlets are composed of aggregates of very fine-grained carbonate, hematite, and chlorite. Remnant zonal structure is apparent in some of these aggregates, and this suggests that the aggregates replaced uranian pyrochlore.

### DYKE ROCKS

Trap, feldspar porphyry, and lamprophyre dykes cut the rocks of the outer part of the complex and the Newman deposit. These dykes range from a few inches to a few feet in width. Some of them are sheared throughout, whereas others are sheared only at their contacts. Many contain hematite spots, but none of those examined by the writer contain uranian pyrochlore, and pyrite was found in only one. It can be seen underground that one of the trap dykes is cut by uranian pyrochlore-bearing rock: this is interpreted by the writer as a boudinage structure. A study of the orientation of the dykes has not been made.

Thin section study shows that most of the dykes consist chiefly of very fine-grained feldspar laths, carbonate, chlorite, and sericite. One thin section of a fresh-looking lamprophyre was found to consist of chlorite-calcite aggregates, serpentine aggregates probably after olivine, and phenocrysts of colourless to very pale brown, zoned pyroxene in a fine-grained groundmass of pale brown biotite, carbonate, pyroxene and magnetite.

Barlow (1908, pp. 113-115) was particularly interested in these dykes and described one as follows: "The rock doubtless belongs to the group which includes the alnoites, monchiquites and fourchites but it is now so decomposed that its exact position cannot be determined."

## DESCRIPTION OF DEPOSIT

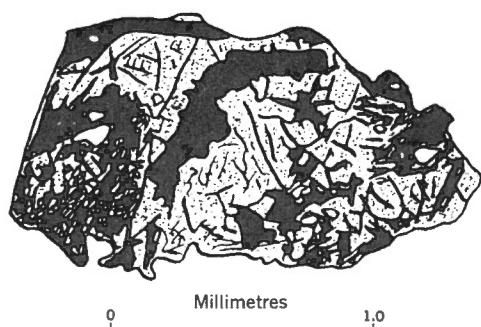
### GENERAL FEATURES

The Newman deposit is the largest and most important of five deposits of disseminated uranian pyrochlore that occur in the second concentric band of the complex (*see* Figure 14). It has been traced along strike for 1,100 feet and has a maximum width of about 400 feet over this distance. The deposit is open at the east end and at depth.

The deposit is mineralogically and structurally complex, and a very generalized description is presented in this report. Two main rock types that contain uranian pyrochlore are distinguished. One is potash feldspar-soda pyroxene rock that is characterized by reddened potash feldspar. The other is soda pyroxene rock that is composed mainly of soda pyroxene, biotite, calcite, and apatite, and that commonly contains fragments of potash feldspar-soda pyroxene rock, more or less replaced by biotite and, or, soda pyroxene. The contact between these two types of mineralized rock dips steeply outward from the centre of the Manitou Island complex



A. Camera-lucida drawing of uranian pyrochlore crystal showing zonal arrangement of light and dark varieties of uranian pyrochlore.



B. Camera-lucida drawing of uranian pyrochlore crystal occurring in a matrix of apatite. Note distribution of light and dark varieties of uranian pyrochlore, and the embayment of the crystal.



C. Camera-lucida drawing of aggregate composed of uranian pyrochlore (stipple pattern), very fine-grained crystals of a green chlorite-like mineral (white), and orange-red hematite (black).

G. S. C.

**Figure 18.** Camera-lucida drawings of uranian pyrochlore crystals illustrating the distribution of the light and dark varieties of uranian pyrochlore, and relations to apatite and alteration products. Newman deposit.

(see Figure 16). Post-mineralization faults and shear zones occur in the deposit, and, in general, there has been little or no relative movement along them. Several ore shoots have been outlined, and some of them cut across the contacts of the two types of pyrochlore-bearing rock (see Figures 16 and 17).

Diamond drilling indicates that the Newman deposit continues to the east, and that calcite-biotite-apatite-uranian pyrochlore rock becomes abundant in this direction.

#### DESCRIPTION OF URANIAN PYROCHLORE

Uranian pyrochlore occurs as disseminated, subhedral to euhedral crystals ranging from less than 0.008 mm. to 3.54 mm. in size, and as

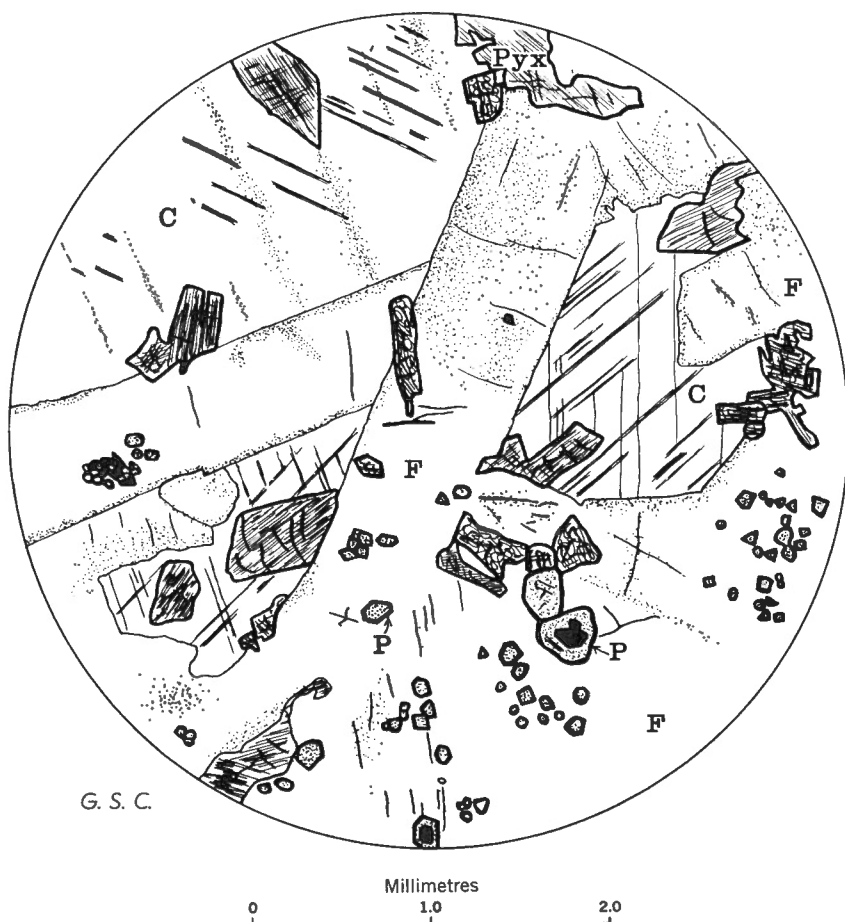
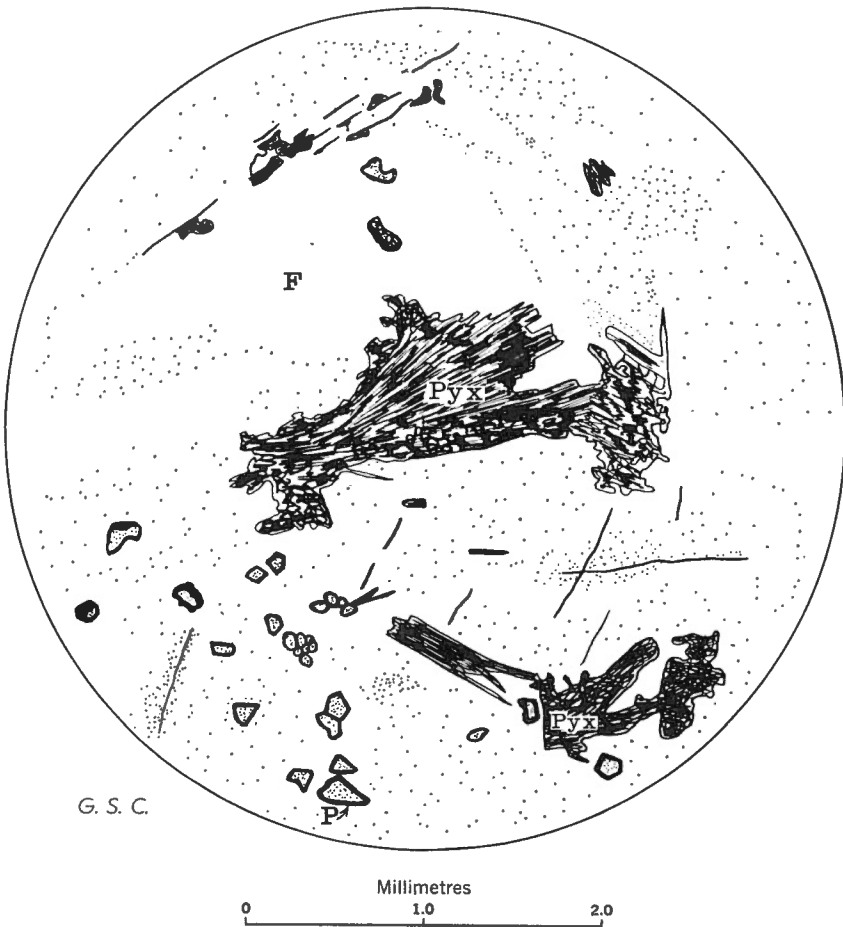


Figure 19. Camera-lucida drawing of potash feldspar-soda pyroxene-uranian pyrochlore rock, showing soda pyroxene (Pyx), potash feldspar (F), calcite (C), and uranian pyrochlore (P). Stippling in the potash feldspar represents hematite dust. Newman deposit.



**Figure 20.** Camera-lucida drawing of potash feldspar-soda pyroxene-uranian pyrochlore rock, showing soda pyroxene (Pyx), potash feldspar (F), and uranian pyrochlore (P). Stippling in the potash feldspar represents hematite dust. Note aggregate of radiating, slender, soda pyroxene crystals. Newman deposit.

aggregates of crystals (see Figures 19, 20, 21, 22, 23, 24 and 25). It is generally chocolate-brown and resinous to submetallic in lustre. Under the microscope it is found that the crystals are composed of light- and dark-coloured varieties, or entirely of the light-coloured variety. The light variety ranges from almost colourless to brown, whereas the dark variety is dark brown to opaque and submetallic in lustre. The two varieties produce similar X-ray powder patterns. In some crystals, there is a zonal arrangement of the two varieties (see Figures 18, 19, and 24), whereas in others the dark variety is apparently associated with fractures (see Figure 18). In one thin section, uranian pyrochlore crystals were found that are replaced in part by aggregates of a very fine-grained, green, chlorite-like

mineral: these aggregates are rimmed by orange-red hematite (see Figure 18). Uranian pyrochlore crystals in biotite have pleochroic haloes. A partial chemical analysis of uranian pyrochlore by the Mines Branch, Ottawa, gave the following composition: uranium oxide, 10.4 to 10.7 per cent; tantalum oxide, not detected; niobium oxide, 44.1 per cent.

## DESCRIPTION OF URANIAN PYROCHLORE-BEARING ROCKS

### *Potash Feldspar-Soda Pyroxene-Uranian Pyrochlore Rock*

Where the potash feldspar-soda pyroxene rock is uranian pyrochlore-bearing there is a noticeable reddening of the potash feldspar and the development of a more massive structure. In addition to potash feldspar and soda pyroxene, the following minerals can be seen in hand specimen: soda hornblende, calcite, uranian pyrochlore, pyrite, and fluorite. The rock is generally medium to coarse grained. Potash feldspar comprises over 50 per cent of the rock and occurs as interlocking grains and laths that range up to  $\frac{1}{2}$  inch in length. Green soda pyroxene occurs as disseminated prismatic grains, aggregates of short prismatic grains, and aggregates and rosettes of slender prismatic grains. Calcite occurs as coarse-grained aggregates, in veinlets, and as very fine, disseminated grains. Potash feldspar laths and soda pyroxene prisms commonly project into the calcite patches. Ragged aggregates and veinlets of pyrite, which generally constitute less than 1 per cent of the rock, are found in places and are usually associated with aggregates of soda pyroxene. Uranian pyrochlore occurs as single crystals and aggregates of crystals. Purple fluorite occurs as small, very fine-grained aggregates that are usually in or near calcite.

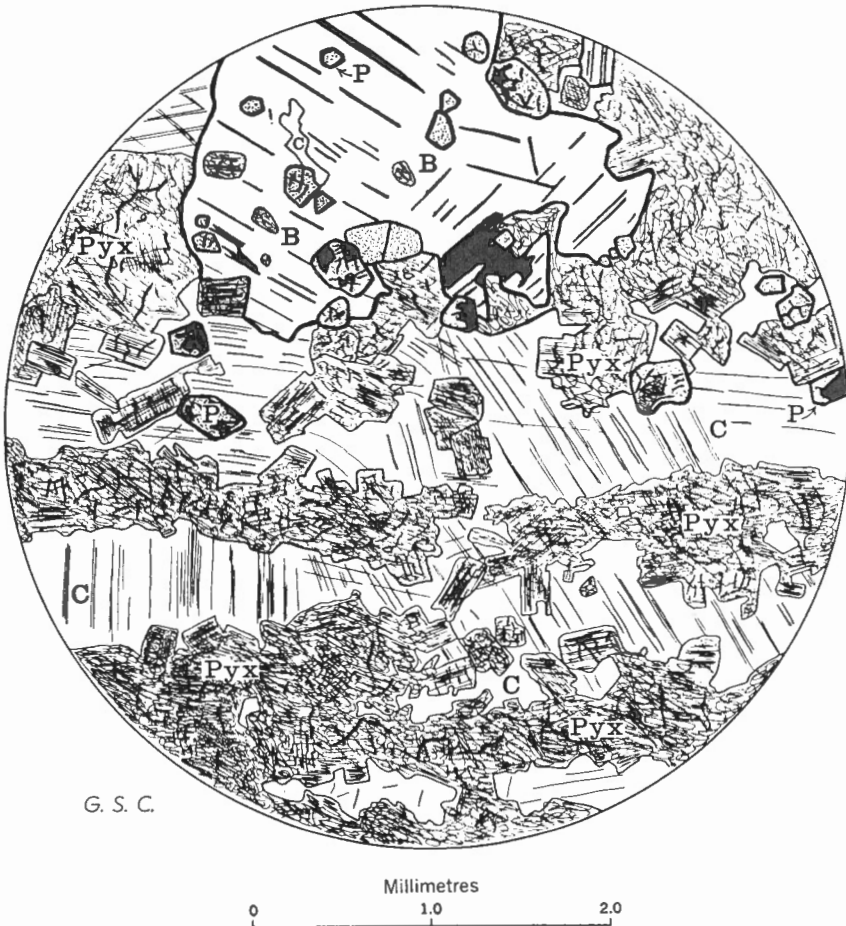
Thin section examination shows that the potash feldspar is cloudy due to opaque grey dust and orange-red dust. The orange-red dust occurs in irregular patches, along fractures, and along grain boundaries (see Figure 19), and is probably hematite. In some thin sections the potash feldspar is perthitic and the plagioclase of the perthite is relatively free from dust. A few very fine- to fine-grained plagioclase grains were seen in some thin sections, and these are also almost free from dust. Short, prismatic, soda pyroxene grains are shown in Figure 19, and an aggregate of slender, radiating, soda pyroxene grains is shown in Figure 10. In places, the soda pyroxene is cloudy or is partly replaced by aggregates of very fine-grained chlorite and biotite. Apatite and fluorite occur in some of the calcite veinlets and patches. Most of the uranian pyrochlore crystals occur in potash feldspar, and vary from less than 0.025 to 0.65 mm. in size. In general, the pyrochlore crystals are pale brown to grey in thin section, but a few zoned crystals that also contain dark brown to opaque varieties occur in places. A few grains of monazite and apatite occur in some of the thin sections.

### *Soda Pyroxene-Uranian Pyrochlore Rock*

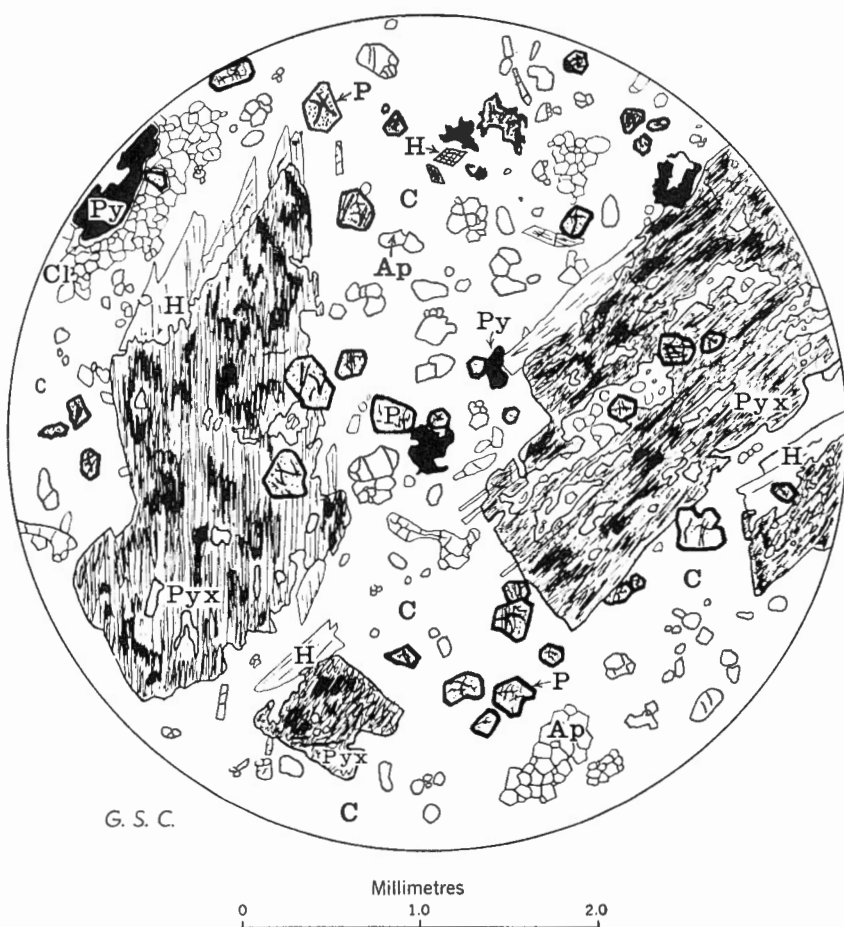
This rock is generally medium grained, and massive, and is composed chiefly of variable amounts of soda pyroxene, calcite, apatite, biotite, and soda hornblende. Uranian pyrochlore, pyrite, and magnetite are usually

present. Minor amounts of chlorite, fluorite, and monazite occur in places. Reddened potash feldspar occurs in a few places in amounts up to 10 per cent.

Green soda pyroxene occurs as prismatic grains in a groundmass of calcite or apatite or both. Biotite occurs as shred-like grains and medium- to coarse-grained porphyroblasts, and comprises up to about 50 per cent of the rock in places. The pyrite is disseminated and forms up to 10 per cent of the rock. Magnetite is generally present in minor amounts, but in a few places it forms up to 50 per cent or more of the rock. The fluorite is purple and occurs in places as very fine-grained aggregates. Uranian pyrochlore



**Figure 21.** Camera-lucida drawing of soda pyroxene-uranian pyrochlore rock, showing soda pyroxene (Pyx), calcite (C), uranian pyrochlore (P), and biotite (B). Note association of uranian pyrochlore crystals with porphyroblast of biotite. Newman deposit.



**Figure 22.** Camera-lucida drawing of soda pyroxene-uranian pyrochlore rock, showing soda pyroxene (Pyx), calcite (C), uranian pyrochlore (P), apatite (Ap), soda hornblende (H), pyrite (Py), and chlorite (Cl). Newman deposit.

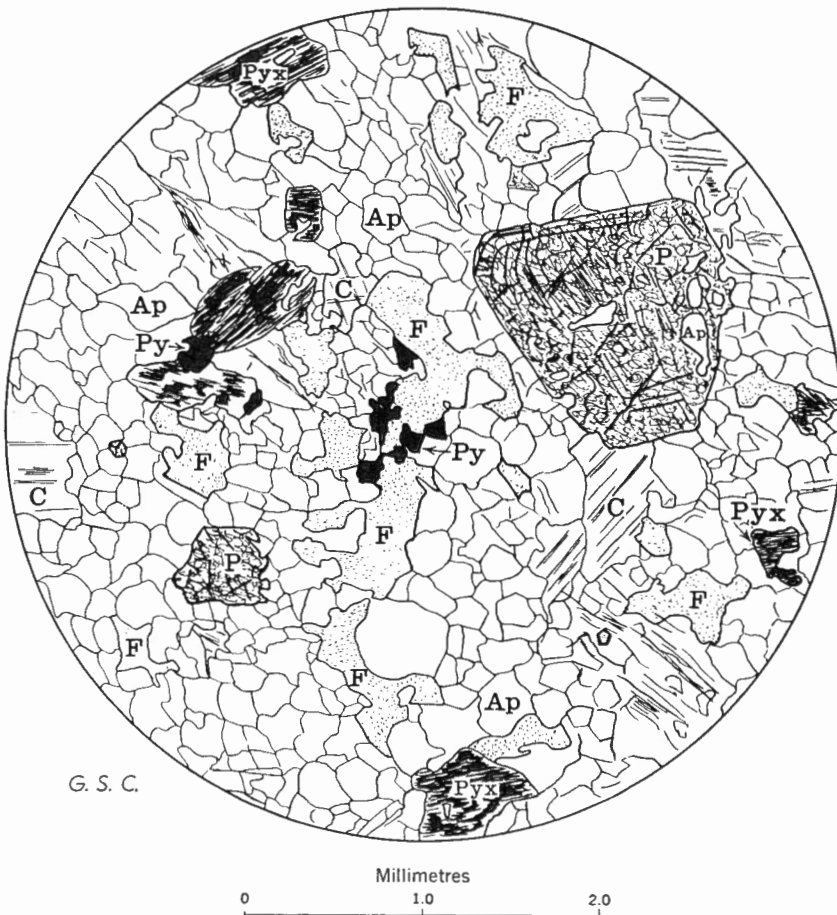
occurs as chocolate-brown, resinous to submetallic crystals ranging up to 3.5 mm. in size, and as clusters of crystals.

In thin section it can be seen that much of the soda pyroxene is replaced by soda hornblende, biotite, chlorite, and an aggregate of somewhat fibrous, dusty, pale green soda pyroxene and very fine-grained calcite. The biotite porphyroblasts have formed mainly at the expense of soda pyroxene. In places, the porphyroblasts are partly or entirely replaced by fine-grained chlorite. The reddened potash feldspar occurs as ragged, unreplaced remnants. Some of the pyrochlore crystals consist of the light-coloured variety, and some are composed of both types. Zoned crystals are common. Several of the microscopic features of this rock are shown in Figures 21, 22, and 23.



*Soda Pyroxene-Potash Feldspar-Uranian Pyrochlore Rock*

Soda pyroxene, feldspar, calcite, biotite, pyrite, and uranian pyrochlore can be identified in hand specimens of this rock, which is dark in colour, generally equigranular, and medium grained. The soda pyroxene grains are dark green, range up to 8 mm. in length, and commonly comprise 60 to 90 per cent of the rock. Reddened feldspar occurs as aggregates and is present in amounts up to about 30 per cent. Calcite occurs in veinlets and anhedral grains interstitial to soda pyroxene and potash feldspar, and generally comprises less than 10 per cent of the rock. A few grains of biotite occur in places. Disseminated, fine-grained pyrite generally comprises less than 5 per cent of the rock. Chocolate-brown uranian pyrochlore is visible in places as disseminated crystals up to about 2.5 mm. in size.



**Figure 23.** Camera-lucida drawing of apatite-rich variety of soda pyroxene-uranian pyrochlore rock, showing soda pyroxene (Pyx), apatite (Ap), calcite (C), potash feldspar (F), uranian pyrochlore (P), and pyrite (Py). Newman deposit.

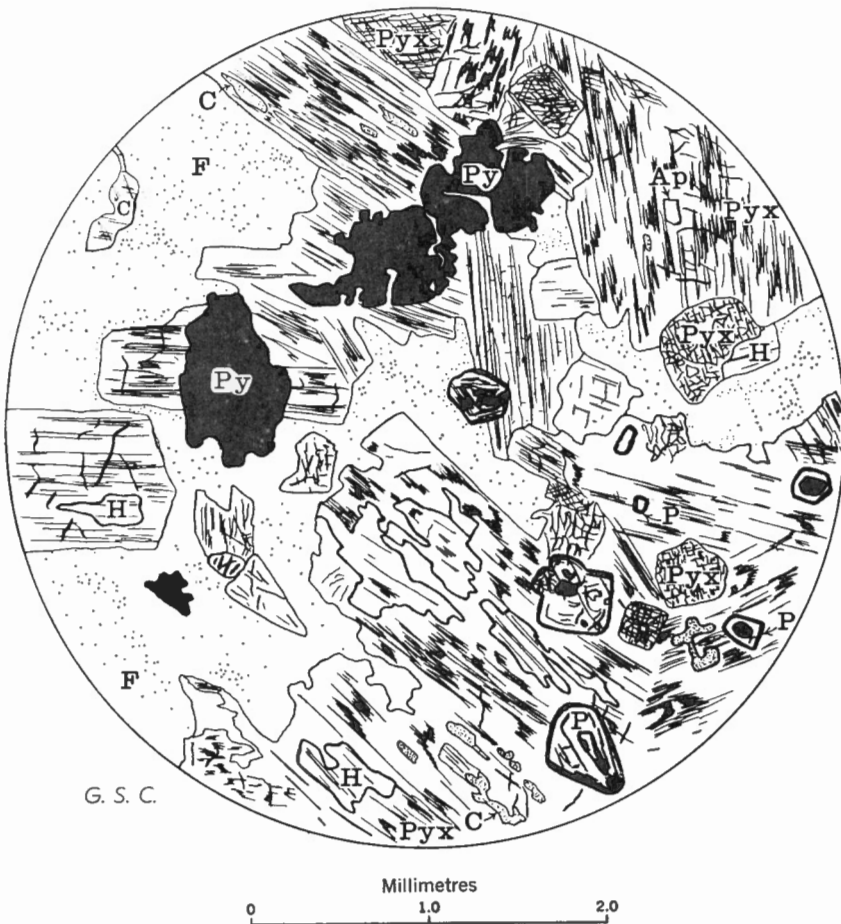


**Figure 24.** Camera-lucida drawing of soda pyroxene-potash feldspar-uranian pyrochlore rock, showing soda pyroxene (Pyx), potash feldspar (F), calcite (C), uranian pyrochlore (P), and dark purple fluorite (Fl). Note light and dark varieties of uranian pyrochlore. Stippling represents hematite dust. Newman deposit.

Under the microscope, several additional features of this rock can be seen, and some of these are shown in Figures 24 and 25. Some of the soda pyroxene is strongly pleochroic in shades of yellow and green, and some is somewhat fibrous, dusty, slightly pleochroic in shades of pale yellow and pale green, and partly replaced by very fine-grained calcite and, or, soda hornblende. The potash feldspar generally occurs as laths with undulatory extinction and contains grey dust and orange-red hematite dust. Perthite is present in one thin section, and a few very fine-grained plagioclase aggregates were seen in a few thin sections. Aggregates of very fine-grained white mica occur in a few thin sections. One of these aggregates has a small core of analcime, indicating that the aggregates

probably formed at the expense of nepheline. Fine- to medium-grained calcite occurs interstitial to soda pyroxene and potash feldspar, and very fine-grained calcite partly replaces some of the soda pyroxene and occurs in minute veinlets. Biotite is present in some of the thin sections as small, shred-like grains and ragged, poikiloblastic grains up to 0.50 mm. in size. Uranian pyrochlore crystals range from less than 0.008 to 1.75 mm. in size, and occur singly or as clusters in soda pyroxene, biotite, potash feldspar and calcite. Minor constituents of the rock include apatite, black metallic to submetallic minerals (mostly hematite and magnetite), fluorite, and monazite.

This rock apparently occurs chiefly at the west end of the deposit.



**Figure 25.** Camera-lucida drawing of soda pyroxene-potash feldspar-uranian pyrochlore rock, showing soda pyroxene (Pyx), potash feldspar (F), uranian pyrochlore (P), soda hornblende (H), calcite (C), pyrite (Py), and apatite (Ap). Stippling in the potash feldspar represents hematite dust. Newman deposit.

## GRADE AND TONNAGE

Beaucage Mines Limited announced in May 1956 that reserves below the 300-foot level are as follows: 2,695,000 tons averaging 0.69 per cent niobium oxide and 0.042 per cent uranium oxide; 1,824,000 tons averaging 0.88 per cent niobium oxide and 0.05 per cent uranium oxide; and 617,000 tons averaging 1.06 per cent niobium oxide and 0.075 per cent uranium oxide. Reserves are stated as below the 300-foot level because it will be necessary to leave rock between the underground workings and the bottom of the lake. The thickness of rock that must be left is not certain as yet.

## ORIGIN

The Newman deposit is a disseminated replacement deposit in a fenite aureole that forms the outer part of an alkaline rock complex.

It is the belief of the writer that the deposit was formed by the action of late pneumatolytic or hydrothermal solutions from an alkaline magma. The magma is represented by the trap, feldspar porphyry and lamprophyre dykes, and by the soda pyroxene syenite and feldspathic rocks of the inner part of the complex. In addition to uranian pyrochlore, the late solutions caused the formation of apatite, magnetite, iron sulphides, biotite, hematite, soda hornblende, and additional soda pyroxene.

The structural control was probably a zone of deformation where intense fracturing was followed by recrystallization and metasomatism. In places, calcite rock flowed into fractures in the more competent potash feldspar-soda pyroxene rock, and a mixed rock that was very favourable for recrystallization and metasomatism was the result. The process is illustrated in the first crosscut south of the drift on the 400-foot level. At the end of the crosscut, potash feldspar-soda pyroxene rock is interbanded with finely laminated calcite rock. Towards the drift, this banded assemblage grades into a rock that is composed of fragments of potash feldspar-soda pyroxene rock in a matrix of finely laminated calcite rock, coarse-grained calcite rock, and soda pyroxene-biotite-calcite rock. The fragments of potash feldspar-soda pyroxene rock commonly have slickensided surfaces, and diverse orientations as indicated by the foliation. Faults with minor displacements are common. Near the drift, the rock is composed of fragments of potash feldspar-soda pyroxene rock in a matrix of soda pyroxene-biotite-calcite-uranian pyrochlore rock. Many of the fragments are rimmed or more or less replaced by biotite.

**Basin Deposit, Bancroft Region, Ontario**

*References:* Giblin, 1955; Satterly and Hewitt, 1955.

The Basin betafite deposit is on the Basin property of Silver Crater Mines Limited, Toronto. The property is lot 31, concession XV, Faraday township, Hastings county, and is about 8 miles west of the town of Bancroft. It is accessible by road.

In 1925, and from 1947 to 1949, the property was worked for black mica. Silver Crater Mines Limited acquired the property and commenced

exploration in 1953. Work done consists of stripping, trenching, diamond drilling, and underground exploration. By September 1955, thirty-four diamond drill-holes, totalling 5,576 feet, and 530 feet of drifting and raising had been completed.

The deposit has been described by Satterly and Hewitt (1955, pp. 53-55) and by Giblin (1955), and the information presented here has been taken from these reports. The writer visited the deposit in July 1955.

The Bancroft region is in the Grenville geological sub-province of the Canadian Shield, and the geology is well known from the studies of Adams and Barlow (1910). Two main types of Precambrian rocks are present: meta-sedimentary rocks of the Grenville series, consisting of marbles, quartzites, amphibolites, and paragneisses; and younger plutonic rocks consisting of gabbros, diorites, ultrabasic rocks, nepheline syenites, syenites, and granites. Uranium deposits of economic interest occur in the Bancroft region, and these have been described by Satterly and Hewitt (1955).

The Basin deposit is a calcite body that occurs in an area of amphibolites (*see* Figure 26). Syenites and nepheline syenites surround the amphibolite area, and a large area of marble is located south of the property.

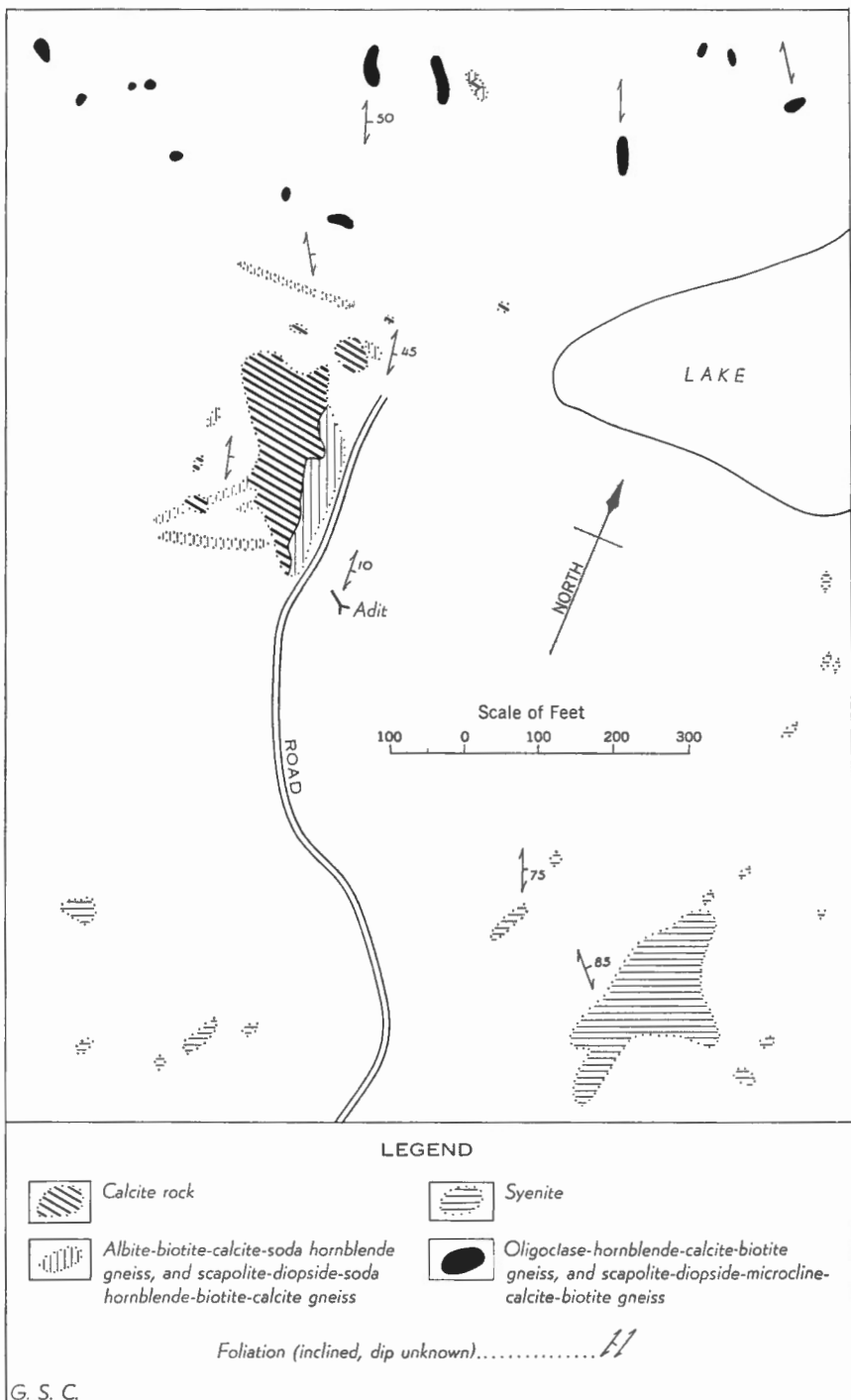
The calcite body is about 400 feet long, 150 feet wide, and 90 feet in maximum thickness. It is composed of coarse-grained, cream-coloured calcite and the following accessory minerals: black mica, soda hornblende, apatite, betafite, zircon, albite, fluorite, molybdenite, and pyrrhotite. The accessory minerals are commonly concentrated in parallel streaks or in patches. A noteworthy feature of the deposit is the size of some of the crystals of accessory minerals: black mica crystals range up to 2 feet in size, soda hornblende up to 3 feet in length, apatite up to 2 feet in length, and betafite up to 3 inches in size.

Betafite occurs as cubo-octahedral crystals and clusters of crystals, and is generally associated with streaks and patches of accessory minerals. Two varieties of betafite are distinguished: a black variety that has a waxy lustre, and a grey variety that has a metallic lustre. The black variety contains about 2 per cent yttrium, whereas the grey variety contains almost no yttrium. Analyses of betafite crystals are given in Table IV. Calcite grains within an inch of betafite crystals are commonly pink to red, and apatite crystals near betafite are commonly reddish brown.

The calcite body is surrounded by an envelope up to 25 feet thick that consists of albite-biotite-calcite-soda hornblende gneiss, and scapolite-diopside-soda hornblende-biotite-calcite gneiss. Interfingering occurs at the contacts of the calcite body and the envelope. Inclusions of the envelope rocks up to 30 feet in length and 2 feet in thickness occur in the calcite body, and small patches and lenses of calcite rock occur in the envelope.

The envelope grades into country rock that consists of oligoclase-hornblende-calcite-biotite gneiss, and scapolite-diopside-microcline-calcite-biotite gneiss.

A striking structural feature is the parallelism of the streaks of accessory minerals, the inclusions of envelope rocks, and the foliation in the country rock gneisses.



**Figure 26.** Geological map of part of the Basin property, Silver Crater Mines Limited, Bancroft region, Ontario, showing the Basin calcite body and vicinity. (From map by P. E. Giblin, 1955.)

Giblin (1955, pp. 59-72) considers that the calcite body represents a marble lens in the gneisses that was attached by pegmatitic solutions from the syenite. The syenite consists of potash feldspar and lesser amounts of biotite, calcite, magnetite, and altered nepheline. Patches of calcite rock with black mica, amphibole, apatite, fluorite, zircon, pyrrhotite, plagioclase, and magnetite occur in the syenite. Giblin notes the association of niobium and zirconium with nepheline syenites, and the concentration of zirconium in the pegmatitic phase rather than the hydrothermal phase. The envelope about the calcite body is believed to have developed by soda metasomatism that is genetically related to the mineralization of the calcite body.

TABLE IV  
*Partial Analyses of Betafite Crystals,  
Basin Property, Bancroft Region, Ontario*

	Per cent				
	A	B	C	D	E
Nb <sub>2</sub> O <sub>5</sub> .....	41.5	40.0	42.0	24.0	18.4
U <sub>3</sub> O <sub>8</sub> .....	21.4	21.2	21.6	20.9	18.2
TiO <sub>2</sub> .....	20.1	20.2	20.0	11.1	9.7
CaO.....	9.9	9.8	10.0	—	—
Ta <sub>2</sub> O <sub>5</sub> .....	1.4	1.4	1.4	0.5	1.6

References: (A) Satterly and Hewitt (1955).  
(B, C, D, E) Giblin (1955).

Analysts: (A, B, C) Provincial Assay Office, Ontario Dept. Mines.  
(D, E) Toronto Testing Laboratory.

### Deposits of the Oka Region, Quebec

*Reference:* Rowe, 1955.

Deposits that are potential large-tonnage sources of niobium occur in the Oka complex of carbonate and alkaline rocks, about 20 miles west of Montreal in the Oka region, Two Mountains county, Quebec. The region is readily accessible by roads and is famous for apples and dairy products, particularly Oka cheese which is manufactured at La Trappe Monastery.

Considerable work has been done. Surface exploration programs have been conducted on eight mining properties within the Oka complex. More than 150 diamond drill-holes have been put down on the complex, and approximately 100,000 feet of diamond drilling had been completed by the end of October 1955. Additional exploration work is planned, and beneficiation and metallurgical tests are being conducted.

The occurrence of unusual rocks in the Oka Region has been known since 1909. Intrusive rocks and breccias were described first by Harvie (1909, pp. 256-258) who believed that these rocks belong to the Monteregian petrographical province of alkaline rocks (Adams, 1903). Howard (1922, pp. 69-82) also placed these rocks in the Monteregian province and divided

the intrusive rocks into biotite, peridotite and lamprophyric rocks. An unusual melilite-bearing rock on the farm of Mr. Herve Hussereau was described by Stansfield (1923, pp. 440-444), and given the name of okaite. Grimes-Graeme (1935, pp. 64-80) described the breccias of the Oka region in detail and concluded that they are diatremes. All of these men described the older carbonate rocks of the Oka region as Grenville crystalline limestone. The writer recognized that the unusual intrusive rocks and breccias and the carbonate rocks are part of a complex.

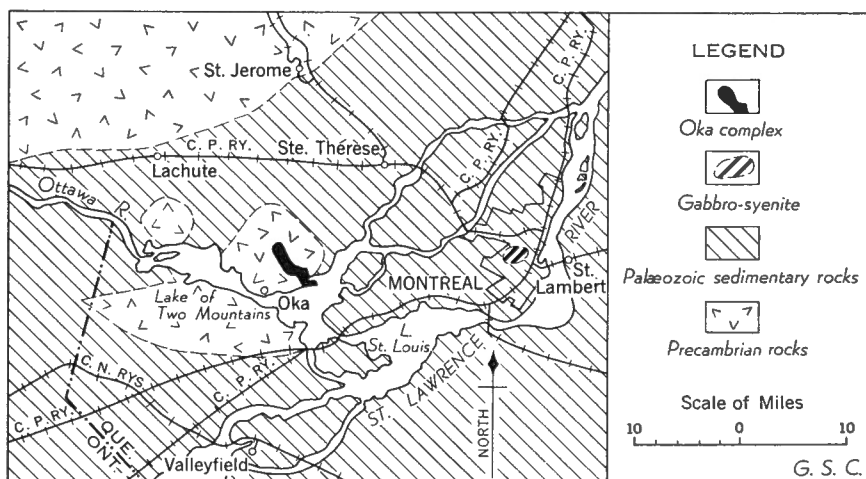


Figure 27. Geological sketch-map of the Oka region and vicinity, Quebec.

Radioactive rocks in the Oka region were apparently first discovered by Mr. F. Manny of Montreal. Mr. Manny sent a specimen of radioactive rock to the Geological Survey of Canada in October 1952, and the radioactivity was found to be due mainly to thorium. A second specimen was sent by Mr. Manny to the Geological Survey in December 1952, and a member of the pyrochlore-microlite series was identified. In June 1953, the Manny property of three mining claims was examined by Mr. Stephen B. Bond of the Molybdenum Corporation of America, and on his recommendation the property was purchased by the company. Meanwhile, Montrose Securities, a Montreal syndicate, began staking ground around the Manny property under the direction of Messrs. J. J. Gourd and P. E. Riverin who realized the potential importance of the Oka region from a mining standpoint. The widespread radioactivity and the general association of radioactivity and niobium minerals were observed by Mr. Bond, and the Molybdenum Corporation of America acquired additional property by purchase and option from Montrose Securities. Other mining property that was originally staked by the syndicate is held by the syndicate and three mining companies. A staking rush took place in the early months of 1954, and several other companies acquired property in the Oka region.

Field studies were conducted by the writer in June and July 1954, and in parts of March, June, October, and November 1955. Three hundred and forty-eight specimens were collected and three hundred and four thin sections were studied.



## GENERAL GEOLOGY

The niobium deposits are in the Oka complex of carbonate and alkaline rocks that occur in the central part of the Oka Hills, a circular group of hills that rise abruptly from the plains of the St. Lawrence Lowlands (*see* Figure 27). Except for the Oka complex, which is probably post-Precambrian in age, the Oka Hills are composed of Precambrian rocks (Grimes-Graeme, 1935 and Osborne, 1938), mainly quartz-feldspar gneisses and granulites, anorthosite and gabbro with lesser amounts of quartzite and garnet gneiss. Structurally, the Oka Hills are regarded as part of the Beauharnois Axis, a ridge of Precambrian rocks extending from the Canadian Shield southward to the Adirondack Mountains. The axis is overlain by Palæozoic sedimentary rocks except for the Oka Hills and two other areas of Precambrian rocks to the west and south.

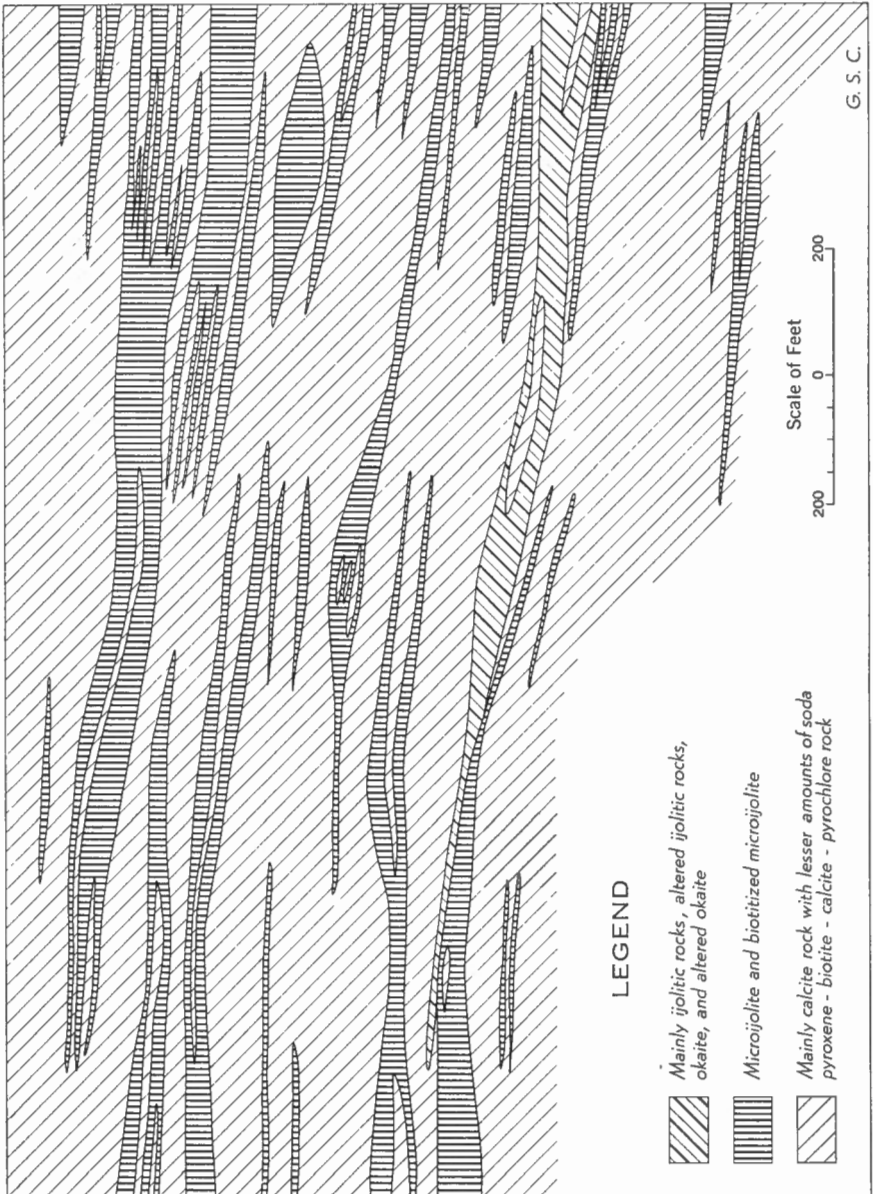
### OKA COMPLEX

#### GENERAL FEATURES

The Oka complex of carbonate and alkaline rocks is oval-shaped, about 4 miles in length and has a maximum width of about  $1\frac{1}{2}$  miles (*see* Figure 28). It clearly cuts across the structure of the enclosing rocks. One diamond drill-hole apparently penetrated the west contact of the complex and the apparent contact dips steeply inward at that place. Disseminated magnetite occurs throughout the complex and causes a sharp and pronounced magnetic anomaly (*see* Figure 29). The complex is markedly radioactive in places. Bodies of explosion-vent breccia and lamprophyre dykes are satellites of the complex, and the country rocks are fenitized in places at the contact of the complex.

The internal structure of the complex is incompletely known. Outcrops are few, and, in general, diamond drilling has failed to reveal structure because of the lack of suitable markers. In many places it is apparent that the complex is composed mainly of an intimate mixture of calcite rock, calc-silicate rocks, and alkaline silicate rocks. Elsewhere, it consists chiefly of parallel lenses, and irregular-shaped bodies of microjoliote in calcite rock (*see* Figure 30). There is a suggestion that lenticles, streaks, and bands of accessory minerals in the calcite rock tend to parallel the contacts of the complex, but more data are necessary to substantiate this. Diamond drilling together with careful assaying have outlined several zones that contain niobium minerals. Several faults and shear zones have been encountered in the diamond drill-core, but they apparently have no bearing on the occurrence of niobium minerals. Breccias of various types are apparently common: in many places, calcite rock has flowed into fractures in brittle silicate rocks, and microjoliote near the contacts of the complex commonly contains fragments of fenite.

The complex is probably post-Precambrian in age. One of the satellite breccia bodies is abnormally radioactive and contains fragments of buff-coloured limestone of post-Precambrian type. Evidence that the complex belongs to the Montereian petrographical province is discussed elsewhere.



**Figure 30.** Composite plan showing general geology of the Bond zone, Molybdenum Corporation property, Oka region, Quebec. (From diamond drill logs compiled by Gilles Joncas, Molybdenum Corporation of America, 1955.)

## PETROGRAPHY

The Oka complex is composed of a great diversity of rocks, all of which are unusual in their composition, and it is beyond the scope of this report to describe all of the petrographical variations. Three main groups of rocks comprise the complex: (1) carbonate rocks, chiefly calcite rock; (2) calc-silicate rocks; and (3) alkaline silicate rocks. The calc-silicate rocks include okaite, a melilite rock, and monticellite rock. The silicate rocks consist mainly of rocks of the ijolite series, rocks of the microijolite series, rocks of the jacupirangite series, and lamprophyric rocks.

*Calcite Rock*

Calcite rock is composed essentially of medium- to coarse-grained white to grey calcite. Some of the calcite rock consists entirely of calcite, and some contains the following accessory minerals: apatite, biotite, magnetite, olivine, pyroxene, monticellite, melilite, pyrite, pyrrhotite, black garnet, pyrochlore, niobian perovskite, and niocalite. Apatite, magnetite, and biotite are probably the most widespread. The accessory minerals are generally concentrated in lenticles, streaks, inconsistent bands, and small patches.

Varieties of calcite rock can be distinguished on the basis of accessory mineral content, and these varieties include: calcite-monticellite rock, calcite-olivine rock, calcite-olivine-pyroxene rock, calcite-pyroxene rock, calcite-melilite rock, and calcite-black garnet rock. Monticellite and pyroxene rarely occur together, and, in such cases, the monticellite is generally altered. Pyroxene, particularly soda pyroxene, is characteristic of calcite rock near bodies of microijolitic and ijolitic rocks.

Calcite rock is widespread in its occurrence and is one of the chief rocks of the Oka complex. It outcrops at several places and has been cut by most of the diamond drill-holes.

*Other Carbonate Rocks*

Dolomite rock occurs in the northern part of the complex. It does not outcrop, and has been found in diamond drill-core from the Advance Red Lake property. Fine- to medium-grained, light grey to bluish grey dolomite is the essential constituent of this rock. In places, medium- to coarse-grained white calcite is present. Accessory minerals occur in places, especially if calcite is present, and include: apatite, magnetite, pyrite, pyroxene, biotite, and pyrochlore.

Carbonate veins occur in places, but they have not been studied in detail because they do not contain niobium minerals. Assays for niobium oxide give *nil* to a trace. Some of the veins are composed of fine- to coarse-grained calcite or dolomite, others are composed of medium- to coarse-grained dolomite, pyrite, and very fine-grained, chalky aggregates of hematite, barite, strontianite, and ancylite.

Some of the carbonate rocks of the complex have relict textures, which suggest that they have formed by the replacement of other rocks. The carbonate replacement rocks are apparently quantitatively and economically unimportant.

### *Soda Pyroxene-Biotite-Calcite-Pyroxchlore Rock*

Soda pyroxene-biotite-calcite-pyroxchlore rock is probably the most important rock of economic interest in the Oka complex. It is generally medium grained and massive, and is composed chiefly of soda pyroxene, biotite, and calcite. Pyroxchlore is almost invariably present in amounts up to 20 per cent and more. Other minerals that are commonly present in variable amounts include: apatite, magnetite, pyrite, and pyrrhotite. Altered nepheline was observed in a few places. In places, the rock is greatly enriched in apatite.

This rock occurs as lenses in calcite rock, particularly near bodies of microijolite and biotitized microijolite, in places at the contacts of calcite rock and microijolite and biotitized microijolite, and between bodies of microijolite and biotitized microijolite.

### *Apatite Rock*

Apatite rock is massive and is composed essentially of sugary apatite. Magnetite, biotite, and calcite are commonly present, and niobian perovskite occurs in places. Many of the specimens of this rock contain incompletely replaced grains of monticellite, olivine, and pyroxene.

This rock occurs as lenses and bands in calcite rock.

Apatite-rich varieties of some of the other rock types of the complex are common.

### *Okaite*

Okaite and nepheline okaite were described first by Stansfield (1923). He defined okaite as consisting essentially of melilite, hauyne, and biotite, and nepheline okaite as consisting essentially of the same minerals plus nepheline.

The writer uses the term "okaite" in a somewhat different manner. He was unable to find hauyne in any of the specimens collected from the original locality. Thus, okaite is re-defined as a generally massive, coarse-grained rock consisting essentially of melilite with nepheline, biotite, and calcite as varietal minerals.

Okaite is usually medium bluish grey with a glassy to greasy lustre. Calcite-rich varieties are lighter in colour. Fine- to medium-grained varieties were observed in a few places, and trachytic texture was noted in one dyke. Other minerals that occur in okaite include: magnetite, pyrite, apatite, niobian perovskite, black garnet, and pyroxene. Inclusions up to about 1 foot in size and consisting of coarse-grained white calcite, magnetite, and aggregates of radiating apatite needles were observed in some of the outcrops.

All gradations from unaltered to completely altered okaite have been found. Under the microscope, it can be seen that incipiently altered melilite contains very fine-grained vesuvianite that occurs as sheaf-like aggregates and as fibres in veinlets, and at the contacts of melilite and nepheline grains. A light brown, micaceous mineral occurs in many of the veinlets and patches with vesuvianite. Further alteration of melilite

is marked by the occurrence of very fine- to fine-grained aggregates of vesuvianite, augite, and carbonate that are pale greenish yellow in hand specimen. In advanced stages of alteration, the melilite is completely replaced by the vesuvianite-augite-carbonate aggregates. Incipient alteration of nepheline is marked by the appearance of very fine-grained natrolite, thomsonite, carbonate, and cancrinite. Further alteration results in the replacement of nepheline by aggregates of these minerals. In general, the niobian perovskite content increases with increasing alteration.

Several features illustrate the replacement of calcite by melilite: (1) calcite inclusions in melilite are embayed, (2) calcite grains in contact with melilite are usually embayed, and (3) calcite inclusions in adjacent melilite grains commonly have identical orientations.

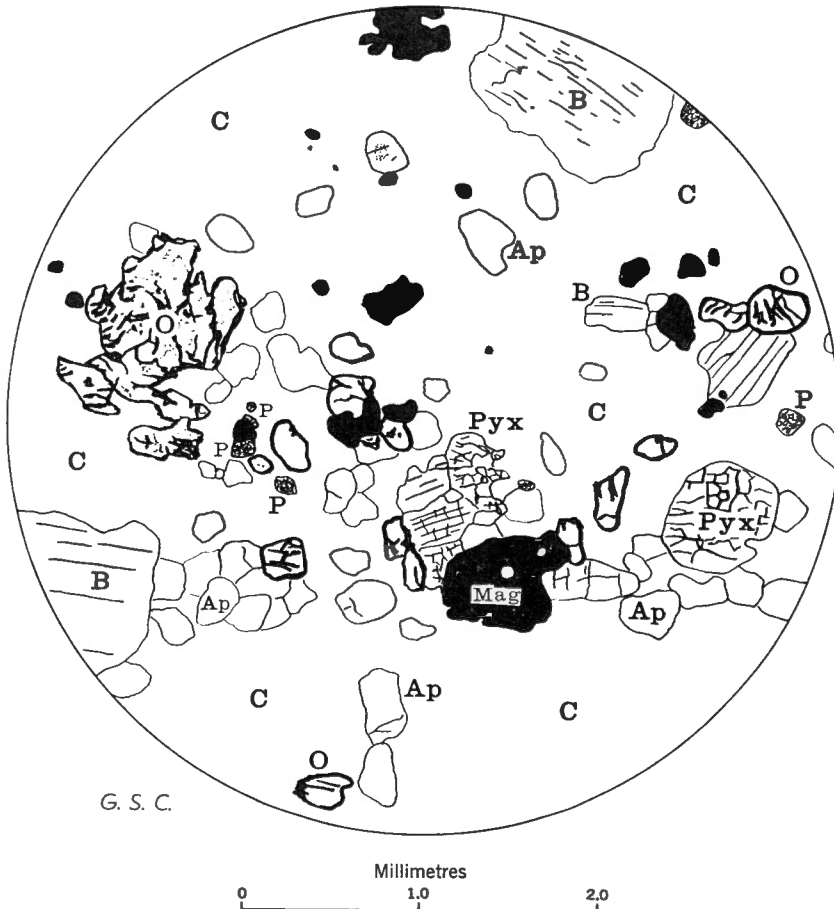


Figure 31. Camera-lucida drawing of calcite-olivine-pyroxene rock, showing olivine (O), pyroxene (Pyx), biotite (B), apatite (Ap), magnetite (Mag), and pyrochlore (P), in a matrix of calcite (C). Oka region, Quebec.

Okaite is found in outcrops and diamond drill-core, and occurs as masses, tabular bodies parallel to the streaks and bands in the carbonate rocks, and less commonly as dykes. It grades into calcite rock, and rocks of the jacupirangite series, and is commonly intimately mixed with altered ijolitic rocks, particularly with the variety that contains brown nepheline.

### *Monticellite Rock*

Monticellite rock is grey and is composed essentially of fine- to coarse-grained monticellite. Medium- to coarse-grained calcite is commonly present. Apatite, magnetite, biotite, and niobian perovskite occur in places.

In thin section it can be seen that the monticellite occurs as irregular grains and less commonly as crystals and broken crystals. Calcite grains are commonly embayed by monticellite, and calcite inclusions in monticellite are embayed. Inclusions of calcite in monticellite grains commonly have identical orientations. These features indicate that the monticellite has formed, in part at least, by the replacement of calcite.

The rock occurs as bands in calcite rock.

### *Nepheline Syenite*

Two short sections of nepheline syenite occur in diamond drill-core from the Bond zone, Molybdenum Corporation property. One section is in calcite rock, the other is in altered ijolitic rocks. The rock is massive and consists of white to grey grains and laths up to a quarter inch in length of perthite and plagioclase, fine- to medium-grained nepheline crystals that are more or less altered to pink analcime, and fine-grained subhedral prismatic crystals of soda pyroxene. Under the microscope, the soda pyroxene is seen to be markedly pleochroic and to have almost parallel extinction, suggesting that it is close to acmite in composition.

### *Ijolite Series*

The ijolitic rocks of the Oka complex are generally medium to coarse grained, equigranular, massive, light to dark coloured, and composed chiefly of variable amounts of nepheline, soda pyroxene, black garnet, biotite, and calcite. Magnetite and apatite occur in places. Varieties include: urtite, black garnet urtite, ijolite, black garnet ijolite, calcite ijolite, biotite ijolite, calcite-black garnet ijolite, and melteigite. The calcite is generally medium to coarse grained and identical in appearance to that of the calcite rock. Nepheline against calcite or in calcite is commonly euhedral. Many of the soda pyroxene grains contain rounded inclusions of nepheline and calcite.

Alteration is common and is marked in hand specimen chiefly by the following: (1) the occurrence of pink to red, blue-grey, and cream-coloured, aphanitic aggregates in place of nepheline, (2) an increase in the magnetite and apatite content, and (3) the occurrence in places of niobian perovskite. Pyroxene generally resists alteration, but black garnet becomes ragged in appearance and less abundant.

Under the microscope, it can be seen that the aggregates that replace nepheline consist of one or more of natrolite, thomsonite, white mica, analcime, carbonate, augite and vesuvianite. The pink to red aggregates are rich in natrolite or thomsonite or both, the blue-grey aggregates are rich in natrolite or thomsonite or both, and the cream-coloured aggregates contain vesuvianite and augite in addition to one or more of the other alteration products.

A very distinctive altered rock is tentatively included in the ijolite series. It is massive and composed chiefly of ragged, brown nepheline grains up to half an inch in size in a pale greenish yellow groundmass of vesuvianite, augite, and carbonate. Biotite, magnetite, apatite, and niobian perovskite are commonly present. Calcite grains and ragged, black garnet grains occur in places.



Figure 32. Camera-lucida drawing of soda pyroxene-biotite-calcite-pyroxchlore rock, showing soda pyroxene (Pyx), biotite (B), calcite (C), apatite (Ap), pyroxchlore (P), and magnetite (Mag). Oka region, Quebec.

The rocks of the ijolite series commonly grade into calcite rock, rocks of the jacupirangite series, and rocks of the microijolite series. The brown nepheline-bearing variety occurs intermixed with okaite in places. At calcite rock contacts, this rock commonly grades sharply into altered ijolite which in turn grades sharply in biotite-calcite-altered nepheline rock which grades into calcite rock.

### *Microijolite Series*

The microijolitic rocks are generally aphanitic to fine grained; equigranular; olive-green, grey, or mottled grey and olive-green; and are composed essentially of nepheline and soda pyroxene. These rocks are usually remarkably fresh. In a few places, nepheline shows incipient zeolitization along fractures or it is altered to a pink aggregate of analcime and white mica. The rocks of the series range in composition from microurtite to micromelteigite with the medium-coloured varieties predominating. Calcite, black garnet, pyrite, pyrrhotite, magnetite, apatite, and biotite occur in places but are relatively uncommon. Both massive and banded types occur. Banding is marked by differences in grain size or in the nepheline to soda pyroxene ratio or both, and is probably due to flowage.

In places, the microijolitic rocks are biotitized. Incipient biotitization resulted in the formation of veinlets and patches of biotite. Some of the veinlets have white calcite cores. Pyrite occurs in places in the calcite and pyrrhotite in the biotite. Betafite is found in places in the veinlets and patches and in the nearby microijolite. All stages from incipient to complete biotitization have been found.

Microijolitic rocks occur as lenses parallel to the streaks and bands in the calcite rock, as dykes in calcite rock, okaite, and rocks of the jacupirangite series, and as irregular bodies in calcite rock.

### *Jacupirangite Series*

The rocks of the jacupirangite series are composed essentially of titanian augite with variable amounts of nepheline or zeolites after nepheline, biotite, apatite, magnetite, and melilite. They are fine to very coarse grained, medium to dark coloured, and massive. Three varieties are recognized: jacupirangite, nepheline jacupirangite, and melilite-nepheline jacupirangite.

In thin section it can be seen that the nepheline is usually altered to very fine-grained mica, carbonate, and zeolites, but a few fresh crystals and grains were noted. Some of the titanian augite grains are rimmed by a leucoxene-like material. The melilite is unaltered or slightly altered and is similar in appearance to the melilite of the okaite. A few grains of black garnet, niobian perovskite, and calcite were noted in some of the thin sections.

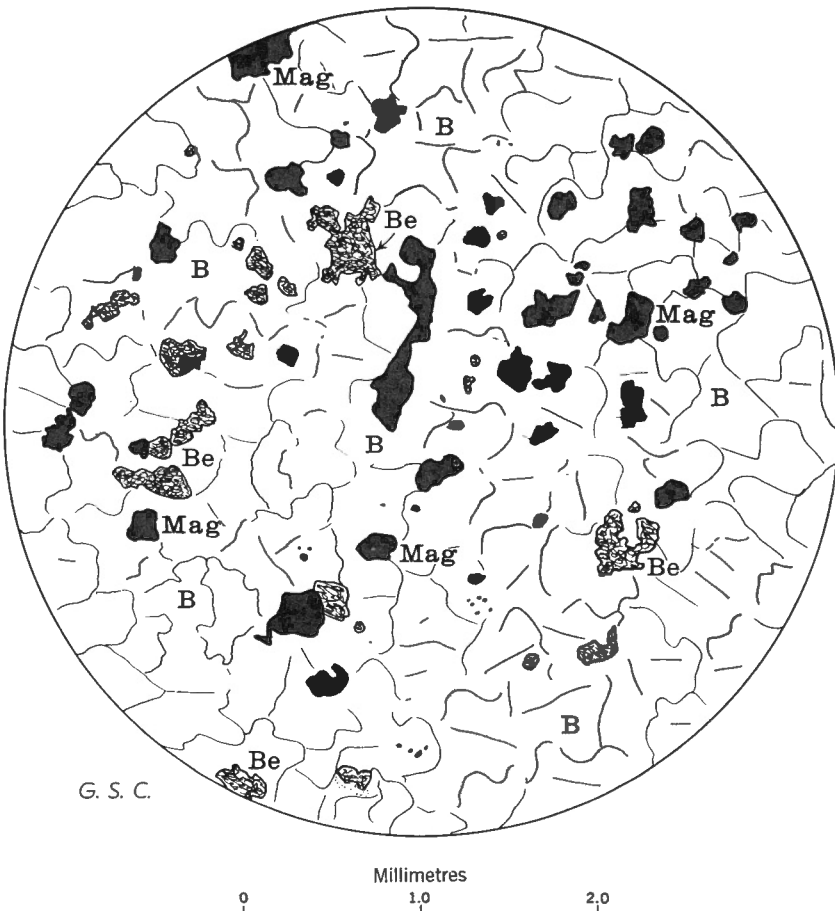
A mass of okaite and altered ijolitic rocks in the northern part of the complex grades into jacupirangitic rocks at depth. Jacupirangites were also found in some of the diamond drill-core associated with altered ijolitic rocks.



*Lamprophyre Rocks*

The lamprophyre rocks of the Oka complex are generally composed of phenocrysts of one or more of olivine, pyroxene (usually titanian augite), biotite, and less commonly hornblende in an aphanitic to fine-grained, dark grey groundmass. Coronas around olivine phenocrysts are common, and less common around pyroxene phenocrysts. Magnetite is usually present in amounts up to about 10 per cent. In general, these rocks are remarkably fresh, but all degrees of alteration have been found. Alteration is generally marked by the replacement of the original minerals by very fine-grained carbonate and mica. In the earlier stages of alteration the porphyritic texture is preserved, but this disappears in the advanced stages.

Thin section study reveals that the principal types of lamprophyre rocks are monchiquites, fourchites, and alnoites.



**Figure 33.** Camera-lucida drawing showing betafite (Be) and magnetite (Mag) in biotite (B) replacement rock. Oka region, Quebec.

The monchiquites and fourchites are similar except that the monchiquites contain both olivine and pyroxene phenocrysts, whereas the fourchites contain only pyroxene phenocrysts. Coronas around olivine grains generally consist of an inner part of magnetite and colourless pyroxene, and an outer part of pale green mica. Microphenocrysts are common and usually consist of titanian augite, olivine, and soda pyroxene. Minerals found in the groundmasses of these rocks include: titanian augite, soda pyroxene, soda amphibole, biotite, nepheline, zeolites, magnetite, carbonate, apatite, and black garnet. Aggregates of nepheline and soda pyroxene occur in places.

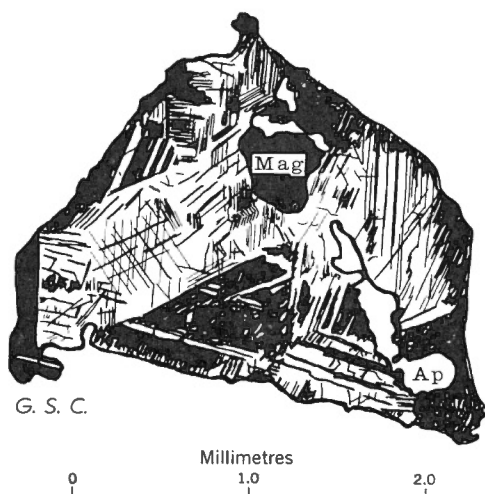


Figure 34. Camera-lucida drawing of niobian perovskite from altered ijolite showing complex twinning. Crossed nicols. Note inclusions of magnetite (Mag), and apatite (Ap). Oka region, Quebec.

The alnoites are characterized by the presence of abundant melilite. Phenocrysts consist of olivine, pyroxene (usually titanian augite), and biotite. Large poikilitic grains of brown hornblende are present in places. Aggregates of melilite have partly or entirely replaced some of the phenocrysts. Many of the olivine phenocrysts have coronas of melilite and magnetite. Microphenocrysts of titanian augite, olivine, and apatite occur in places. The following minerals were found in the groundmasses of specimens examined in thin section: melilite, hornblende, biotite, magnetite, pyrite, calcite, zeolites, apatite, titanian augite, and soda pyroxene. An alnoite dyke that cuts okaite contains patches of biotite okaite.

An unusual rock, tentatively classified as lamprophyre, outcrops in places on a small hill between La Trappe Monastery and the nearby agricultural college. This rock was originally described by Harvie (1909), and given the name of biotite peridotite by Howard (1922, pp. 69-76). The rock contains olivine phenocrysts up to 3 inches in size that have perfectly developed coronas of grey, fibrous material. Smaller phenocrysts consist of olivine, biotite, augite, and titanian augite. Black, opaque coronas occur around the biotite phenocrysts and some of the pyroxene phenocrysts, and fibrous coronas occur around the remaining pyroxene phenocrysts. The groundmass of this rock consists chiefly of magnetite, apatite, and very fine-grained monticellite. Biotite, calcite, and altered plagioclase grains were noted in some of the thin sections. A small inclusion of jacupirangite was found in one of the specimens of this rock.

The lamprophyres occur as small bodies and dykes that cut the other rocks of the Oka complex, and as dykes in the Precambrian rocks of the Oka Hills and in the surrounding Palaeozoic sedimentary rocks (Harvie,

1909, Howard, 1922, and Stansfield, 1923). In places at the contacts with lamprophyre dykes, calcite rock is biotitized or sheared. One of the satellitic lamprophyre dykes near the west contact of the complex contains angular inclusions of Precambrian rocks (Grimes-Graeme, 1935, p. 64).



Figure 35. Camera-lucida drawing of okaite, showing melilite (Me), natrolite (Nt), thomsonite (T), biotite (B), magnetite (Mag), niobian perovskite (Per), and apatite (Ap). Oka region, Quebec.

### *Fenites*

Fenites occur in places at the contact of the Oka complex and as inclusions in the rocks of the microijolite series and include fenitized gneisses, granulites, anorthosite, and gabbro. Fenitization is marked chiefly by the replacement of original minerals by very fine-grained calcite and, or, the occurrence of veinlets and small patches of one or more of green soda pyroxene, green soda amphibole, and green to prussian blue chlorite. In thin section it can be seen that the quartz in quartz-bearing

fenites is strained and the twin lamellae of the plagioclase are deformed. The soda pyroxene and amphibole, and the chlorite are usually fibrous or needle-like.

### *Explosion-Vent Breccias*

Three bodies of explosion-vent breccia, circular to oval in shape, have been found within 4,000 feet of the east contact of the Oka complex. The diameters of these bodies are apparently less than 500 feet. The breccias consist of fragments as much as 1 foot or more in size of a variety of Precambrian rocks in a very fine-grained carbonate matrix. One of the breccia bodies contains fragments of a buff-coloured limestone that appears to be post-Precambrian type. This breccia body is also abnormally radioactive.

## OCURRENCE OF NIOBIUM MINERALS

Disseminated niobium minerals are widespread within the Oka complex, and most, if not all, of the diamond drill-holes put down on the complex have encountered niobium minerals. Betafite, niobian perovskite, pyrochlore, and niocalite have been identified to date. Magnetite and black garnet contain trace amounts of niobium.

### PYROCHLORE

Pyrochlore appears to be the most important niobium mineral. It occurs as grains and crystals up to 5 mm. in size. On the smooth surfaces of diamond drill-core it is generally brownish red, but on rough surfaces it is usually chocolate-brown. In thin section, the pyrochlore is brown to brownish red to reddish brown. The grains and crystals are generally unzoned, but a few zoned crystals were noted. Inclusions of calcite, apatite, and biotite are common. Biotite near pyrochlore is usually bright orange-red in thin section. In general, the pyrochlore is more or less radioactive. Pyrochlore occurs in soda pyroxene-biotite-calcite rock, and in calcite rock, particularly near bodies of microijolite or biotitized microijolite. In calcite rock, pyrochlore usually occurs in association with soda pyroxene, biotite, apatite, and magnetite in lenticles, streaks, bands and patches of accessory minerals. Figures 31 and 32 are camera-lucida drawings that show the occurrence of pyrochlore in calcite rock and soda pyroxene-biotite-calcite rock. A chemical analysis of pyrochlore from the Bond zone, Molybdenum Corporation property, was made at the Mines Branch, Ottawa, and gave the following composition:

	Per cent
CaO.....	17.1
Na <sub>2</sub> O.....	2.5
FeO.....	2.3
Rare earth oxides.....	9.0
U <sub>3</sub> O <sub>8</sub> .....	0.3
ThO <sub>2</sub> .....	1.8
Nb <sub>2</sub> O <sub>5</sub> .....	49.4
TiO <sub>2</sub> .....	7.7
Loss on ignition.....	2.1

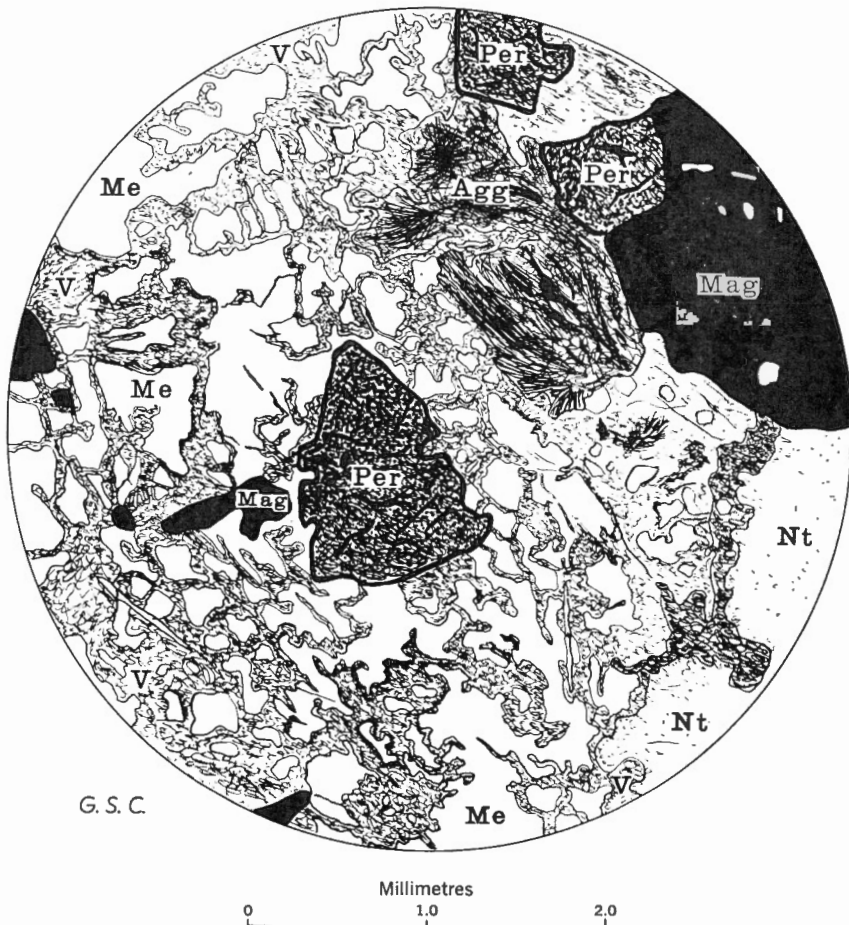


Figure 36. Camera-lucida drawing of altered nepheline okaite, showing melilite (Me), vesuvianite (V), natrolite (Nt) after nepheline, vesuvianite-augite-carbonate aggregate (Agg), magnetite (Mag), and niobian perovskite (Per). Oka region, Quebec.

#### BETAFITE

Betafite occurs as grains and crystals in places in biotitized rocks of the ijolite series and microijolite series, and is invariably strongly radioactive. Most of the grains are less than 0.5 mm. in size. On the smooth surfaces of diamond drill-core the betafite is reddish brown, whereas on rough surfaces it is dark purplish grey. In thin section it is reddish brown. Some crystals are zoned. Many of the grains and crystals are rimmed or entirely replaced by greenish yellow material. Figure 33 is a camera-lucida drawing of betafite in biotite rock. Partial X-ray spectrographic analyses of two specimens of betafite from the Molybdenum Corporation

property were made by R. J. Traill of the Geological Survey with the following results:

	Per cent	
	A	B
Nb <sub>2</sub> O <sub>5</sub> .....	35.5	32.8
U <sub>3</sub> O <sub>8</sub> .....	1.1	0.9
ThO <sub>2</sub> .....	8.2	8.0

#### NIOBIAN PEROVSKITE

Niobian perovskite occurs chiefly in altered okaite, and altered ijolitic rocks as grains and cubo-octahedral crystals up to 7 mm. in size. It is very dark purplish brown to dark purple, and has a submetallic lustre, grey streak, and uneven fracture. In thin section, the niobian perovskite is dark brown to reddish brown, generally anisotropic, and very complexly twinned (*see* Figure 34). Many of the grains and crystals contain rounded inclusions of biotite, calcite, and apatite. Figures 35, 36, 37, 38, and 39 are camera-lucida drawings showing niobian perovskite in okaite, altered okaite, monticellite rock, and altered ijolitic rocks. A chemical analysis of niobian perovskite for niobium oxide was made at the Mines Branch, Ottawa, and gave 22.1 per cent. The specimen was from the Molybdenum Corporation property.

#### NIOCALITE

Niocalite occurs as elongate, yellowish green crystals up to a quarter inch or more in length in calcite rock from the Bond zone, Molybdenum Corporation property. It is possible that niocalite will be found in rocks from the other properties. Niocalite is associated with black garnet, altered melilite, apatite, magnetite, and biotite. It is colourless in thin section. Under crossed nicols it shows very complex twinning: sections parallel or almost parallel with the long axis give lemon yellow, grey, and blue-grey interference colours, and sections perpendicular to the long axis give red and blue colours. Figure 40 is a camera-lucida drawing of niocalite in calcite rock. The following chemical analysis of niocalite was made by J. A. Maxwell of the Geological Survey:

	Per cent
CaO.....	46.8
Na <sub>2</sub> O.....	0.7
Nb <sub>2</sub> O <sub>5</sub> .....	16.8
Rare earth oxides + Al <sub>2</sub> O <sub>3</sub> .....	2.0
SiO <sub>2</sub> .....	26.8
H <sub>2</sub> O.....	0.2
F.....	1.7

## ORESHOOTS

Several lenticular, medium- to high-grade oreshoots have been outlined by diamond drilling. They range from 50 feet in length and 10 feet in maximum width to about 1,700 feet in length and 200 feet in maximum width. Some of the oreshoots cut across different rock types, and, in such cases, two or more niobium minerals are involved. For instance, one of the oreshoots in the Bond zone, Molybdenum Corporation property, consists of biotitized microijolite containing betafite, soda pyroxene-biotite-calcite-pyroxchlore rock, calcite rock containing pyroxchlore, and calcite rock containing niocalite.



Figure 37. Camera-lucida drawing of monticellite rock, showing monticellite (M), biotite (B), calcite (C), magnetite (Mag), niobian perovskite (Per), and apatite (Ap). Oka region, Quebec.

## ORIGIN OF THE OKA COMPLEX AND THE NIOBIUM DEPOSITS

The Oka complex of carbonate and alkaline rocks is believed by the writer to belong to the Monteregian petrographical province.

The Monteregian province is characterized by more or less circular-shaped bodies of gabbros and nepheline syenites of post-Middle Devonian age with satellitic lamprophyre dykes and breccias. According to Adams (1903), the bodies are laccoliths, volcanic or laccolithic necks, and probably also stocks. Analyses of the Monteregian rocks show the course of differentiation of the Monteregian magma (Dresser and Denis, 1944, pp. 455-482). As differentiation proceeded, the rocks became richer in sodium, and this is evidenced by the appearance of nepheline and soda pyroxene in the syenites. In general, the silica content increased until the later stages of differentiation when a sharp decrease occurred. The presence of titanium in the rocks is evidenced by the common occurrence of titanian augite and titaniferous magnetite in the gabbros, and sphene and titaniferous magnetite in many of the syenites. Phosphorus and fluorine were also available during the crystallization of these rocks as evidenced by the common occurrence of apatite. Fluorite has also been found in some of the syenites. A radioactive, niobium occurrence in the nepheline syenite of Mount St-Hilaire has been reported. Extensive contact metamorphism of the limestone adjacent to the Mount Royal body has been described by Dresser and Denis (1944, pp. 466-467). The limestone has been recrystallized to a fine- to coarse-grained marble, and, in places, metasomatism has resulted in the formation in the marble of a variety of minerals of which garnet, vesuvianite, and diopside are the most common.

Although structural, chemical, and mineralogical similarities between the Oka complex and the normal Monteregian gabbro-nepheline syenite complexes are apparent, the Oka complex is different in many respects. Probably the greatest difference is the abundance of carbonate rock in the Oka complex. Some of the carbonate rock occurs as late veins and replacement bodies and is probably of hydrothermal origin, but the bulk of the carbonate rock is calcite rock that was in place before the other rocks of the complex. No gabbro has been found, and nepheline syenite is scarce. Many of the rocks are much richer in sodium than the rocks of the other Monteregian bodies, and Oka complex is usually rich in several elements, notably niobium, thorium, uranium, and the rare earths.

The calcite rock could have formed in one or more of three ways: (1) from post-Precambrian sedimentary carbonate rock, (2) from Grenville marble, or (3) from a magma. Fragments of limestone that appear to be post-Precambrian type are in one of the satellitic breccia bodies, so it is possible that sedimentary carbonate rock was available at the time of the formation of the complex. The ability of Monteregian activity to convert limestone to coarse-grained marble is demonstrated at Mount Royal. However, relict limestone has not been found in the Oka complex. Several geologists who have had experience with Grenville rocks declare that the calcite rock looks like Grenville marble. It is possible that Grenville marble was mobilized and squeezed into a discordant zone of weakness which was also the locus for the intrusion of alkaline silicate rocks. The calcite rock could have been emplaced as a carbonate magma or by hydro-



thermal activity. Geologists who are familiar with the African carbonatites, which are generally held to be magmatic, note that the Oka calcite rock looks like carbonatite. At Iron Hill, Gunnison county, Colorado, dolomitic carbonate rock is the oldest rock of a complex of carbonate and alkaline rocks that is very similar to the Oka complex. Larsen (1942) believes that the carbonate rock is a large hydrothermal deposit in the throat of a volcano. Whatever the origin of the calcite rock, the accessory mineral content of the rock indicates a complex history. The presence in places of monticellite and melilite suggests conditions of the sanidine facies. The occurrence of soda pyroxene and biotite in the calcite rock is apparently related spatially to bodies of silicate rocks, particularly microijolite, and it is probable that these minerals were produced chiefly by hydrothermal or pneumatolytic metasomatism.

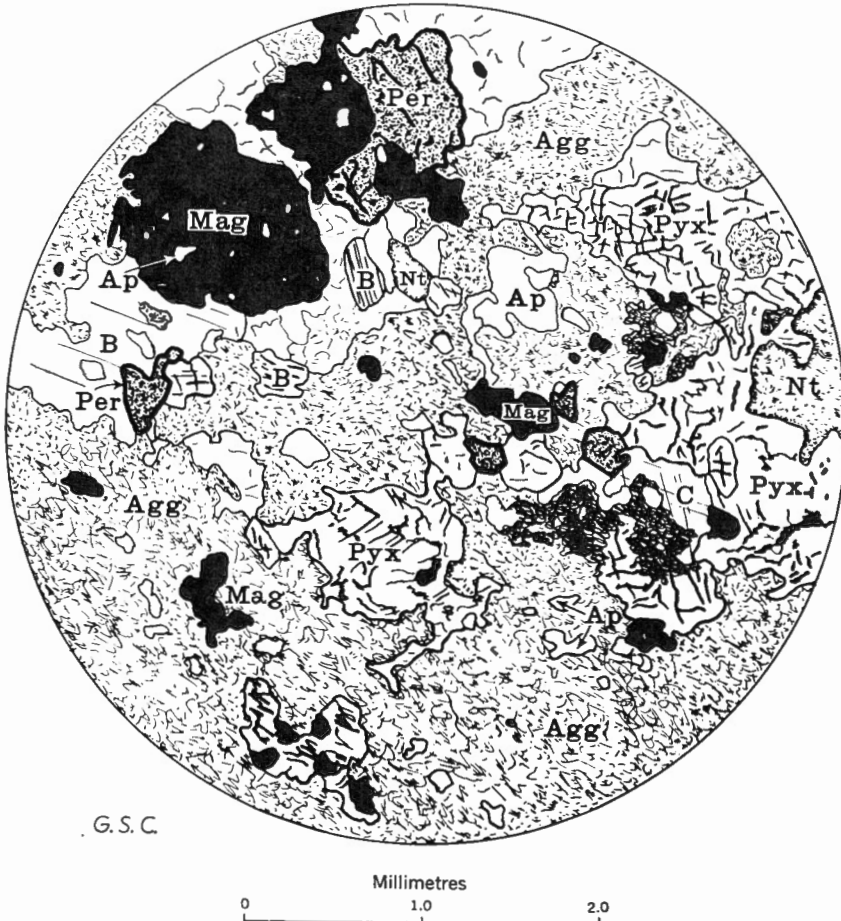


Figure 38. Camera-lucida drawing of altered ijolite showing niobian perovskite (Per), magnetite (Mag), soda pyroxene (Pyx), apatite (Ap), biotite (B), calcite (C), natrolite (Nt), and vesuvianite-pyroxene-carbonate aggregate (Agg). Oka region, Quebec.

The rocks of the microijolite series and jacupirangite series could have formed by the reaction of the pre-existing calcite rock and Montereian gabbro-nepheline syenite magma, or they could represent a late fraction of the Montereian magma—an agpaite fraction that was even less siliceous and more sodic. The writer favours the latter idea because the tendency towards agpaite differentiation in the later stages of the differentiation of the Montereian magma is illustrated in the other Montereian complexes, and because the Oka complex is enriched in niobium, thorium, uranium, rare earths, and other elements. It is possible that the agpaite fraction is represented to a greater extent at Oka because the Montereian magma was more confined by the greater thickness of competent Precambrian rocks in the Beauharnois Axis and differentiation was able to proceed to a greater degree.

Some of the rocks of the Oka complex, particularly okaite and the rocks of the ijolite series, are believed to be hybrid rocks that formed by the reaction of alkaline silicate magma and calcite rock.

The formation of the niobium minerals was probably due to hydrothermal or pneumatolytic metasomatism. Solutions that evolved during the agpaite stage of the differentiation of the Montereian magma are considered by the writer to be the most likely agents of metasomatism. At least four niobium minerals occur in the complex and these minerals occur in different rock types. These facts indicate that the solutions were available at different stages in the formation of the complex, and that temperature and the chemistry of the host rocks were important factors.

## DESCRIPTIONS OF PROPERTIES

Ten mining properties are underlain in part or entirely by the Oka complex of alkaline and carbonate rocks, and Figure 28 shows their locations. Diamond-drilling programs have been conducted on eight of the properties. Although drilling has been done on one of the properties of Montrose Securities Limited and on the property of Oka Uranium and Metals Limited, these properties are not described because drill-core was not made available to the writer for study. Maps showing the locations of diamond drill-holes and the rock types encountered were provided by these companies, and the data were used in the compilation of Figure 28.

### ADVANCE RED LAKE PROPERTY

This property is held by Advance Red Lake Gold Mines Limited, Toronto. Five diamond drill-holes had been completed by October 31, 1955, and drilling was proceeding in November.

The Oka complex does not outcrop on the property, and the overburden varies from 284 to 299 feet in thickness.

The diamond drill-core consists chiefly of dolomite rock and altered lamprophyre rocks that are commonly sheared. Disseminated yellowish brown to reddish brown pyrochlore grains and crystals occur in places in the dolomite rock with calcite, pyroxene, apatite, magnetite, biotite, and pyrite.

The company announced that diamond drilling had indicated 3,500,000 tons of rock with an average of 0.31 per cent niobium oxide, 0.39 per cent rare earth oxides, and 9.1 per cent apatite.

#### BOUSCADILLAC PROPERTY

The Bouscadillac property is held by Bouscadillac Gold Mines Limited, Toronto. Work done by October 31, 1955, consisted of 4,539 feet of diamond drilling. Drilling was proceeding in November, 1955.

Rocks of the Oka complex encountered by the drill-holes include breccia, ijolitic rocks, altered ijolitic rocks, altered okaite, lamprophyre, altered lamprophyre, and calcite rock. Pyrochlore was observed by the writer in calcite rock in places near the contacts with altered lamprophyre, and niobian perovskite occurs in the altered okaite.

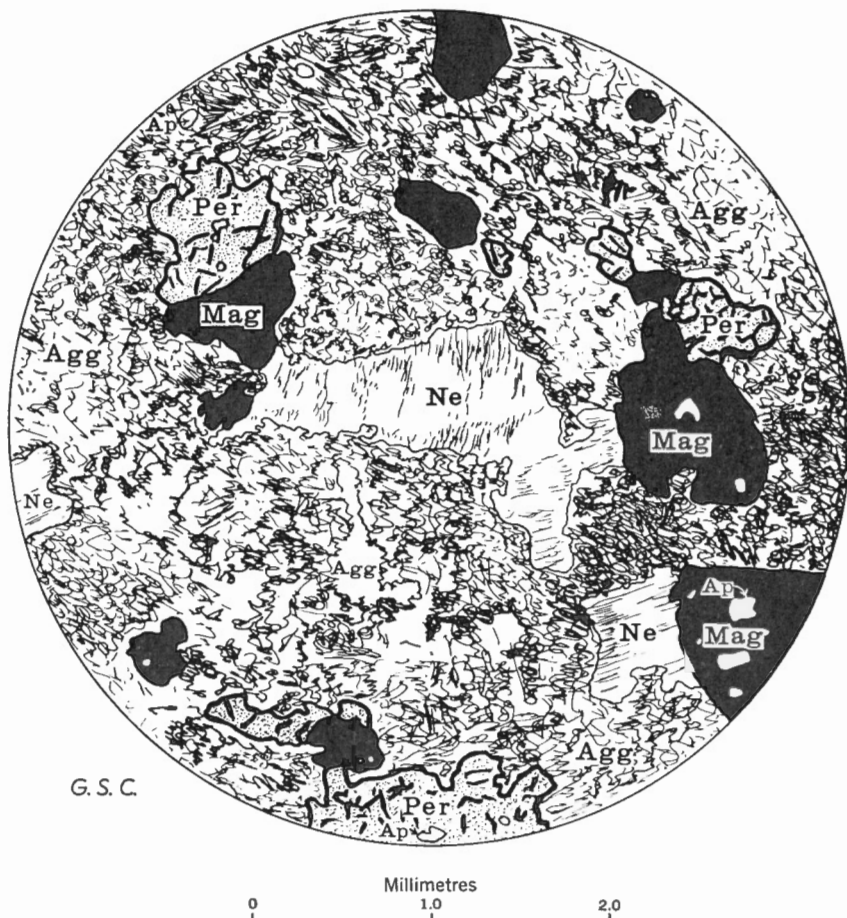


Figure 39. Camera-lucida drawing of altered ijolitic (?) rock that contains brown nepheline, showing nepheline (Ne), vesuvianite-augite-carbonate aggregate (Agg), magnetite (Mag), niobian perovskite (Per), and apatite (Ap). Oka region, Quebec.

The company announced in November, 1955, that diamond drilling had indicated a deposit of 3,800,000 tons of rock with an average grade of 0.31 per cent niobium oxide. The deposit is reported to be 1,200 feet in length and to have a lateral extension of 200 feet. It was also stated that large tonnages grading 0.20 per cent niobium oxide were not included in these figures.

#### COULEE-HEADWAY PROPERTY

Coulee Lead and Zinc Mines Limited, and Headway Red Lake Gold Mines Limited, Toronto, jointly hold this property (*see* Figure 28). Seventeen diamond drill-holes were completed in the spring of 1955. Diamond drilling was resumed in April, 1956, and extraction tests are being conducted.

The companies announced that diamond drilling had indicated a zone containing 15 million tons of rock with an average niobium content of 0.39 per cent. The zone is reported to be 1,200 feet long, 250 feet wide, and at least 500 feet in depth.

Diamond drill-core from this zone consists mainly of calcite rock, microijolite, biotitized microijolite, and lamprophyre. Pyrochlore occurs in places in calcite rock, particularly near microijolite and biotitized microijolite. Betafite occurs in places in biotitized microijolite.

#### MAIN OKA PROPERTY

The Main Oka property is held by Main Oka Mining Corporation, Montreal. Work done consists of a seismic survey to establish the depth of bedrock, and diamond drilling. By October 31, 1955, fourteen diamond drill-holes, totalling over 10,000 feet of drilling, had been completed. An additional eleven holes failed to reach bedrock.

The diamond drill-core consists of calcite rock, monticellite rock, microijolitic rocks that commonly contain fenite inclusions, fenites, lamprophyre rocks, ijolitic rocks, and explosion-vent breccia. Pyrochlore was observed in places in calcite rock, and niobian perovskite was seen in places in monticellite rock. The results of the diamond drilling have not been announced.

#### MOLYBDENUM CORPORATION PROPERTY

The Molybdenum Corporation of America, New York, holds this property. Work done consists of radiometric and magnetic surveys, stripping, trenching, and diamond drilling. Forty-five diamond drill-holes, totalling about 30,000 feet had been completed by October 31, 1955. Extraction tests are being conducted by several agencies.

A large mass of okaite, altered okaite, and jacupirangitic rocks occurs in the north part of the property, and the remainder is underlain mainly by calcite rock with lesser amounts of the other rock types of the complex.

Since the latter part of 1954, the company has been concerned mainly with the exploration of the Bond zone (*see* Figure 28) which has been

diamond drilled at 100- and 200-foot intervals. The Bond zone is composed mainly of calcite rock, microijolite, and biotitized microijolite with lesser amounts of ijolitic rocks, altered ijolitic rocks, okaite, altered okaite, and soda pyroxene-biotite-calcite-pyroxchlore rock. Pyroxchlore is apparently the most abundant niobium mineral, and it occurs in soda pyroxene-biotite-calcite-pyroxchlore rock, and in places in calcite rock. Betafite occurs in places in biotitized microijolite. Calcite rock contains niocalite in places. Niobian perovskite occurs chiefly in altered ijolitic rocks and altered okaite. Several medium- and high-grade shoots have been outlined. Some of these cut across rock types and contain two or more niobium minerals.

Grade and tonnage figures have not been announced.

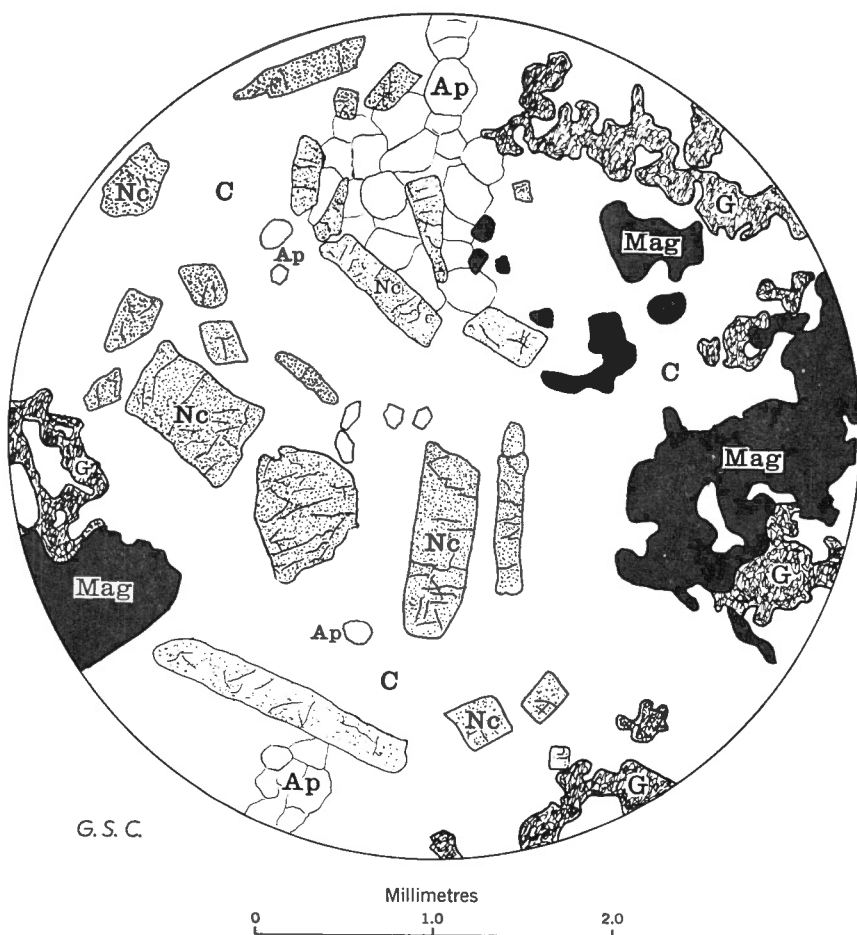


Figure 40. Camera-lucida drawing of calcite rock showing calcite (C), niocalite (Nc), magnetite (Mag), black garnet (G), and apatite (Ap). Oka region, Quebec.

### ST. LAWRENCE PROPERTY

This property is held by St. Lawrence River Mines Limited, Montreal. Work done consists of a radiometric survey and diamond drilling. Fifty-six diamond drill-holes, totalling over 32,000 feet of drilling, had been completed by October 31, 1955.

Most of the rock types of the Oka complex are found in the diamond drill-core, but calcite rock, microijolitic rocks, and biotitized microijolitic rocks are the most abundant. Pyrochlore occurs in calcite rock, and soda pyroxene-biotite-calcite-pyrochlore rock, particularly in apatite-rich varieties; betafite occurs in biotitized microijolitic and ijolitic rocks; and niobian perovskite occurs in altered ijolitic rocks.

Twenty irregular, lenticular and pod-like shoots, ranging from 10 to 165 feet in maximum width and 50 to 700 feet in length, have been discovered. C. Carbonneau (personal communication) has estimated that these shoots contain an indicated reserve of 5,600,000 tons of rock with an average niobium oxide content of 0.50 per cent. Pyrochlore is apparently the most abundant niobium mineral.

### Other Deposits and Occurrences

Deposits and occurrences of niobium minerals that are not described in detail are listed in Table V.

TABLE V  
*Other Deposits and Occurrences of Niobium Minerals in Canada*  
NORTHWEST TERRITORIES

Location	Name	Owner, company or person familiar with occurrence	Type	Mineral(s)	References	Remarks
Marian River area	Vic No. 4 claim	Yellowknife Uranium Corp.	Fractures in granite	Fergusonite		
Yellowknife-Beaulieu region	Best Bet dyke	Boreal Rare Metals Ltd.	Granitic pegmatite	Columbite-tantalite	Rowe (1952, pp. 24-25)	
Yellowknife-Beaulieu region	Big Hill claims	Boreal Rare Metals Ltd.	Granitic pegmatite	Columbite-tantalite	Rowe (1952, p. 27)	
Yellowknife-Beaulieu region	Blaisdell Lake pegmatites		Granitic pegmatite	Columbite-tantalite	Lord (1951, pp. 85-86)	
Yellowknife-Beaulieu region	Freda No. 1 claim	E. Sutherland, Yellowknife	Granitic pegmatite	Columbite-tantalite	Lord (1951, pp. 152-154)	
Yellowknife-Beaulieu region	Lita claims	Frobisher Exploration Co. Ltd.	Granitic pegmatite	Columbite-tantalite	Rowe (1952, p. 27)	
Yellowknife-Beaulieu region	Moose No. 2 dyke	Boreal Rare Metals Ltd.	Granitic pegmatite	Columbite-tantalite	Rowe (1952, pp. 22-24)	
Yellowknife-Beaulieu region	Peg claims	Tantalum Refining and Mining Corp. of America	Granitic pegmatite	Columbite-tantalite	Rowe (1952, pp. 29-30)	
Yellowknife-Beaulieu region	Prelude Lake pegmatites		Granitic pegmatite	Columbite-tantalite	Rowe (1952, pp. 30-31)	
Yellowknife-Beaulieu region	Ramona claims	Boreal Rare Metals Ltd.	Granitic pegmatite	Columbite-tantalite	Lord (1951, pp. 122-123)	
Yellowknife-Beaulieu region	Sproule Lake pegmatites		Granitic pegmatite	Columbite-tantalite	Rowe (1952, pp. 32-33)	
Yellowknife-Beaulieu region	Tan claims	Boreal Rare Metals Ltd.	Granitic pegmatite	Columbite-tantalite	Rowe (1952, pp. 25-26)	
Yellowknife-Beaulieu region	Waco pegmatite sill		Granitic pegmatite	Columbite-tantalite	Lord (1951, p. 287)	

## BRITISH COLUMBIA

Location	Name	Owner, company or person familiar with occurrence	Type	Mineral(s)	References	Remarks
Near Kamloops				Columbite-tantalite	Ellsworth (1932, p. 137)	
15 miles east of Kelowna		O. Hill, Kelowna	Granitic pegmatite	Fergusonite	Lang (1952, p. 45)	

## SASKATCHEWAN

Location	Name	Owner, company or person familiar with occurrence	Type	Mineral(s)	References	Remarks
Goldfields region	Viking Lake deposit	Lorado Uranium Mines Ltd.	Granitic pegmatite	Pyrochlore-microlite	Robinson (1955, pp. 35-36)	
Goldfields region, Viking Lake	Lor group	American-Canadian Uranium Mines Ltd.	Pegmatite or fracture in granite gneiss (?)	Fergusonite		
Goldfields region	KK Concession		Gossan capping	Fergusonite	Lang (1952, p. 82); and Robinson (1955, p. 69)	
East of Hazelton Lake, 26 miles northwest of Camsell Portage	Bess group	C. M. Kilbreath and G. W. Macdonnell, Uranium City, Sask.	Chloritic shear zones in coarse-grained granite	Euxenite-polyserase (?) and pyrochlore-microlite (?)		
Lac la Ronge	Nistowiak group	La Ronge Uranium Mines Ltd.	Granitic pegmatite	Uranian pyrochlore-microlite (?)		



## MANITOBA

Location	Name	Owner, company or person familiar with occurrence	Type	Mineral(s)	References	Remarks
Winnipeg River area	Silver Leaf pegmatite		Granitic pegmatite	Columbite-tantalite	Ellsworth (1932, pp. 148-157)	
Winnipeg River area	Huron pegmatite		Granitic pegmatite	Columbite-tantalite	Ellsworth (1932, p. 166)	

## ONTARIO

Location	Name	Owner, company or person familiar with occurrence	Type	Mineral(s)	References	Remarks
Alice tp., Con. XV, Lot 13		R. McCoshen, Sudbury	Granitic pegmatite	Euxenite-polyerase	Lang (1952, p. 136)	
Auld tp.		H. G. Walton, New Liskeard	Granitic pegmatite(?)	Fergusonite		
Bathurst tp., Con. IX, N $\frac{1}{2}$ Lot 22		H. S. Spence, Ottawa	Granitic pegmatite	Euxenite-polyerase	Lang (1952, p. 137)	
Butt tp., Con. IX, Lot 5		D'Eldona Gold Mines Ltd.	Granitic pegmatite	Fergusonite, pyrochlore	Eng. and Min. Jour. (1954)	
Butt tp., Con. IX, Lot 5	Yankee Dam group	E. K. Fockler, Toronto	Granitic pegmatite	Pyrochlore-microlite and eschynite-priorite		
Calvin tp., Con. IX, Lot 22		Molybdenum Corp. of America	Granitic pegmatite	Euxenite-polyerase, samarskite?	Lang (1952, p. 147)	Four pegmatite dykes once worked for feldspar

## ONTARIO (cont'd)

Location	Name	Owner, company or person familiar with occurrence	Type	Mineral(s)	References	Remarks
Calvin tp.		J. W. MacFarlane, Toronto	Granitic pegmatite	Euxenite-polycrase	Lang (1952, p. 137)	
Calvin tp., Con. I, Lots 11, 12		W. Stewart, Eau Claire, Ont.	Granitic pegmatite(?)	Fergusonite	Lang (1952, p. 138)	
Calvin tp., Con. IX, Lot 20			Granitic pegmatite	Euxenite-polycrase	Ellsworth (1932, p. 189)	
Cardiff tp.	Hogan property	Halo Uranium Mines Ltd.	Calcite vein	Pyrochlore	Satterly & Hewitt (1955, pp. 33-34)	Veins also contain fluorite, apatite, biotite
Cardiff tp., Con. XII, XIII		Canada Radium Mines Ltd.	Granitic pegmatite	Uranian pyrochlore	Lang (1952, p. 138)	Pegmatite once worked for feldspar
Cardiff tp., Con. IX-XIII, Lots 23-30		Centre Lake Uranium Mines Ltd.	Pegmatite	Pyrochlore	Satterly and Hewitt (1955, p. 21)	
Cardiff tp., Con. VIII, Lots 12-14		Dyno Mines Ltd.		Uranian pyrochlore		
Carter tp., mileage 98, C.N. railways	Leach and Johns property		Granitic pegmatite	Euxenite-polycrase(?)	Lang (1952, p. 150)	Pegmatite once explored for feldspar
Cavendish tp., Con. VIII, IX, Lot 15				Fergusonite		
Chapman tp., Con. VIII, Lot 3	Raney property	W. Raney, Sr., Sundridge		Pyrochlore-microlite		
Conger tp., Con. IX, on line between Lots 9 and 10			Granitic pegmatite	Calcio-samaraskite	Lang (1952, p. 141)	
Conger tp., Con. IX, Lot 10			Granitic pegmatite	Calcio-samaraskite	Lang (1952, p. 141)	

Conger tp., Con. X, Lot 7	Opeongo Mining Co.	Granitic pegmatite	Euxenite- pyrochlore and columbite	Lang (1952, p. 141)	Property operated for feldspar
Dickens tp., Con. XIII, Lot 9		Granitic pegmatite	Euxenite- pyrochlore or samarskite(?)	Lang (1952, p. 142)	
Dickens tp., Con. V, Lot 27		Granitic pegmatite	Uranian pyro- chlore and euxenite- pyrochlore	Lang (1952, p. 142)	Pegmatite, once worked for feld- spar and mica
Dickens tp., Con. II, Lot 2	J. C. Cunningham-Dunlop	Granitic pegmatite	Euxenite- pyrochlore	Lang (1952, p. 142)	Pegmatite once worked for feldspar
Dill tp., Con. II, Lot 2, north half	Cubar Uranium Mines Ltd.	Granitic pegmatite	Betafite and uranian pyrochlore		Pegmatite once worked for feldspar
Dill tp., Con. III, Lot 4		Granitic pegmatite	Uranian columbite	Lang (1952, p. 142)	Pegmatite once worked for feldspar
Faraday tp., Con. XVI, Lot 31	J. W. Griffith, Toronto	Granitic pegmatite	Pyrochlore- microcline	Lang (1952, p. 142)	
Faraday tp., Con. A, Lot 23	Bonville Gold Mines Ltd.	Granitic pegmatite	Uranian pyrochlore	Satterly and Hewitt (1955, p. 49)	
Faraday tp., Con. XV, Lots 30 and 31	Bancroft Mica Co.	Granitic pegmatite	Euxenite- pyrochlore	Thompson (1943)	
Galway tp., Con. VIII, Lot 26	Lun-Echo Gold Mines Ltd.		Pyrochlore- microcline		
Herschel tp., Con. I, Lots 22 and 33	J. W. Griffith, Toronto		Pyrochlore- microcline	Lang (1952, p. 142)	
Herschel tp., Con. I, Lot 30	Brown occurrence		Uranian pyrochlore	Lang (1952, p. 137)	
Herschel tp., Con. VIII, Lots 2 and 3; Con. IX, Lots 2 and 4; Con. X, Lots 2 and 3	Peter Rock Mining Co.		Uranian pyrochlore		

ONTARIO (*cont'd*)

Location	Name	Owner, company or person familiar with occurrence	Type	Mineral(s)	References	Remarks
Herschel tp., Con. XVI, Lots 12 and 18	Patterson occurrence			Eschynite- priorite		
Henvey tp., Con. A, Lot 4		H. S. Spence	Granitic pegmatite	Euxenite- polycrase	Lang (1952, p. 146)	
Henvey tp.	Ambeau occurrence		Granitic pegmatite	Euxenite- polycrase(?)	Lang (1952, p. 136)	Pegmatite once worked for feldspar
Henvey tp.	Key River occurrence	R. M. Clarke, Levack	Granitic pegmatite	Fergusonite		
Loughborough tp., Con. IX, Lot 11		M. J. O'Brien Ltd.	Granitic pegmatite	Euxenite	Lang (1952, p. 146)	Pegmatite formerly worked by M. J. O'Brien Ltd.
Lyndoch tp., Con. XV, Lot 23	Caldwell occurrence		Granitic pegmatite	Columbite and euxenite- polycrase	Ellsworth (1932, pp. 228-230) Satterly (1944)	
Lyndoch tp., Con. XV, Lot 30				Columbite and euxenite- polycrase	Satterly (1944)	
Lyndoch tp., Con. XV, Lot 25		Universal Light Metals Co.	Granitic pegmatite	Columbite and euxenite- polycrase	Lang (1952, p. 146)	
Lyndoch tp., Con. XXIII, Lot 23			Granitic pegmatite	Euxenite- polycrase	Lang (1952, p. 146)	Pegmatite pro- duced several tons of beryl
Mattawan tp., Con. III, Lot 29	O'Brien-Fowler property	Molybdenum Corporation of America	Granitic pegmatite	Euxenite- polycrase	Lang (1952, p. 148)	Pegmatite dyke once worked for feldspar
Mattawan tp., Con. II, Lot 29		C. Palangio, North Bay		Euxenite- polycrase	Lang (1952, p. 147)	

Monmouth tp., Con. III, Lots 3-5, Con. IV, south half Lots 24, Lot 5	Sovereign property	Fairley Red Lake Gold Mines Ltd.	Granitic pegmatite	Euxenite- polycrase		
Monteagle tp., Con. VII, north halves of Lots 18 and 19	MacDonald Mine	P. MacDonald, Hybla	Granitic pegmatite	Uranian pyrochlore	Satterly and Hewitt (1955, pp. 55-57)	Pegmatite once worked for feldspar
Monteagle tp., Con. VII, Lot 17	Woodcox Mine	Northern Uranium Mines Ltd.	Granitic pegmatite	Uranian pyrochlore, columbite, calcio- samarskite	Lang (1952, p. 149)	Pegmatite dyke once worked for feldspar
Monteagle tp., Con. VII, Lot 14	Genesee No. 2 property	W. Jessup	Granitic pegmatite	Euxenite- polycrase	Lang (1952, p. 145)	Pegmatite worked for feldspar
Murchison tp.	Cameron Mine	Keystone Contractors Ltd., Windsor	Granitic pegmatite	Euxenite- polycrase	Lang (1952, p. 138)	Pegmatite dyke once worked for feldspar
Murchison tp., Con. IV, Lot 15		E. Kohls, Pembroke	Granitic pegmatite	Fergusonite		Pegmatite once worked for feldspar
Murchison tp., Con. IV, Lot 14		Madawaska Feldspar Co.	Granitic pegmatite	Fergusonite	Lang (1952, p. 147)	Pegmatite dyke once worked for feldspar and quartz
North Burgess tp., Con. VI, Lot 23		J. P. Quinn, Stanleyville		Pyrochlore- microcline and euxenite- polycrase		
Olden tp., Con. VII, Lot 8		H. G. Quinn, Tichborne		Euxenite- polycrase (?)		
Raglan tp.	Craigmont Mine		Syenite pegmatite	Euxenite- polycrase (?)	Lang (1952, p. 141)	Mine formerly worked for corundum
Renfrew Co., near Quodville	Canadian Beryllium property		Granitic pegmatite	Euxenite- polycrase		Pegmatite once mined for feldspar

ONTARIO (*cont'd*)

Location	Name	Owner, company or person familiar with occurrence	Type	Mineral(s)	References	Remarks
Richards tp., Con. XIV, Lot 2		E. Betz, Toronto		Fergusonite and eschynite-priorite		
Sabine tp., Con. I, south half Lot 2, Lot 8		Sabine Uranium Mines Ltd.		Eschynite-priorite		
Sabine tp., Con. I, Lot 28			Granitic pegmatite	Euxenite-polycrase	Lang (1952, p. 149)	Pegmatite once worked for feldspar
Sherbrooke tp.		R. M. Clark, Lindsay	Granitic pegmatite	Euxenite-polycrase	Lang (1952, p. 149)	
Servos tp., Con. VI, Lot 6		Graham Lake Mining Syndicate		Euxenite-polycrase	Lang (1952, p. 149)	
South Sherbrooke tp., Con. V, Lot 13	Maberly property	Orser-Kraft Feldspar Co.	Granitic pegmatite	Euxenite-polycrase	Lang (1952, p. 146)	Pegmatite once worked for feldspar
MacGregor Cove, Lake Superior	McCombe property	J. G. McCombe, Sault Ste. Marie		Uranian pyrochlore	Lang (1952, p. 130)	
Ely Lake, Kenora region		M. McMillan, North Bay		Betafite		
Near Marathon, Lake Superior		Lun-Echo Gold Mines Ltd.				
Near Marathon, Lake Superior		Orchan Uranium Mines Ltd.	Syenite dykes associated with nepheline syenite complex	Pyrochlore(?)		

## QUEBEC

Location	Name	Owner, company or person familiar with occurrence	Type	Mineral(s)	References	Remarks
Baskatong tp., Rge. II, Lot 30		Gatineau Uranium Mines Ltd.	Calcite rock	Uranian pyrochlore		
Callieres tp.		St. Simeon Uranium Corp.	Granitic pegmatite	Fergusonite	Lang (1952, pp. 151-152)	
Deux Montagnes Co., near St. Benoit		Oka Rare Metals Mining Co. Ltd.		Niobian perovskite(?)		
Labelle Co., near Pope		A. Duquette, Val Limoges	Granitic pegmatite	Uranian pyrochlore		
Lacorne tp., Rge. IX, Lots 52 and 53			Granitic pegmatite	Betafite	Tremblay (1950, p. 76)	
Lacorne tp.		Quebec Lithium Corp.	Granitic pegmatite	Columbite-tantalite	Rowe (1953, p. 16)	Pegmatite is mined for spodumene
Lacorne tp., south halves Lots 14 to 19		P. F. Massicotte, Val d'Or	Granitic pegmatite	Columbite-tantalite	Rowe (1953, p. 16)	
Lacorne tp., Rge. II, Lot 11		Great Lakes Carbon Corp.	Granitic pegmatite	Columbite-tantalite	Tremblay (1950, p. 74)	
Lacorne tp., Rge. X, Lot 58			Granitic pegmatite	Columbite-tantalite	Tremblay (1950, p. 76)	
Landrienne tp., Rge. I, Lot 25			Granitic pegmatite	Columbite-tantalite	Tremblay (1950, p. 77)	
Landrienne tp., Rge. I, Lot 26			Granitic pegmatite	Columbite-tantalite	Tremblay (1950, p. 77)	
Rouville Co., St-Hilaire parish, Lots 301-330		Chess Uranium Corp.	Associated with gabbro nepheline syenite complex	Pyrochlore(?)		

QUEBEC (*cont'd*)

Location	Name	Owner, company or person familiar with occurrence	Type	Mineral(s)	References	Remarks
Templeton tp., Rge. XII, south half Lot 20		W. M. Wallingford, Gatineau Point	Granitic pegmatite	Euxenite-polycrase	Lang (1952, p. 153)	
Villedieu tp., near Lake Sairs	Lariviere and Cunningham property		Granitic pegmatite(?)	Betafite or pyrochlore-microlite		
Wakefield tp., Rge. III, Lot 25		O'Leary Malartic Mines Ltd.	Granitic pegmatite	Euxenite-polycrase		
West Portland tp., Rge. V, Lot 2			Granitic pegmatite	Euxenite-polycrase	Lang (1952, p. 154)	Pegmatite once mined for feldspar
10 miles north of St. Michel des Saints	Maisonneuve Mine	South State Uranium Mines Ltd.	Granitic pegmatite	Euxenite-polycrase and samarskite	Lang (1952, p. 153)	

## NOVA SCOTIA

Location	Name	Owner, company or person familiar with occurrence	Type	Mineral(s)	References	Remarks
Near Lake Ramsay				Columbite(?)	Ellsworth (1932, p. 257)	
1 mile east of New Ross	Lavers Mine		Granitic pegmatite	Columbite	Ellsworth (1932, p. 257)	



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