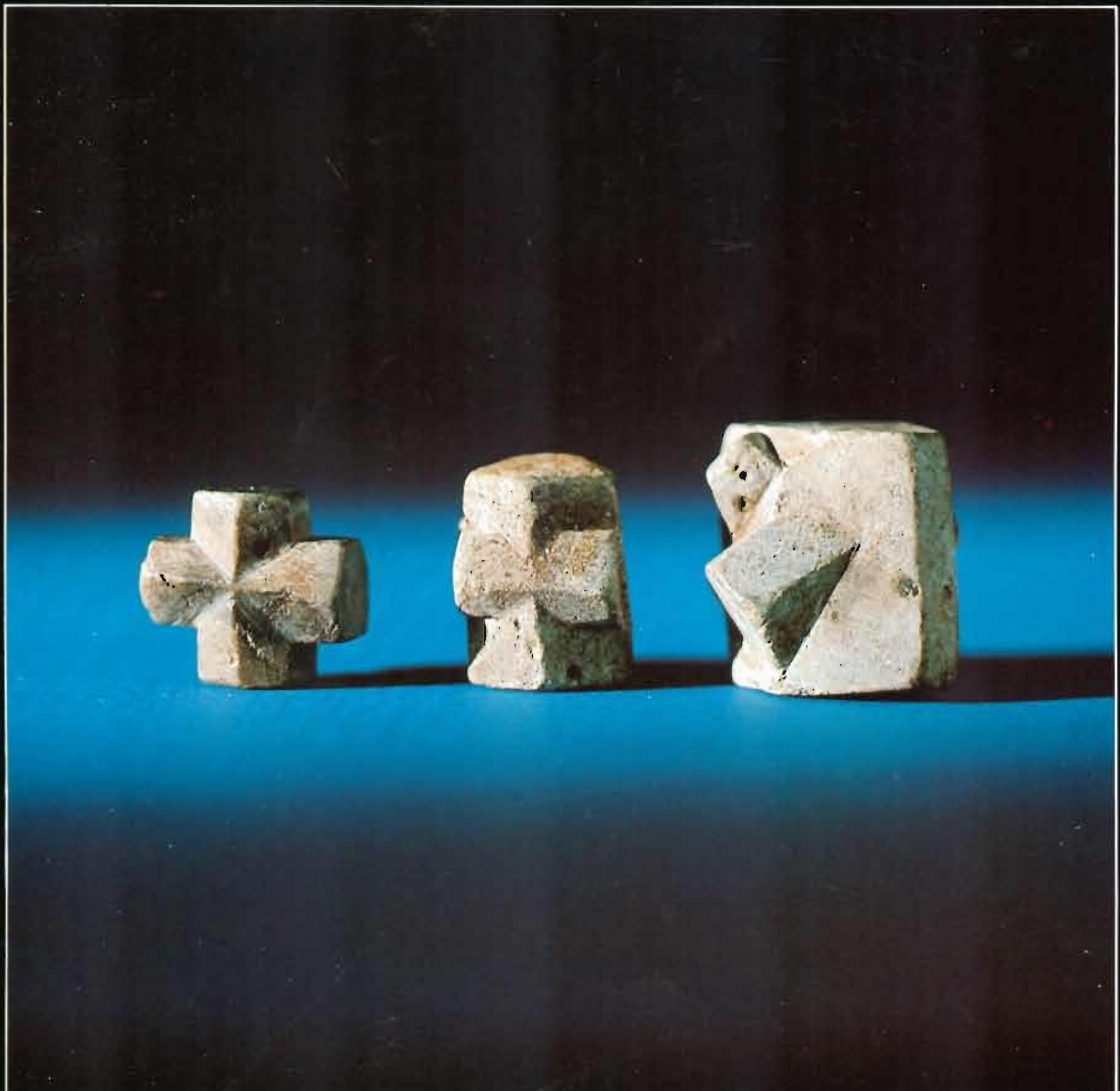

Minerals of Manitoba

Volume I: Non-metallic and pegmatitic

Department of Mines, Resources
and Environmental Management

MANITOBA
MINERAL RESOURCES DIVISION

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Minerals of Manitoba

Volume I: Non-metallic and pegmatitic

by

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Winnipeg, 1978

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Volume I: Non-metallic and pegmatitic*

* *Owing to their mode of occurrence in Manitoba, certain metallic oxides such as cassiterite and uraninite are included with the pegmatitic minerals in this volume. Sulphides, major ore minerals and most other metallic minerals are scheduled for inclusion in volume II.*

Foreword

This publication is the second in an educational series intended to introduce the general public to the rocks and minerals of Manitoba. The first publication (1975) was "Common Rocks in Manitoba" by the same author, explaining how various rocks are formed and how to recognize them. In the present work it has been assumed that the reader has access to this or an alternative book of reference. In the absence of a geological text, an encyclopaedia or a comprehensive modern dictionary will define the more commonly used rock-names and some geological terms. The present volume is a summary of the principal non-metallic minerals that can be seen and studied in outcrops, quarries or rock-dumps within the province. Although a few metallic minerals (such as cassiterite and uraninite) have been included because of their pegmatitic mode of occurrence in Manitoba, descriptions of the major metallic and ore minerals (including all the sulphides) have been reserved for a separate volume.

The source material for the present volume has been drawn mainly from the published works of government geologists, supplemented by other studies in areas of particular interest. Most of the field descriptions are from geological maps and reports of the Manitoba Government, issued over the past thirty years, but publications of the Geological Survey of Canada (active in Manitoba for the past hundred years) have also proved extremely valuable. These various sources have been acknowledged throughout the text so that geologists or others requiring more detailed information can refer to the original publications.

The twenty-six maps that accompany the text range from simplified geological maps to small locality maps, but all are designed to show where the various minerals can be found. Maps A to M (though not restricted to roadside outcrops) show some areas between the Trans-Canada Highway and the Flin Flon – Snow Lake region that are accessible by road. Maps N to P show areas north of the Grass River Provincial Park and requiring supplementary journeys either by boat or aeroplane. Maps Q to T cover areas further north (Thompson – Lynn Lake regions) that can nevertheless be entered by road transport. Maps U to W are Indian Reserve areas to which regular air services are flown. For the remaining three areas (Maps X to Z) charter aircraft are currently the only means of ready access.

Maps

Plates

PHOTOGRAPHY

Photographic services were rendered by Robert R. Taylor of Environmental Images, Winnipeg. Many of the specimens were kindly lent by Dr. G.E. Lammers, Chief Curator of the Manitoba Museum of Man and Nature.

Figures

Acknowledgements

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Introduction

Rocks are mixtures of various kinds of minerals, either intergrown or held together by some form of natural cement. In coarse-grained rocks the constituent minerals can be easily seen, but in fine-grained rocks they can only be seen under a magnifying lens or microscope. Although well over 2,000 minerals are known, only a few of these are at all common as rock-forming minerals. The Catalogue of Canadian Minerals published by the Geological Survey of Canada records over 70 different minerals at various localities in Manitoba, but there are many more that have not yet been officially catalogued. Owing to the diversity of its geology, Manitoba is in fact well endowed with a great variety of minerals.

To introduce newcomers to the study or collection of minerals, perhaps the simplest approach is through gemstones. Almost everyone knows what a *diamond* is (although it is one of the rarest of minerals), while relatively few are familiar with *feldspar*, the commonest of all minerals. Yet both have the following characteristics:

(i) They are naturally occurring, not man-made; artificial diamonds are not minerals.

(ii) They are inorganic, in contrast to wood, bones or pearls which were formed from organic (living) material.

(iii) They have fixed chemical compositions, just as common salt (which occurs as a mineral in rock salt) consists essentially of sodium combined chemically with chlorine in unvarying proportions.

(iv) They have definite physical properties by which they can be distinguished from other minerals; these properties can be checked by simple tests that help to identify the mineral.

Physical Properties

1. Hardness

A few minerals (such as talc and gypsum) are so soft that they can be scratched with the finger-nail, while others (such as quartz) are so hard they cannot be scratched with a knife; each mineral has its own distinctive degree of hardness. The softest mineral, talc, is said to have a hardness index of 1; the hardest mineral, diamond, is indexed as 10. The full scale is 1 Talc, 2 Gypsum, 3 Calcite, 4 Fluorite, 5 Apatite, 6 Feldspar, 7 Quartz, 8 Topaz, 9 Corundum, 10 Diamond. This is known as Moh's Scale, named after its originator.

2. Specific Gravity

A cupful of mercury (quicksilver) would weigh more than the same cupful of water; in fact it would take about 13½ cups of water to balance the weight of one cup of mercury; this gives the specific gravity of mercury (actually 13.6) because specific gravity is measured against the relative weight of water. But nearly all minerals are solid substances, so how do we go about measuring the specific gravity of gold for instance? One way would be to lower a piece of gold into a measuring cylinder of water and read the graduations to see how much water was displaced. It would then be simple to find out how much that volume of water would weigh. Then by weighing the piece of gold we would find that, if pure, it would weigh about 19 times as much as the same volume of water. If its specific gravity were less than 19 we would know that the metal was not pure gold.

3. Cleavage

Some minerals have the ability to split readily along certain well-defined planes (called cleavage planes). This is well illustrated by mica, the flaky mineral seen in many granitic rocks. A "book" of mica can be easily split along its cleavage planes, almost like separating the pages of a book; or perhaps a sticky deck of cards would be a closer comparison. Some minerals have more than one cleavage direction: feldspar, the commonest mineral in granitic rocks, has two cleavage planes that intersect each other at approximately right angles; they can be seen by tapping a large piece of feldspar with a hammer – the mineral always tends to break along these cleavage planes. This property is one way of distinguishing between feldspar and quartz (also abundant in granite): quartz has no cleavage, so breaks irregularly.

4. Crystal Form

Keen mineral collectors are constantly searching for minerals that show well developed crystalline form. These are not easily found because perfectly shaped crystals are only formed under ideal conditions. However, some minerals develop crystalline form more readily than others, and some rocks (coarse-grained igneous and metamorphic rocks) are more likely than others to show crystals. Pegmatites (as explained in section N) are often favourable for mineral collectors, as their constituent minerals tend to show fair crystal development. There are six crystal systems (fig. 1) each distinguished by its symmetry. Every crystalline mineral belongs to one of these systems, but many variations and complexities of form occur in each system. However, each mineral (except for the amorphous ones) tends to develop certain typical forms within its system. Familiarity with these characteristic shapes is an important aid in mineral identification. The six crystal systems with an example of each are:

Isometric	Garnet (fig. 30)
Tetragonal	Scapolite (fig. 24)
Hexagonal	Quartz (fig. 2)
Orthorhombic	Staurolite (fig. 31)
Monoclinic	Gypsum (fig. 13)
Triclinic	Plagioclase (figs. 5, 6, 7)

5. Streak

Colour is one of the first things to catch the eye when a mineral is first noticed, but colour alone is rarely diagnostic, because many minerals occur in a variety of colours. Also, the weathered surface of a mineral may be quite different in colour from its unweathered core. Fresh material can usually be obtained by hammering an outcrop. If a fresh mineral is rubbed against a hard, white, unglazed porcelain plate or tile, its powder will in many cases leave a streaky mark. If the mineral is harder than the streak-plate, a hard file will usually show the colour of its streak, failing which, very hard minerals may have to be crushed to a powder. The streak, as it is called, remains practically constant for one mineral, regardless of variations in the mineral's apparent colour. The streak may be more significant than the colour and is occasionally diagnostic.

6. Lustre

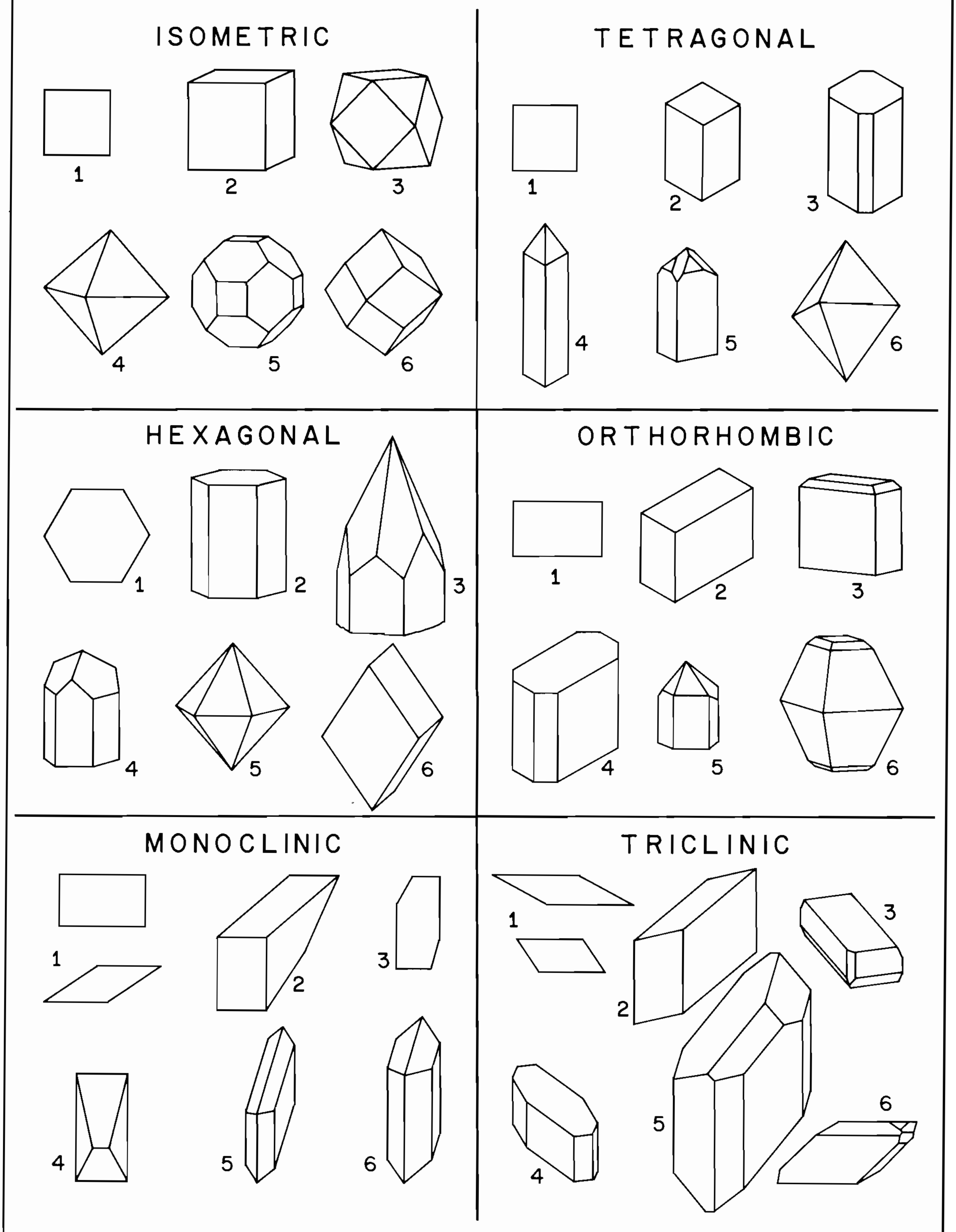
In trying to identify a mineral, it is useful to note whether its lustre is metallic, sub-metallic or non-metallic. Most metallic minerals are more or less shiny because their surfaces, if untarnished, reflect the light just as metals do. The numerous non-metallic minerals show various types of non-metallic lustre – glassy or vitreous like quartz, brilliant or adamantine like diamond, dull or earthy like some clay minerals, and other terms that will be self-explanatory when encountered.

The foregoing physical properties are the bases of mineral identification in the field and are tabulated systematically in mineral identification tables given in various textbooks and guidebooks, such as Dana's Manual of Mineralogy and others. The physical properties and chemical composition of the minerals described are tabulated at the end of this volume.

Chemical Composition

As regards their chemical composition, most rock-forming minerals are silicates. Silicon is a non-metallic element that is very abundant in the earth's crust (27.7% by weight), but occurs only in chemical combination with other elements, especially oxygen. Silica (SiO_2) is the naturally occurring oxide of silicon, best known in its crystalline form as quartz. Silicates, on the other hand, are compounds in which silica is chemically combined with other oxides, mainly metallic ones. Let's take a look first at the silica minerals, then pass on to the main rock-forming silicate minerals, leaving until last some less plentiful groups which, partly because of their comparative rarity, include some minerals of great interest to collectors.

Fig. 1 The Six Crystal Systems



ISOMETRIC: Square cross-sections (1) are typical since the basic form is a cube (2); development of crystal faces across the corners (3) can result in the octahedron (4), modifications of which (5) lead to the dodecahedron (6); there are many other forms but cube-like or ball-like shapes, and square or symmetrically triangular faces are characteristic; see also figures 30 & 36.

TETRAGONAL: Stretching a cube leaves two square end-faces or pinacoids (1) and four rectangular faces known as prisms (2); other prismatic faces can develop down the edges of the rectangles (3); pyramid faces can develop at the ends of the prisms (4 & 5), and in the absence of prisms these can result in dipyramids (6); long prisms terminated either by square or 8-sided pinacoids, or by pyramids, are characteristic; see also figures 24, 27 & 34.

HEXAGONAL: The symmetrical 6-sided cross-section (1) also represents a pinacoidal face at the end of a hexagonal prism (2), but pyramids often develop instead at the ends of the prisms (3 & 4), and hexagonal dipyramids are also possible (5). The rhombohedral division of the hexagonal system has only three fold (instead of sixfold) symmetry, and is typified by the rhombohedron (6) from which many variations are derived, especially in calcite; see also figures 2, 11, 12, 25, 33 & 42.

ORTHORHOMBIC: Rectangular cross-sections are characteristic (1) but square faces are absent since the basic shape is that of a brick (2); hence 6 rectangular faces are theorectically possible but their edges are frequently bevelled off by dome faces (3) or additional prism faces (4); prisms may impart either elongated or boxy shapes, and are often terminated by pyramids (5); dipyramids are not uncommon, here illustrated by a sulfur crystal capped by pinacoid faces (6); see also figures 14, 15, 17, 28, 31, 32, 35, 40 & 41.

MONOCLINIC: The basic shape may be visualized hypothetically as a brick-shaped block that has been deformed in one direction only, so that one of the three pairs of opposite faces is no longer rectangular (1 & 2); natural shapes may be blocky, stubby or platy, and opposite matching faces are possible (3 & 4); prisms and pinacoids may be well developed as in the gypsum crystals illustrated (5 & 6); there are many variations, some of them shown in figures 3, 8, 9, 10, 13, 18, 19, 21, 22, 23, 26, 38, 39 & 43.

TRICLINIC: crystals lack right angles on faces and edges, and only opposite, parallel faces can match each other (1); a few minerals may show blocky habits, but sharp-edged, wafer-like shapes are more typical (2 to 6); see also figures 4, 5, 6, 7 & 29.

Quartz and other Silica Minerals

1) Typical quartz crystals (Museum)

2) Smoky quartz from Bernic Lake

Silica occurs in nature in many different forms, of which quartz is the most widespread. Collectors will also be interested in amethyst, opal, agate, and jasper. The silica minerals can be better understood, however, if we classify them as either strongly crystalline (quartz) or weakly to non-crystalline (mainly chalcedony).

(a) Strongly crystalline silica minerals

Quartz (plate 1) is the hard, usually colourless to white mineral with glassy lustre, seen abundantly in:

(1) siliceous igneous rocks such as granite
(2) sedimentary rocks such as sandstone
(3) metamorphic rocks such as quartzite and gneiss

Quartz is also conspicuous in quartz veins and pegmatites (section N), and altogether makes up about 12 per cent of the earth's crust. The best formed crystals are found in geodes. These are rock-cavities lined with inward-projecting crystals. Such crystals may be six-sided with pyramidal end-faces (fig. 2), though the full crystalline form is rarely seen. Clear, colourless quartz crystals were much used in past centuries as gemstones, and massive transparent quartz (known as *rock-crystal)* was carved and polished in ancient Greece as ornamental bowls and vases. Flawless transparent quartz crystals are used nowadays for optical and piezoelectrical applications (see Tourmaline). Such crystals, and other coloured varieties, including *amethyst* (purple) and *citrine* (yellow), are widely used as relatively inexpensive gemstones. Commercial uses of silica are: as the chief constituent in glass; as metallurgical flux; in the manufacture of silicon carbide; as an ore of silicon and ferrosilicon; as foundry sand for metal castings; in sand blasting; and as a filler material in tile, asbestos pipe, concrete and bricks. Quartz sand is sometimes used in cement and mortar, and powdered quartz is used in pottery, porcelain, fused silica-ware, paints, scouring soaps and sandpaper. Unusually pure and friable *quartz sandstone* of Ordovician age is quarried as a source of high-grade silica sand on Black Island in **Lake Winnipeg** (Map C) and is processed at Selkirk by Steel Brothers Canada Limited; this sand is used in glass manufacture, as foundry sand, filter sand and blasting sand.

The distribution of *quartz* in Manitoba is so widespread as to make it one of the easiest minerals to study in the Precambrian regions of the province. Good places to look for specimens would be granitic contact zones where pegmatites are plentiful. In looking for the rare pegmatitic minerals (described on subsequent pages), a collector would be sure to come across a great deal of quartz which may be clear, white, milky, smoky or almost black. Likely areas in **the southeast** include zones east of the northeast shore of Lac du Bonnet, along the Winnipeg River, and northwest of West Hawk Lake.

Some of the finest museum specimens of quartz are of a smoky variety; the smoky appearance is due to microscopic fluid inclusions. *Smoky quartz* (plate 2) varies in colour from yellowish to dark brownish or black (then called morion) and is semi-transparent, but always with a smoky hue. Black quartz with a glassy lustre occurs in Manitoba's **Whiteshell Park** at the Huron pegmatite (Map C), located about 1,000 yards west of Greer Lake and reached by trail from the Winnipeg River. Black quartz crystals have also been found at the Bernic Lake pegmatite mine of Tantalum Corporation of

3) Rose quartz from Birse Lake

4) Typical specimen of jasper (Museum)

5) Typical agate pebble from Souris

Canada Limited (Map C). Both these occurrences are further described under the heading of Pegmatitic Minerals.

Rose quartz (plate 3) is a pale pink to deep rose-red variety, sometimes transparent, that occasionally forms quite large masses in certain pegmatites. The rose colour is caused by numerous tiny, needle-shaped crystals of rutile that developed during crystallization of the quartz. A pegmatite near **Birse Lake** (Map C), contains one of the few sizable deposits known in Canada. The rose quartz is deep pink with an opalescent lustre and has been used as an ornamental stone. It occupies pockets, some several feet in length, within a large pod-shaped mass of white, smoky and banded quartz; the whole quartz mass forms the core of a pegmatite dyke, and is exposed for over 100 feet. *Topaz* (see Pegmatitic Minerals) is also present in minor amounts. The deposit was originally staked in 1927 and is privately owned; hence it could not be visited except by prior permission of the lease-holder.

Small stringers of *rose quartz* have been observed south and southwest of Suwanee Lake (Map S), and other minor occurrences have recently been noted near Russell Lake South, **northern Manitoba.**

References: Barry & Gait 1966; Davies 1954, 1957; McRitchie 1971b, 1975; Phillips 1975; Sabina 1963.

Some of the best *quartzite* outcrops in Manitoba are those east of the port of **Churchill.** They are cut by quartz veins, a few of which contain small amounts of the rare blue phosphate mineral, *lazulite* (see plate 54), known elsewhere as a minor gemstone. Occurrences have also been observed near the Cape Merry historic site northwest of Churchill (Schledewitz, pers. com.).

(b) Other silica minerals

Chalcedony is a general name for the several varieties of crypto-crystalline quartz. Chalcedony is identical to quartz in chemical composition, but differs in appearance and mode of occurrence. This is because chalcedony forms at temperatures too low to permit good crystalline development. A typical mode of occurrence is as crusty aggregates that line or fill rock-cavities. These aggregates show curved surfaces described as reniform (kidney-like) or botryoidal (grape-like); they usually have a waxy lustre and may be dull greyish, bluish or almost colourless. Coloured and banded varieties of chalcedony, often opaque, have long been polished to make attractive ornaments, but the non-ornamental varieties, especially chert, are much more abundant.

Chert is a pale greyish to black, opaque form of chalcedony found as large nodules in limestone and as extensive bedded deposits with volcanic rocks. Both types of deposit occur in Manitoba. Strikingly banded outcrops of pale chert and dark "ironstone" make up the rock known as cherty iron formation in the Precambrian regions. Good examples can be seen east of **Bissett** at Wallace Lake (Map D), especially on the main island, adjacent peninsula and northerly shores. The cherty iron formation is associated with altered volcanic and sedimentary rocks. The association of chert with limestone or dolomite is not unusual in the Palaeozoic rocks of southern Manitoba. Grey *chert* nodules along the dolomite bedding planes at Cat Head, on the west shore of **Lake Winnipeg** (10 miles west-southwest of Commissioner Island), are as much as a foot in length. The 40-foot thick exposure of dolomite is the type-section for the Cat Head Member of the Ordovician Red

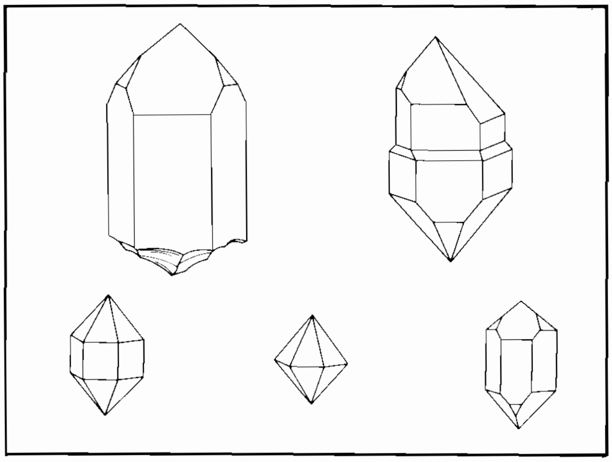


Fig 2: Quartz

River Formation, but is not readily accessible except by boat. More accessible examples are to be seen in other members of the Red River Formation, as at the Tyndall-stone quarries of the **Garson** district (Selkirk Member). This well known building stone contains many impure chert nodules two or three inches in length but considerably altered to soft white material. The quarry of Mulder Bros. Sand and Gravel Limited, some 5½ miles northeast of **Stony Mountain** (Map E) shows bedded dolomite (Fort Garry Member) containing chert nodules underlain by a bed of red shale. An abandoned quarry 3 miles south of Hodgson and north of **Fisher Branch** showed many small chert nodules in thin-bedded dolomite of the Gunton Member; a decorative "marble" was quarried there many years ago by Winnipeg Marble Quarries Limited. This old quarry is on the east side of provincial road 224, near the railway crossing.

Typically hard, grey to bluish *chert* nodules can be found at Denbeigh Point in the northeast corner of **Lake Winnipegosis,** accessible via provincial road 327. The nodules occur along bedding planes near the top of the Interlake Dolomite of Silurian Age. No large outcrops are known, but chert rubble is plentiful near the fishermen's jetty. The chert appears to be widely distributed as it is also abundant on the beach at Devil Point on the opposite (west) shore of Lake Winnipegosis, near Grand Island (McCabe, pers. com.).

Jasper (plate 4) can be regarded as chert that contains enough impurities to render it opaque and distinctly coloured. The impurities are mainly iron oxides, which form up to 20 per cent of some jasper, giving the typical red or brown colorations. Jasper may show colour-banding, and has been used as ornamental stone since ancient times. Specimens can be found at the Souris gravel pit, about three quarters of a mile east of **Souris** on Highway 2 in southwest Manitoba. The Souris gravel and sand deposit differs from the typical glacial gravels of this region in that it contains a large proportion of pre-glacial material brought in from the Rocky Mountain regions by streams that existed before the (Quaternary) Ice Age. About a quarter of the pebbles at Souris gravel pit are chert, jasper or agate; about a fifth are quartz and volcanic or associated rocks; the rest are mainly from metamorphic rocks such as quartzite and argillite. Some of the jasper and chert nodules weigh several pounds; they occur in various colours, while some are banded.

Agate is a sub-variety of chalcedony, usually found as nodules, and distinguished by attractive colour-banding. The different coloured bands or layers are concentric to the shape of the nodule, the centre of which may be occupied by quartz. The agate pebbles in the **Souris** pit (plate 5) are generally less than four inches across. They show various colours and patterns, including yellow, light blue with black inclusions, clear with red or white inclusions, banded and jet black.

Opal shows no crystallinity under the microscope and can be regarded as hydrous, non-crystalline silica, formed from a silica gel and containing variable amounts of water. The name opal apparently originated from an ancient Sanskrit word (upala) meaning precious stone. Precious opal was considered of great value by the Romans and until the nineteenth century first-class gemstones were valued as highly as diamonds. The decline from this status followed the discovery of relatively abundant gem sources in Australia, and perhaps also a more general realization of the tendency of opal to crack as a result of dehydration in dry climates. Precious opal and fire-opal are characterized by a brilliant play of colours, usually against a milky or other pale, translucent background. Other varieties include wood opal, milk opal, and moss opal. Common opal is white, colourless or weakly coloured, but impurities can cause darker colours. The somewhat pearly or milky appearance is called "opalescence". Opal is not prominent at the **Souris** pit but occurs with agate in silicified wood, some of which is coloured red to brown and black; some specimens weigh up to ten pounds and larger ones have occasionally been recorded. The handiest way to distinguish between opal and agate would be by means of the hardness test: opal has a hardness of 5 to 6 and can be scratched by a hard steel knife or a sharp-edged piece of quartz, whereas agate has approximately the same hardness as quartz (7). *Opal* has lower specific gravity (1.9 to 2.2) than agate (2.6), and if heated strongly in the laboratory would yield water.

Permission to enter the Souris pit to collect material there is obtainable from the rock and agate shop at Souris, upon payment of a small fee. A 30-acre park with modern campground is situated within a mile of the gravel pit.

References: Baillie 1952; Klassen 1969; McRitchie 1971c; Phillips 1975.

The Feldspars

The feldspars are quantitatively the most important rock-forming minerals as they make up about 60 per cent of the earth's crust and are the dominant mineral in most igneous and many metamorphic rocks. In general, their colour is whitish, greyish or pale shades of red. Their hardness is about 6 and their specific gravity ranges from 2.5 to over 3. They crystallize in either the monoclinic or triclinic system, usually in blocky or tabular-shaped crystals, and they have two principal cleavages intersecting nearly at right angles. Feldspar crystals may grow to a large size: coarse granite at Utik Lake has feldspars up to a foot in length; pegmatite 2 miles southwest of Beau-Cache Lake contains feldspar crystals as much as 4 feet long. Giant pegmatitic feldspars at the Bernic Lake (TANCO) mine reach dimensions up to 8 x 5 feet. Feldspars are essentially silicates of aluminum with variable proportions of potassium, sodium and calcium (rarely barium). These variations cause differences in the microstructures of the feldspars, and a microscope is used if precise identification is required. As the classification of the igneous rocks depends to a large extent upon what kind of feldspar they contain, microscopic determinations of feldspar are frequently made. The feldspars are also found abundantly in metamorphic rocks such as gneiss and migmatite. The feldspars grade into each other, and some crystals show microscopic intergrowths of more than one kind of feldspar. However, there are three well marked end-members as follows:

ORTHOCLASE ($K_2O \cdot Al_2O_3 \cdot 6SiO_2$	potassium aluminum silicate ("potash feldspar")
ALBITE ($Na_2O \cdot Al_2O_3 \cdot 6SiO_2$)	sodium aluminum silicate ("soda feldspar")
ANORTHITE ($CaO \cdot Al_2O_3 \cdot 2SiO_2$)	calcium aluminum silicate ("lime feldspar")

References: Cerny & Macek 1972; Milligan 1951; Milligan & Take 1954; Phillips 1975.

The *alkali-feldspars* (orthoclase, microcline, albite) are used in glass manufacturing to supply alumina, potash and soda, but have been considerably replaced in recent years by nepheline syenite which contains more alumina. They are also used for the making and glazing of pottery, in enamels for household utensils, tile, porcelain-ware and other ceramic uses. Potash feldspar is essential in the manufacture of electric porcelain for high-voltage purposes. Dental spar is pure white potash feldspar used in the manufacture of artificial teeth. Other uses for alkali-feldspar are as a flux coating on welding rods, and as a moderate abrasive in cleaning compounds. Other (soda-lime) feldspars are unsuitable for fusion because they form crystals after being fused, whereas the alkali-feldspars cool to a solid glass. Commercial feldspar is quarried from pegmatites and the potassium-rich varieties are most in demand. Some soda-lime feldspars, however, especially *labradorite,* may show an attractive play of colours, best seen on polished slabs; rocks containing such feldspars are used as decorative stone in public buildings. Labradorite was known to the Eskimos as "fire-rock", and worn ornamentally by their chiefs; it can yield excellent gemstones showing striking inter-plays of blue, green, gold and copper-bronze colours. *Moonstone* is another feldspar gemstone (mainly orthoclase) which, when cut and polished, shows a delicate play of colours; it is distinguished by its pearly lustre and opalescent reflection. *Sunstone* owes its golden sparkling effect to minute, wafer-like inclusions of other minerals that reflect the light from crystals of feldspar, especially oligoclase. *Amazonstone* is a green gemstone of microcline described subsequently.

Orthoclase (fig. 3) is a monoclinic potassic feldspar (plate 6) found in many granitic rocks. A granite quarry on the south side of the Trans-Canada highway, adjoining the fire watchtower near East Braintree (70 miles east of Winnipeg), shows some well formed, buff-weathering phenocrysts of orthoclase an inch or two in diameter. The crystals are scattered randomly in pink pegmatitic lenses that also contain smoky quartz. Microscopically, the orthoclase shows partial conversion to microcline. Another occurrence is in granite porphyry south of Elbow Lake (4 miles northeast of Bird Lake) in **southeast Manitoba** (Map C). The orthoclase occurs as pink to brown and grey rectangular phenocrysts up to one inch in length. This granite extends southeast across the Ontario border 2

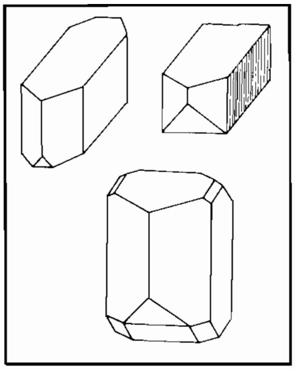


Fig. 3a: Orthoclase

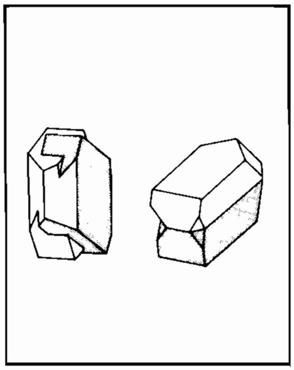


Fig. 3b: Orthoclase twins

miles north of provincial road 315, and thins out to the northwest 1½ miles northeast of Cat Lake. In another example, 80 miles northwest of Churchill, phenocrysts of orthoclase (up to 1½ inches) occur in pink porphyritic granite northeast of Caribou Lake. Orthoclase grades into microcline in the Mynarski-Notigi Lakes area of **northern Manitoba.**

References: Davies *et al* 1962, p.129; Elphick 1972; Manitoba Mines Branch 1965; Springer 1949; Traill 1970.

Microcline (fig. 4) is more abundant than orthoclase in the Canadian Shield. It is a triclinic potassic feldspar identical in composition to orthoclase, but distinguishable from it under the microscope. Pink microcline is a major constituent of certain coarse granite found in the **Lac du Bonnet** quartz monzonite pluton, which is well exposed along the south shore of Lac du Bonnet and southward along the Winnipeg and Lee Rivers (Map B). Coarse-grained granite northwest of Glenn (Map A) is made up mainly of microcline and quartz. Large microcline crystals are an outstanding feature of the pink porphyritic granodiorite that occupies the south shore of **Falcon Lake** (Map A) and extends some miles to the south and southwest. The coarse pink porphyritic granite 4 miles west of West Hawk Lake is characterized by large pink *microcline* phenocrysts; the same rock occurs at the southeast end of Falcon Lake. Much microcline (and other feldspars) occurs in the granitic rocks of the **Bissett** region, e.g. around Manigotagan Lake (Map D). In northern Manitoba, extensive microcline granite has been recorded around **Rat Lake** (Map S); each microcline crystal is surrounded by quartz, giving the outcrop surfaces a "brick and mortar" appearance. Much of the microcline encountered in Manitoba is pinkish or flesh-coloured. Many microcline crystals contain microscopic streaks and blebs of intergrown albite; they are then called *perthitic microcline* or microcline-perthite (plate 7); the giant feldspars at **Bernic Lake** are of this type, as described by Cerny & Macek (1972). A somewhat rare, bright green variety of microcline called *amazonstone* (plate 8) is attractive as an ornamental or gemstone, and has been recorded in pegmatites near **Sherridon** and west of Wood Lake (Map O).

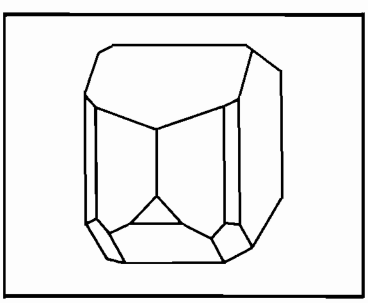


Fig. 4: Microcline

References: Cerny & Macek 1972; Davies 1954; McRitchie 1971b; Robertson 1953; Schledewitz 1972; Springer 1952.

Albite (fig. 5), the sodic feldspar, is closely associated with microcline at the **Greer Lake** feldspar quarry (Map C). The quarry exposes part of a pegmatite body (see Pegmatitic Minerals) composed mainly of pink feldspars with some quartz and mica. The feldspars, which are found in large crystals and clusters several feet across, consist of both albite and microcline. Intricate intergrowths of these two alkalic feldspars (as in many granites and pegmatites) may be called *perthite.* Perthite is a general term for an intergrowth of albite or oligoclase in orthoclase or microcline; the sodic feldspar is generally subordinate in quantity. Some pegmatites on the north side of **Cat Lake** (Map C) consist largely of brick-red *albite* with minor quartz; these pegmatites (Irgon claim) contain cavities that are lined with well formed crystals. There is a great deal of albite in the **Bernic Lake** pegmatites, as exposed in the open-cut at the east end of the lake. Some of the albite in the Bernic Lake TANCO mine is the white platy variety named *cleavelandite* (plate 9). Bands of cleavelandite up to one foot thick occur in the Silver Leaf pegmatite (Map C). Further information about these occurrences is given under Pegmatitic Minerals.

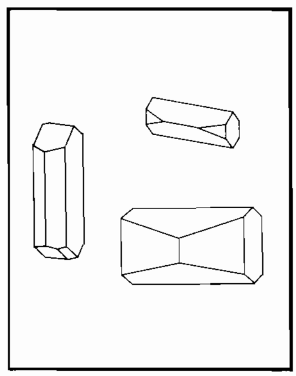


Fig. 5a: Albite

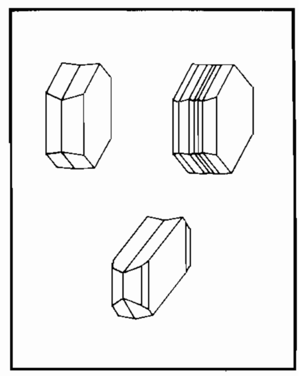


Fig. 5b: Albite twins

References: Cerny & Macek 1972; Cerny & Turnock 1971; Crouse & Cerny 1972; Davies 1957; Sabina 1963.

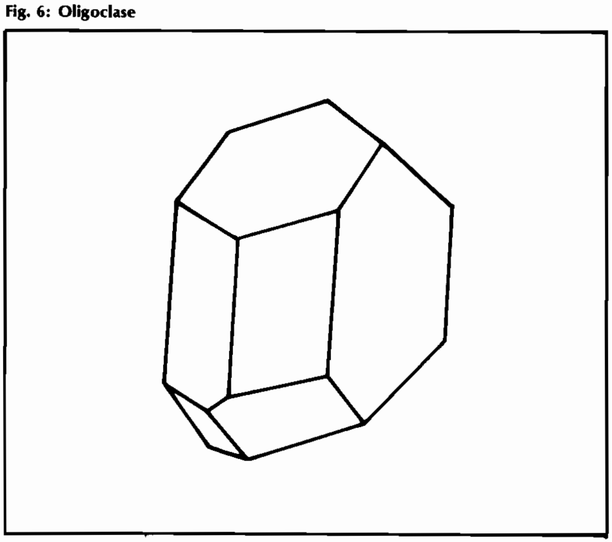
Albite and anorthite are the two end-members of a gradational series called the **Plagioclase** or soda-lime feldspars (plate 10). Albite, oligoclase and andesine contain more soda than lime, while labradorite, bytownite and anorthite contain more lime than soda. Just as the alkali-feldspars (including oligoclase) are typically found in the light-coloured igneous rocks such as granite and rhyolite, so the lime-rich plagioclases (labradorite, bytownite and anorthite) are characteristic of the darker rocks of higher specific gravity such as gabbro and basalt. Andesine is typical of the intermediate igneous rocks such as diorite and andesine.

References: Phillips 1975; Traill 1970.

Oligoclase (fig. 6) is a major constituent of many granitic rocks. In Manitoba granites it is often subordinate to microcline, but generally equals or exceeds microcline in the quartz monzonites and granodiorites. These feldspars can be seen in the **Lac du Bonnet** pluton (Map B). The bulk composition of pink quartz monzonite east of Lac du Bonnet is approximately 30% microcline (crystals up to 2 cms in length), 30% oligoclase (mostly in smaller crystals), 30% quartz, and the rest mainly dark mica. Two or three miles from Pointe du Bois, however, provincial road 313 leaves the Lac du Bonnet pluton and crosses grey gneissic granodiorite in which the prominent feldspar is grey or white *oligoclase*. In the **Whiteshell Park** (Map A) similar oligoclase-rich granodiorite occurs between West Hawk and North Cross Lakes; this grey, granite-like rock, containing about 45% oligoclase, 30% quartz, 10% microcline and 10% dark mica, is well exposed in a roadside quarry (provincial road 44) 2 miles northwest of **West Hawk Lake.**

References: McRitchie 1971a, 1971b; Springer 1952; Wright 1932b.

Fig. 6: Oligoclase



Andesine, which contains slightly more soda than lime, is also widely distributed, especially in the tonalites, diorites and andesites of Manitoba. It is well displayed in the black and white diorite found in the outer zone of the **Falcon Lake** stock (Map A): the white mineral that makes up three quarters of this diorite is coarse andesine, in crystals up to half an inch long. The feldspar of the quartz diorite along the south shore of High Lake (Map A) is again andesine; this dark grey to black rock forms a small stock, partly straddling the Ontario border; some of its quartz is the dark bluish variety. Small intrusions of quartz-feldspar porphyry in the West Hawk-Falcon Lakes area (Map A) are composed of andesine (grading to oligoclase), quartz and dark mica. The porphyry is characterized by numerous stubby feldspar tablets and small, bluish quartz "eyes". This rock is exposed at the south tip of Star Lake, and at the eastern extremity of Falcon Lake. The andesites between Falcon and West Hawk Lakes also contain major amounts of andesine, in tiny plates and laths that can rarely be seen without magnification. Immediately east of **Bissett,** however, well formed phenocrysts of *andesine* are conspicuous in greenish andesite porphyry which forms a prominent, 3-mile-long ridge along the south side of provincial road 304 (Map D).

References: Davies 1950, 1954; Gibbins 1971; Springer 1952.

Labradorite, which contains slightly more lime than soda, is typical of the gabbros and basalts. Its colour varies from light to dark grey and some specimens show blue or green irridescence (plate 11) which may render them attractive as ornamental or gemstones. Labradorite is a major constituent of the gabbro that occurs in the outer zone of the **Falcon Lake** stock (Map A). It is a coarse-grained black rock, in contrast to the black and white mottled diorite. The gabbro that forms part of the **Bird River** sill (Map B) also contains a great deal of labradorite. Outcrops can be found at the west end of Bird Lake (Map C), and for 5 miles to the west along provincial road 315. The commonest type of gabbro is coarse-grained, dark green, and has large plates and tablets of grey plagioclase, but some outcrops consist almost entirely of coarsely crystalline labradorite. Mottled gabbro with large patches of white plagioclase is a distinctive variation. In a few outcrops the *labradorite* forms perfectly rounded clusters up to 5 inches in diameter. A small outcrop of this type occurs on the north shore of Bernic Lake between the narrows and the central islands. Fresh, well formed phenocrysts of labradorite are conspicuous in a speckled basalt porphyry (compare plate 10) east-southeast of **Rice Lake** (Map D). The milky white phenocrysts are set in a fine-grained black groundmass.


6) Othoclase from railway cutting, southern Whiteshell area


7) Perthite from quary northwest of West Hawk Lake


8) Amazonstone (Museum)


9) Cleavelandite from Bernic Lake


10) Plagioclase phenosrysts in basalt porphyry from Utik Lake


11) Ornamental labradorite from Labrador (Museum)

Labradorite is also found in many gabbroic intrusions throughout northern Manitoba. One example is in quartz gabbro on the south side of Herb Bay, **Wekusko Lake** (Map K); a porphyritic phase of the rock contains phenocrysts of *labradorite* up to 2 inches long. The **Lynn Lake** gabbro (Map T), from which nickel-copper orebodies have been mined, contains labradorite grading to andesine. Similar gabbro occurs south of **Barrington Lake** (Map S).

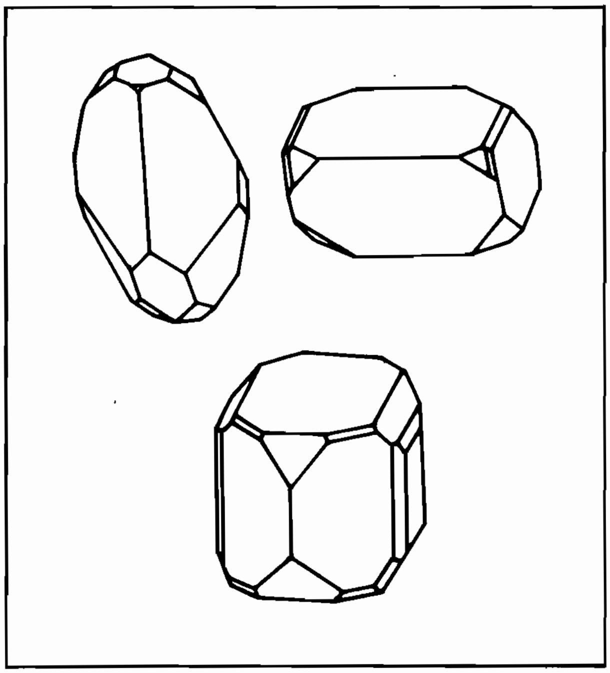
References: Davies 1950, 1952, 1954; Gibbons 1971; Milligan 1960; Russell 1957; Traill 1970.

Bytownite and **Anorthite** (fig. 7), the lime-rich plagioclases that contain only minor amounts of soda, are much less common but have been recorded in basic rocks called anorthosite in the **Bird River** sill (Maps B & C). The anorthosites are very coarse, pale grey rocks related to gabbro but composed almost entirely of plagioclase (more than 90% of the rock). Variations in composition are found even in individual crystals; the core may be bytownite or anorthite while the rim can be labradorite or even andesine.

In northern Manitoba bytownite and anorthite have been reported in gabbro at **Goodwin Lake** (Map S), 5 miles east of the Suwanee River road-bridge. The gabbro shows black hornblende-rich layers containing up to 60% *bytownite,* and grey layers with olivine and pyroxene in which bytownite grades to *anorthite.* The plagioclase does not form particularly large or well-shaped crystals however.

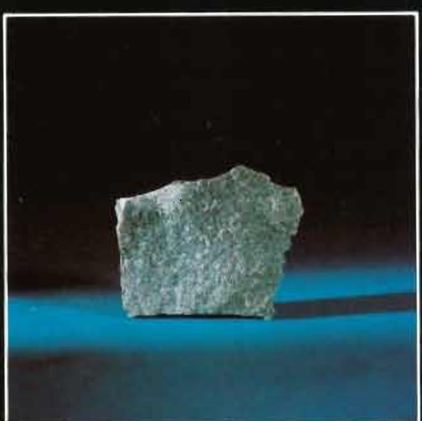
References: Schledewitz 1962; Trueman 1971.

Fig. 7: Anorthite



12) Muscovite book from Greer Lake quarry

13) Fuchsite from old workings near Lamprey Falls



14) Fine-grained lepidolite from Bernic Lake

Mica, Chlorite and Graphite

These three distinct mineral groups are described under the same heading because, owing to their very strong cleavage, all have a marked tendency to form thin leaves, flakes or scales, and all occur characteristically in foliated rocks, especially schists. The micas are alkali-hydroxyl-alumino-silicates, with or without iron or magnesium. The chlorites are hydrated alumino-silicates that lack alkalis but are rich in iron and magnesium. Graphite is composed simply of carbon.

THE MICAS crystallize in the monoclinic system. Their specific gravities range from 2.7 to 3.1 and the average hardness is about 2.5. Their flakes are not only flexible but also elastic, causing them to snap back to their original shape if bent and released. The most widespread rock-forming micas in Manitoba are:

(a) Muscovite (igneous) and sericite (metamorphic), both of which are potassium-rich "white micas";
(b) Biotite, the dark brown to black, magnesium-iron mica.

The micas are abundant in both igneous and metamorphic rocks. As regards their igneous associations, both are typical in granite and pegmatic, but biotite extends also into the more basic rocks, such as diorite and even gabbro, whereas muscovite tends to be restricted to the granites and especially the pegmatites. Sericite is a common alteration product resulting from the metamorphic breakdown of potassic feldspars, while secondary biotite is formed from the breakdown of ferromagnesian minerals (i.e. those rich in iron and magnesium). Other, less common varieties of mica that occur in Manitoba will be introduced subsequently.

References: Phillips 1975; Traill 1970.

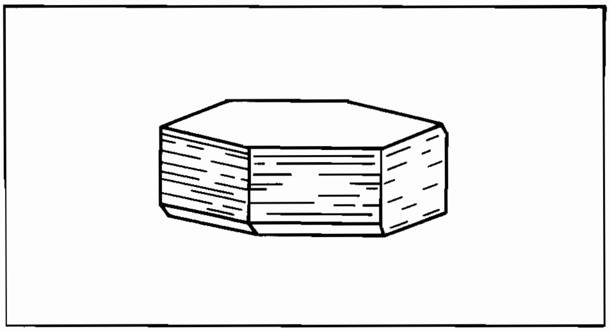


Fig. 8: Muscovite

Muscovite (fig. 8) used to be popularly known as Muscovy-glass in the days when transparent sheets were used as windows in Russia (Muscovy). Not so long ago it was used (as isinglass) in stove doors and lanterns, and more recently became indispensable as electrical insulating material. Natural sheet-mica is used in electrical and electronic equipment and appliances, but built-up sheet has taken its place for many purposes: mica-splittings are bonded together to make flexible insulating material in the form of sheet, tape and cloth; built-up sheet can be cut or moulded into washers, tubes and many other forms. Mica-paper and mica-board have been developed as substitutes for built-up sheet, using ground mica and a binder. Ground mica is also used for dusting asphalt products and rubber tires; as a filler in plastic products, hard rubber, sealing compounds and some paints; as a mould lubricant, and for minor decorative purposes (wallpaper). Since 1966 Canada has imported all of its industrial mica.

Muscovite (plate 12) is abundant in pegmatitic granite around the north shore of **Greer Lake** (Map C) and the south shore of the **Winnipeg River.** Coarse-grained phases of this granite contain concentrations of pale grey and amber mica in the form of "sunbursts" (spherical forms consisting of blades radiating from a centre), plumes (bundles of radiating blades), multiple crosses (blades crossing each other in various directions), groups of randomly oriented blades and forms resembling cedar boughs. Faintly banded parts of this granite show thin trains of muscovite, some of it pale yellowish green. Unusually coloured muscovite occurs in some pegmatites: some muscovite on the Silver Leaf property (Map C) is purplish grey owing to the presence of small amounts of lithium; this mica is found in veinlets and as rosettes up to 2 inches in diameter. Similarly, muscovite in the Annie pegmatite is silvery grey and pale lilac; the flakes are strongly curved, some almost hemispherical (Map C). Other details of these pegmatites are given under Albite, Lepidolite, and Pegmatitic Minerals. In northern Manitoba, dykes of muscovite-pegmatite cut the altered volcanic rocks around **Southern Indian Lake.**

References: Davies 1957; Davies *et al* 1962, p.124; Sabina 1963; Traill 1970.

Sericite (see plate 56) is a fine-grained form of muscovite that is typically found in sericite schist, a striking rock with silvery lustre when fresh. Because such rock is relatively soft and easily weathered, it does not usually form large outcrops but good specimens can be found as waste-rock from some excavations. Well documented occurrences have been described at:

(i) **Flin Flon** copper-zinc mine (Map H), where *sericite* schist is the host-rock for some of the ore;

(ii) Schist Lake copper-zinc mine (Map H), where the host-rock is again sericitic schist;

(iii) Anderson Lake copper-zinc mine (Map K), a few miles south of **Snow Lake;** (N.B. Due to safety regulations, visitors are not permitted at operational mines except by special permission, but there is an accessible outcrop of *sericite* schist exposed by the railway cutting 500 yards east of this mine);

(iv) the old Kiski (gold) mine, near the east shore of **Wekusko Lake** (Map K), 2¼ miles south of Herb Lake settlement (now a ghost town); one of the host-rocks at this mine was quartz-feldspar porphyry from which some *sericite* schist was formed as an alteration product; access is by boat from the Government Dock (Map K) just off provincial road 392, but the 8-mile lake crossing should only be attempted in calm weather.

References: Davies *et al* 1962, pp.64-91; Sabina 1972.

Fuchsite (plate 13) is a green, chrome-bearing variety of muscovite, rarely found in sizeable concentrations. Flakes of fuchsite were found in a narrow band of quartzose rock near Lamprey Falls on the **Winnipeg River** (Map C), and in 1926 about 150 tons of fuchsite rock were transported from a deposit south of the Falls. A road was built from the quarry for ¾ mile to the river whence the rock was shipped to Pointe du Bois en route to Winnipeg for use as stucco dash. The rock contains bright emerald-green lenses and streaks a few inches wide, composed of *fuchsite* flakes. The brilliant green mica made up perhaps five per cent of the siliceous rock for a width of 15 or 20 feet and a length of 50 feet. In eastern Manitoba, shear zones in volcanic rocks on several small islands near the south shore of **Oxford Lake** (lat. 54° 47'30"; long. 95° 39') contain fuchsite and quartz-carbonate veinlets (Map W).

References: Barry 1960; Davies 1957; Wright 1932a.

Lepidolite (lithia mica) is a lithium-rich mica (plate 14) occurring in granite pegmatites, usually in association with other lithium minerals. It can often be distinguished from the white mica by its striking violet or lilac colour, but it may be yellowish, greyish or even white. Because lepidolite grades in composition from muscovite, there are intermediate varieties, principally *lithian muscovite.* Lepidolite is used as a source of lithium compounds. In particular, it increases the strength of ceramic articles and inhibits their expansion; it is used for non-shattering glass and is a good opacifier for white opaque glassware. Other lithium applications are given under Spodumene (Pegmatitic Minerals).

Lepidolite occurs in the Deer pegmatite immediately southwest of **West Hawk Lake** (Map A). At Bernic Lake, lepidolite is less abundant than lithian muscovite in the TANCO pegmatite (Map C), which consists of quartz, feldspar, mica and other minerals. About 600 yards east of **Bernic Lake** there is a disused open-cut, formerly worked by the Lithium Corporation of Canada, where lepidolite and other minerals can be found in the pegmatite. There is another well documented occurrence of lepidolite (Map C) at the Silver Leaf pegmatite property (formerly worked for lithium) which is located at the side of a hill 1¼ miles south of the **Winnipeg River**; the trail to the deposit leaves the Winnipeg River 4¾ miles east of Lamprey Falls. The pegmatite consists mainly of feldspar, quartz and muscovite, but some massive lilac-coloured rock is composed almost entirely of lepidolite; associated minerals are quartz and cleavelandite. Other interesting minerals at these localities are described under Pegmatitic Minerals.

In northern Manitoba a few of the numerous pegmatite dykes that intrude migmatite 4 to 6 miles west of Cross Island in the **Cross Lake** area contain *lepidolite.* Also at **Red Cross Lake,** 40 miles northeast of Gods Lake, some pegmatite dykes contain fine-grained purple lepidolite.

References: Bell 1962; Davies 1957; Jambor & Potter 1967; Rinaldi, Cerny & Ferguson 1972; Rowe 1956; Sabina 1963; Traill 1970.

Zinnwaldite, an iron-lithium mica intermediate in composition between biotite and lepidolite, is found with the lithium micas at the **Bernic Lake** (TANCO) pegmatite mine. At the Silver Leaf pegmatite (Map C), grey zinnwaldite (plate 15) accompanies coarse lilac-coloured mica and fine-grained purple lepidolite. Davies has described large masses of zinnwaldite in a pegmatite dyke near the south shore (east end) of **Shatford Lake** (Map C):

> "Much of the zinnwaldite occurs as large circular forms or wheels with a convex upper surface. Each wheel is composed of individual tapering books with hexagonal and rhombic curved surfaces. These books taper towards the centre of the wheel. The zinnwaldite is smoky grey in colour with a slightly metallic lustre."

Other information is given under Pegmatitic Minerals.

References: Davies 1957; Sabina 1963.

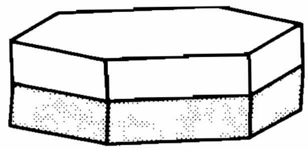


Fig. 9: Biotite

Biotite (fig. 9) is a very common rock-forming mineral in the Precambrian rocks of Manitoba. The largest flakes are to be found in pegmatite (plate 16) but the dark mica is most abundant in biotite schist. Thin bands of biotite schist occur in the altered sedimentary rocks on the east and west shores of **West Hawk Lake** (Map A), and coarse biotite flakes are found in pegmatitic veins that cut across them. Similar veins occur near Toniata Beach on the north shore of Falcon Lake. Large flakes of biotite are abundant with microcline and quartz in the coarse pink pegmatite that forms roadside outcrops northwest of West Hawk Lake. The pink porphyritic granite further west is of similar composition. Biotite is also abundant in the grey granite of this area (Map A), which is well exposed in a roadside quarry immediately north of the pegmatite. Forty miles to the north, large books of biotite occur at the **Greer Lake** feldspar quarry (see Albite), where mica is very prominent (Map C).

In northern Manitoba, biotite schist is common in the altered sedimentary rocks that are widespread to the east and northeast of **Wekusko Lake** (Map K), forming extensive outcrops along the shores of Crowduck Bay and Wekusko Bay. In this general area, biotite schist was host-rock for the gold-bearing quartz veins at the old Ferro Mine (Map K). Elsewhere, fine-grained *biotite* is a major constituent of the Black Trout diorite which occurs as dykes, plugs and sills 14 to 35 miles southeast of **Lynn Lake,** and is also well exposed on the east shore of **Suwanee Lake** (Map S).

References: Barry & Gait 1966; Davies 1954; Davies *et al* 1962, p.79; Milligan 1960; Phillips 1975; Sabina 1963, 1972.

Phlogopite, a pale brown or amber, magnesium mica, is closely related to biotite, but is generally found in magnesium-rich metamorphic rocks such as dolomitic marble. Metamorphism of carbonate rocks such as limestone and dolomite frequently causes formation of new minerals in rocks that are then called skarn. Skarn-rocks containing phlogopite are found at the Thompson Mine (Map Q) and elsewhere in the **Manitoba Nickel Belt.** Where found in large concentrations, phlogopite can be mined and utilized in much the same way as muscovite. It is generally less effective than muscovite for electrical insulation, but is of some value because of its high thermal resistance.

Reference: Quirke, Cranstone, Bell & Coates 1970.

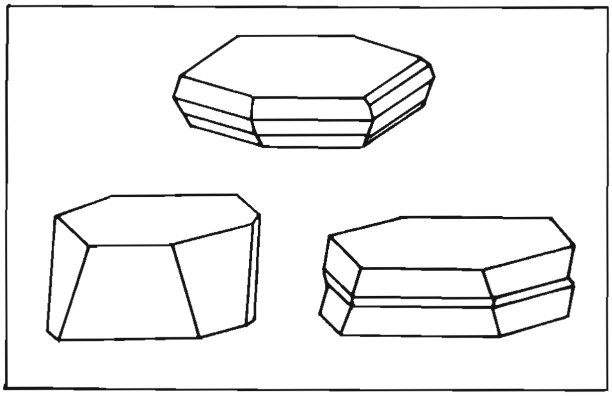


Fig. 10: Chlorite

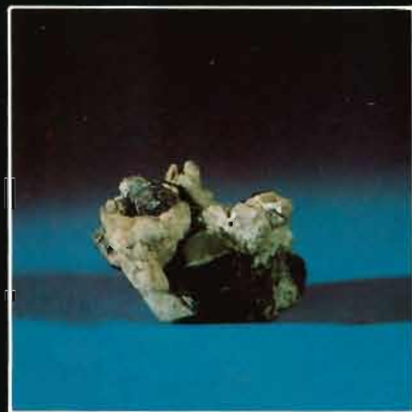
Chlorite (fig. 10) is the general name for a group of soft green ferromagnesian minerals (average hardness about 2) that tend to occur (like mica) in leaf-like or foliated forms (plate 17); but the flakes, though flexible, are non-elastic, and are generally very small. Crystals are monoclinic. Chlorite is usually seen in foliated massive form, as in chlorite schist, a dark green rock that is composed mainly of chlorite. Chlorite is widespread as a rock-forming mineral, and is generally of secondary origin; it results from the alteration of other ferromagnesian minerals, including biotite, pyroxene and amphibole. An interesting location in **Hecla Provincial Park** is off the east shore of Black Island: chlorite schist is well exposed along the east side of Gray Point (Map D).

Outcrops of *chlorite* schist can be seen in the western part of Reed Lake (Map J) which is in the **Grass River Provincial Park.** Most of the southern shoreline is dolomitic limestone but the underlying chlorite schist is exposed in places near the road. This rock also occurs immediately to the north on parts of Fourmile Island (Map J), and on numerous islands further northwest in Reed Lake.

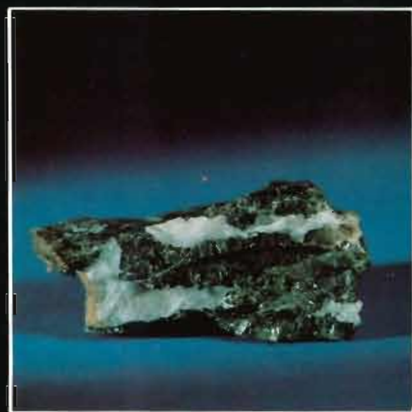
Reed Lake is located on the south edge of the **Flin Flon – Snow Lake** greenstone belt, famous for its copper-zinc mines. Chlorite schist is a host rock for certain orebodies at the Flin Flon Mine (Map H), the Chisel Lake Mine (Map L), the Anderson Lake Mine and at Stall Lake (Map K). Mineralized specimens of cherty *chlorite* schist and sericite schist can be obtained from numerous rock dumps at the disused Baker-Patton deposit (Map H) about ten miles due east of Flin Flon. Chlorite schist is also abundant along **Crowduck Bay** (Map K), and can be found in greenstone belts throughout Manitoba.

References: Davies 1951; Rousell 1970; Sabina 1972.

15) Zinnwaldite from Greer Lake area



16) Typical book of biotite with quartz and feldspar (Museum)



17) Chlorite from vein, with calcite (Museum)

18) Coarse graphite with quartz and feldspar (Museum)

Graphite (plate 18) crystallizes in the hexagonal system and is easily recognizable because it leaves a black mark on paper, a property that has long been utilized in the manufacture of "lead" pencils in which graphite is mixed with fine clay. Graphite has a hardness of less than 2, can be cut with a knife, and feels greasy when touched. Its black to steel-grey colour, black streak and metallic lustre are also distinctive. Graphite is an important industrial mineral for use in facings for foundry-moulds; in refractory crucibles for the steel, brass and bronze industries; in electro-plating to provide a conducting surface for non-metallic substances which are to be plated; in commutators, and as electrodes for the electric furnace. High-grade flaked graphite (as produced in Ceylon) is required for crucibles, while low-grade graphite is useful for paint manufacture. Graphite is also widely used, mixed with oil, as a lubricant. There is currently little or no graphite production in Canada.

The general occurrence of graphite is in metamorphic rocks such as schist, gneiss and recrystallized limestone. Graphite is abundant in certain Precambrian zones in Manitoba. Graphite occurs in quartzo-feldspathic gneiss found on the rock-dumps of the former copper-zinc mine at **Sherridon,** and is extensive 17 miles to the east in the graphitic gneiss of the **Batty Lake** area (Map O) where it may form as much as 50 per cent of rusty weathered parts of the gneiss. The graphitic Nokomis gneiss is here overlain by lime-rich gneisses and recrystallized limestones of the Sherridon Group. These rocks occur around the southwest shore of Batty Lake. In the **Flin Flon** area (Map H), the wall-rocks of the copper-zinc deposits include graphitic and other schists. Graphitic schist with a greasy black appearance is plentiful on the rock dumps of the Cuprus Mine (Map H), which was in production between 1948 and 1954. West of **Kississing Lake,** graphite is locally very abundant in the Nokomis paragneiss, so much so that the mineral is conspicuous in beach sands at the south end of Kipahigan Lake (Map X). There are localized but more accessible occurrences along the Grass River northwest of Iskwasum Lake (Map I): a small island about 4 miles from the lake shows outcrops containing much *graphite.* About 1½ miles further upstream, graphite occurs on the west bank of the river, ¾ mile south of the railway bridge. These localities are in the **Grass River Provincial Park,** accessible from provincial road 391.

References: Davies *et al* 1962, pp.25, 73; Hunt 1970; Pollock 1964; Robertson 1953; Sabina 1972.

19) A large calcite crystal (Museum)

20) Dolomite crystals (Museum)

Calcite, Dolomite and other Carbonates

The carbonates include the important rock-forming minerals, calcite and dolomite, both of which are abundant in the Paleozoic rocks of southwest Manitoba. These rocks are about 330 to 420 million years old and are thus much younger than the Pre-cambrian rocks to the north and east. Calcite is calcium carbonate ($CaCO_3$), the essential constituent of lime-stone. Dolomite ($CaCO_3 \cdot MgCO_3$), which consists of an equimolecular chemical combination of calcium carbon-ate and magnesium carbonate, is the essential constit-uent of dolostone (dolomite-rock). Siderite is the iron carbonate ($FeCO_3$) which (in clay ironstone) has been mined as iron ore in Europe. Generally however it occurs more sparsely as a vein mineral, as do magnesite ($MgCO_3$), rhodochrosite ($MnCO_3$) and smithsonite ($ZnCO_3$), the carbonates of magnesium, manganese and zinc respectively.

Calcite, as the principal constituent of limestone, is the most important industrial (non-metallic) mineral in Manitoba, mainly because of the large quantities used in the cement industry. The process consists essentially of crushing limestone, adding a certain proportion of crushed shale or clay, and burning the mixture to a clinker. The burning drives off the carbon dioxide, and the remaining constituents form various compounds of calcium with silica, alumina and iron; magnesia should not normally exceed a few per cent of the finished product, and the limestone used must therefore be a relatively pure variety known as high-calcium limestone. Natural cement, as used in the past, was made from argillaceous limestone that already contained the right amount of clay material. As such limestones are rela-tively scarce, the modern process usually entails mixing limestone and shale to make what is then called Portland cement, formed when water is added to the powdered clinker. The principal quarrying areas for high-calcium limestone in Manitoba are near the east shore of **Lake Manitoba** (Map E), and near **Dawson Bay** (Map G). From Steep Rock and Lily Bay (Map E), Canada Cement Lafarge Limited sends limestone to two cement plants near Winnipeg. From its quarry 10 miles north of Mafeking (Map G), Inland Cement Industries Limited sends limestone to its plant in Regina.

The lime industry, as well as the cement industry, uses *calcite* (from limestone) as its principal raw material. The limestone is crushed and burned to quicklime. Slaked lime is formed when water is added, and the addition of sand can make mortar or sand-lime bricks. Lime is also used as flux in the manufacture of steel; other uses are in the pulp and paper industry, chemical industries, water purification, sewage treat-ment, soil stablilization, sugar refining, tanning, and the manufacture of paint, bleach and insecticide. Lime is produced in Manitoba by Steel Brothers Canada Limited, from plants at Faulkner (Map E) and Fort Whyte (Winnipeg). The plants are supplied with high-calcium limestone from the Faulkner quarry near Steep Rock (Map E).

Clear, transparent crystals of calcite, known as *Iceland spar,* are used in optical instruments. Only a very small proportion of the spar recovered from high-grade deposits is sufficiently flawless for this purpose. Iceland has long been the source of the best specimens for optical use.

Dolomitic lime has special uses such as neutralization of acid industrial waste and stabilization of certain soils. It is also used for making refractory furnace-linings. *Dolomite* is used in chemical industries as a source of carbon dioxide and in the preparation of magnesium salts. In the pulp and paper industry, dolomitic lime is used in some sulphide-process plants. Dolomitic limestones can be used as flux for iron sinters and in the manufacture of glass. They are also used as poultry grit and are an important source of crushed stone and aggregate for constructional purposes in Manitoba.

Disused quarries showing good limestone and dolostone sections in the **Winnipeg** and **Interlake** regions are indicated on Map E which also shows some important quarries producing high-calcium limestone and dolomitic limestone, including the Tyndall building stone. Operational quarries are not normally open to casual visitors owing to safety regulations.

References: Bannatyne, 1975; Davies *et al* 1962, pp.161-172; Manitoba Mines Branch 1965; Phillips 1975.

Calcite (fig. 11) crystallizes in the hexagonal system, and good crystals are not hard to find. They show great variety of form (over 300 have been described), but all are modifications of the rhombohedral type. A rhombohedron can be visualized as a pushed-over cube. Two common forms of calcite are known as dog-tooth spar and nail-head spar, both self-explanatory. Crystals are usually white or colourless, occasionally tinted (plate 19), but may be black or brown if impure. They can be readily recognized by their softness (easily scratched with a knife), by their strong cleavages (two planes intersecting at 73½ degrees), or by the application of a drop of cold, dilute hydrochloric acid which causes strong effervescence. Vinegar will give a similar, though milder, reaction.

One of the best places to look for *calcite* is in the Devonian limestone that occurs in the southwesterly regions of Manitoba. Limestone is easy to identify by means of the hardness and acid tests just described. An excellent place to study calcitic limestone is the large, disused quarry of the Winnipeg Supply and Fuel Company Limited at **Spearhill** (Map E), east of Lake Manitoba. The quarry is on a hill which rises about 50 feet above the surrounding countryside, and was for many years a source of high-calcium limestone from the Elm Point Formation of the Devonian System. In places the limestone shows veins and cavities containing secondary calcite crystals; here and there, angular masses of limestone have been cemented into the surrounding rock by drusy calcite. A drusy cavity is one lined with secondary crystals (often minute) of the same minerals as those of the enclosing rock.

Similar features occur at the large limestone quarry near **Dawson Bay** (Map G), 10 miles north of Mafeking, which is currently in operation (Inland Cement Industries Limited). However, there is a road-cut on highway 10, 1½ miles north of the quarry, where *calcite* can be readily found. The 7-foot section shows an uppermost 3½ feet of limestone containing abundant sparry calcite and a ¼-inch-thick, drusy layer at its lowest contact. The limestone is underlain by 3 feet of bedded dolomite that contains numerous small openings (up to an inch across) lined with secondary calcite. The sheer limestone cliffs a few miles east of here provide the largest outcrops in the Dawson Bay area, reaching a maximum height of 90 feet at **Steep Rock Point** (Map G). Good exposures of limestone occur along the shore 2 miles south of Steep Rock Point. These beds are finely crystalline and contain numerous fossils (brachiopods and gastropods). On the north shore of the **Salt Point Peninsula,** several cliffs form prominent headlands along a two-mile stretch (Map G). The lowermost beds are massive dolomite but these grade upwards into calcareous shale and argillaceous limestone, which are overlain by yellowish white crystalline limestone. Secondary calcite is abundant in small vugs within the transition beds between the lower dolomite and the upper limestone. Large calcite crystals can be found further along the road, one mile east of the **Bell River** outlet: a prominent cliff exposes yellowish grey and olive grey limestones (about 14 feet thick) underlain by 9 feet of argillaceous limestone and calcareous shale. In the shaly beds, which weather to a knobbly surface, there are small solution caves lined with banded calcite nodules and containing, near the east end of the outcrop, some large *calcite* crystals.

References: Baillie 1950; Bannatyne 1975.

Dolomite (fig. 12) also crystallizes in the rhombohedral class and has similar cleavage to calcite, but can often be distinguished by its curved rhombohedral faces (plate 20). A pinkish, brownish or flesh colour is characteristic for dolomite but it may also be white or otherwise tinted. The acid test is diagnostic, as cold dilute hydrochloric acid does not cause effervescence, unless the mineral is first powdered; this can be done by scratching it with a knife and dropping acid into the groove. When hot or concentrated acid is applied however, dolomite effervesces readily. The same test can be used to differentiate between limestone and dolostone (a convenient though little-used term for the rock composed of dolomite grains or crystals).

In the Ordovician dolomitic limestone of southern Manitoba, calcite and *dolomite* crystals are closely associated, though usually too fine-grained to be seen without magnification. At the Gillis quarry near **Garson** (Map E), the uppermost six feet consist of yellowish grey limestone containing much calcite, but the mottled greyish orange areas are composed of many small dolomite rhombs in a calcitic groundmass. This mottling adds to the attractiveness of the Tyndall building stone, a dolomitic limestone now quarried at Garson and used extensively in Winnipeg (e.g. the Legislative Building), and elsewhere. A stone quarry at the northwest tip of **Hecla Island** (Map D) shows similar features; the mottled dolomite patches are greyish yellow and are more crystalline than the olive grey limestone groundmass. The disused quarry at **Gunton** (Map E) is a suitable location for the study of some fine-grained Ordovician dolostones. A measured section of 42 feet showed 16 feet of argillaceous dolostone overlain by 26 feet of greyish yellow, finely crystalline dolostone; vugs in the top 11 feet contain drusy *dolomite* crystals.

Palaeozoic dolostone is extensive around **The Pas,** and there are many accessible outcrops in an east-west zone that includes the Clearwater Provincial Park, Cormorant Provincial Forest and the southern part of the **Grass River Provincial Park** (Maps I & J). A few relatively large *dolomite* crystals have been reported from outcrops on the north shore of **Rocky Lake** (east of Wanless).

Some of the larger and better formed carbonate crystals are found in veins and pegmatites. *Rhodochrosite* of an attractive pink colour occurs sparsely in the **Bernic Lake** pegmatite, and good calcite crystals are also encountered there (Map C). Details of this pegmatite at the TANCO MINE are given under Pegmatitic Minerals.

References: Baillie 1952; Phillips 1975; Sabina, 1963, 1972.

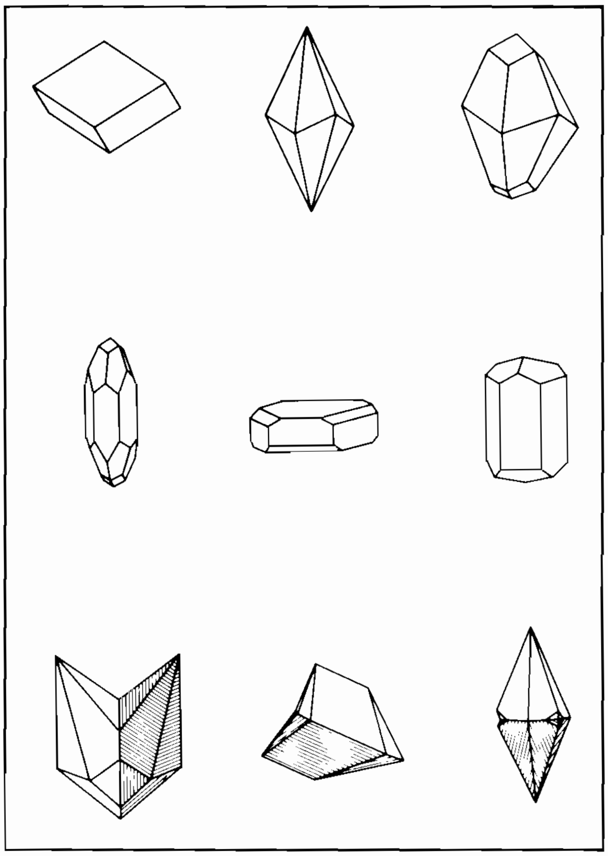
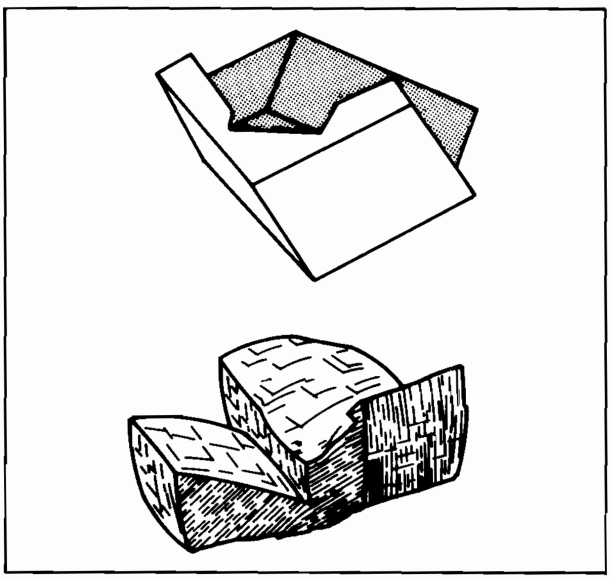


Fig. 11: Calcite

Fig. 12: Dolomite



Gypsum and Anhydrite

21) Selenite crystal from Altona

22) Alabaster from Gypsumville

The calcium sulphate minerals, gypsum ($CaSO_4 \cdot 2H_2O$) and anhydrite ($CaSO_4$), occurring in the evaporite beds around **Gypsumville,** have provided the raw material for Manitoba's oldest mining industry, dating back to the turn of the century. Gypsum has also been mined further south at Amaranth and Silver Plains, but little can be seen there because both were underground mines, whereas at Gypsumville the rocks and minerals are well exposed in quarries. These deposits, which show typical sedimentary features, were laid down as saline residues (calcium sulphate) from the evaporation of enclosed sea-water basins during the Jurassic period, approximately 150 million years ago, and are thus much younger than the ancient rocks and minerals of the Precambrian Shield. The close association of gypsum and anhydrite in these beds is due to the fact that anhydrite is converted to gypsum by hydration, even by the action of circulating ground-waters. Conversely, gypsum loses its water of crystallization when heated strongly, and reverts to anhydrite. This reversion also takes place at depth by natural processes. For industrial purposes, *gypsum* is valuable because of its ability to form "calcined gypsum" when three quarters of its water is driven off; when water is added to powdered, calcined gypsum, the result is Plaster of Paris, which is composed of an interlocking mass of needle-like gypsum crystals. The presence of more than a minor proportion of anhydrite is detrimental for most commercial purposes. The main uses of gypsum in Manitoba are for wallboard and plaster, and as a cement-retarder to prolong the setting of Portland cement. In the building trades calcined gypsum is used as a base-coat and in the manufacture of lath, wallboard, sheathing and tile. Laminated board consists of plaster between sheets of heavy paper. Pure white gypsum is used in terra-cotta plaster, molding plaster and dental plaster; with hydrated lime it is used as a finishing coat for house-walls. *Anhydrite* can be mixed with gypsum in cement-retarder, and a mixture is also used as a soil-conditioner for legumes in the eastern United States. Anhydrite is used in Europe to make sulphuric acid, and is a potential source of sulphur.

Gypsum (fig. 13) crystallizes readily in the monoclinic system and is an interesting mineral to collect as it shows a wide variety of large, prismatic, tabular and other forms; swallow-tail twins and arrow-head twins are fairly common. Gypsum has one perfect and two weak cleavage directions; the former causes the mineral to split into thin, flexible, non-elastic plates. Gypsum is also easily recognized by its low hardness rating (2), soft enough to be scratched with a finger-nail. Well formed crystals which split into transparent cleavage plates are called *selenite;* such crystals are usually colourless with vitreous lustre (plate 21). A secondary mode of occurrence for selenite is as random crystals formed in clay by the action of circulating ground-waters; crystals found during construction of the Red River Floodway near **Winnipeg** are of this type; other locations are the bentonite (clay) quarries of the **Morden-Thornhill-Miami** area. In spite of its softness and lack of durability, two varieties of gypsum, both occurring in Manitoba, are extensively used elsewhere for decorative and ornamental purposes. *Alabaster* (plate 22) has for centuries been carved into ornamental objects; it is a very compact, fine-grained, massive


23) Satin-spar from Gypsumville


24) Typical anhydrite specimen (Museum)


25) Gypsum rock showing bedding, from Gypsumville

variety, usually snow-white or faintly coloured. Somewhat less common is *satin-spar* (plate 23), which consists of delicate, parallel fibres packed closely together and reflecting the light from many angles to give an effect known as chatoyancy. Satin-spar fills veins or seams in ordinary gypsum and is outstanding for its silky lustre. Excellent catseyes can be cut from this material but it has been most used as beads in necklaces. These potential applications are largely undeveloped in Manitoba.

Anhydrite crystals (very rare) are thick, tabular or prismatic, orthorhombic forms (fig. 14). Most crystalline specimens (plate 24) are simple cleavage blocks; anhydrite has three distinct cleavages at right angles to each other, yielding rectangular fragments. The colour is usually white with grey, bluish or reddish tints. Lustre is vitreous, but pearly on cleavage-faces, and the mineral is transparent to translucent. In Manitoba deposits the anhydrite is usually bluish white, and occurs in finely crystalline to massive beds. Some massive varieties of anhydrite are difficult to identify, but the lethargic reaction with cold dilute hydrochloric acid (hardly detectable) eliminates possible confusion with calcite, while its relative hardness (3 to 3½) and rectangular cleavage distinguish anhydrite from massive gypsum, with which it is often associated.

Classic localities for the study of gypsum and anhydrite in Manitoba are the **Gypsumville** quarries, 164 miles northwest of Winnipeg (Map F). The following is a brief historical review of the deposits, which were discovered some time before 1887, the year when they were first surveyed by Tyrrell for the Geological Survey of Canada. The rocks in which the gypsum is concentrated form isolated ridges immediately north and northeast of Gypsumville, rising 20 to 50 feet above the surrounding swamps. The largest ridge extends 3 miles north from Gypsumville and is about ½ mile wide. In 1901 the Manitoba Union Mining Company began quarrying in the southerly part of this ridge. They built a mill at Old Gypsumville at the head of Portage Bay, and hauled the raw gypsum there from the quarries. At the mill the gypsum was crushed, calcined and made into plaster before being shipped by barge to the south end of Lake Manitoba, and up the Whitemud River to McArthur's Siding near Westbourne. From there it was distributed by rail to midwest Canadian markets. In 1904 Manitoba Gypsum Company Limited bought out the original company, but their expansion plans were delayed when the mill and all the company buildings at Old Gypsumville burnt down in 1906. A new mill was located in Winnipeg but this in turn was gutted by fire in 1909; it was replaced the following year by a mill of concrete construction. In 1910 the Canadian Northern Railway was extended from Oak Point to Gypsumville. Since then the gypsum rock has been hauled overland. In 1908 Canada Gypsum and Alabastine Limited took over, and they expanded into Gypsum, Lime and Alabastine, Canada Limited. This company sold most of its assets to Dominion Tar and Chemical Company Limited in 1959, and the operating company at Gypsumville became Domtar Construction Materials Limited, as at present. Hence the quarrying at Gypsumville has been going on for three quarters of a century, which makes it one of the oldest mining locations still in production in western Canada.

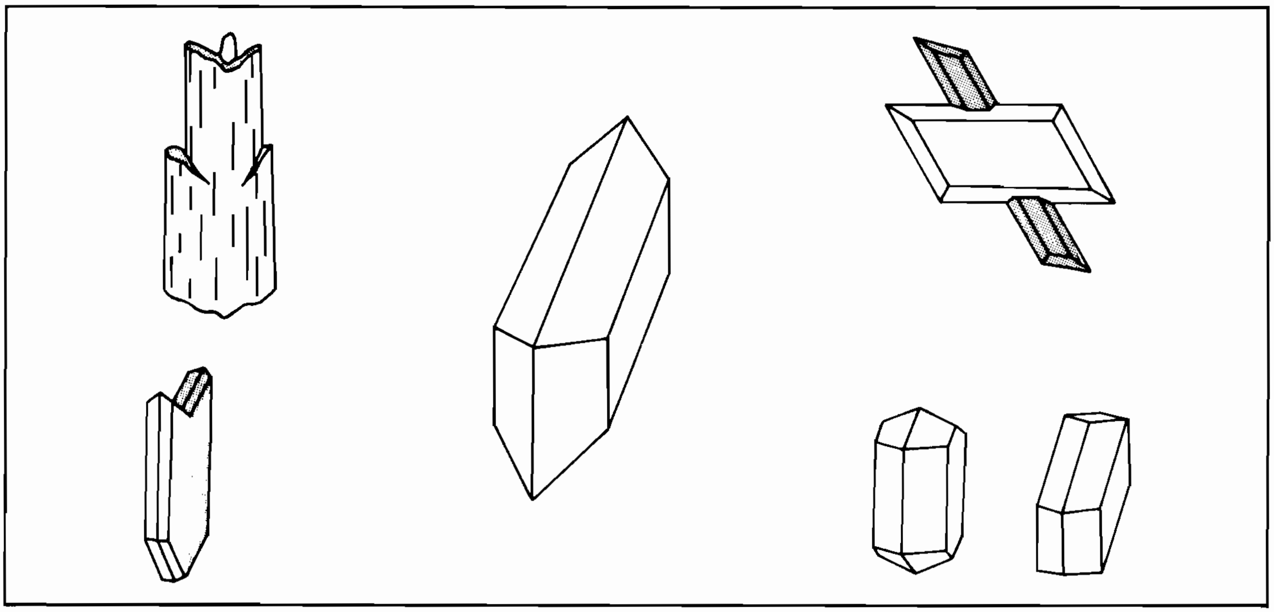


Fig. 13: Gypsum

The Gypsumville ridge (Map F) lies on the western edge of a roughly oval-shaped area (about 10 miles north-south by 7 miles east-west) in which several ridges and some smaller knolls of gypsum-anhydrite rock rise above the extensive swamps. The swamps cause serious access difficulties in summer-time and visitors interested in the more remote locations should make careful enquiries at **Gypsumville** before venturing off the beaten track. The peculiar topography of the area is emphasized by numerous clay-filled sink-holes, a few feet in diameter, in the ridges, caused by solution of gypsum during weathering. The original quarry, now disused, is located ½ mile northeast of Gypsumville, at the south end of the ridge, and is accessible by road. The quarry is U-shaped and over ½ mile wide. Within the quarry the bedding is generally horizontal; the strata consist of gypsum beds 1 inch to 3 feet thick, separated by clay partings. The massive *gypsum* (plate 25) is finely crystalline, often appearing dull white and amorphous, except where discoloured by clay impurities. The west arm of the quarry extends northerly for 1,500 feet and is up to 400 feet wide, exposing beds to a depth of 10 to 20 feet on the west wall; to the south the gypsum is fairly pure but to the north it is grey owing to numerous clay interbeds. In the northwest part of the quarry the clay is red, giving the gypsum a pink, banded, mottled appearance. Along the north wall there are some round masses of pure white gypsum enclosed in the impure beds. The northeast part of the quarry shows gypsum beds containing red clay. The beds on the east wall have been slightly warped, with one pronounced fold in which several distinct beds of massive white *anhydrite,* up to 2 feet thick, are interbedded with gypsum.

The large quarry now being worked towards the north end of the ridge, 2 miles north of **Gypsumville,** was opened about 1953 and cannot be visited without permission owing to operational hazards. The exposed beds include brownish and red-stained gypsum with stringers of *satin spar,* massive white *gypsum* with a few darker anhydrite portions, and some greyish masses of *selenite.* A section on the east wall showed beds of selenite up to 1 foot thick; these beds are composed of a compact interlocking mass of transparent, greyish, platy crystals of selenite, mostly less than an inch across. Recently, quarrying operations have been commenced between the two quarries just described.

Pits at "Whippoorwill Hill" (Map F) are accessible by walking 2½ miles east along a trail from the Old Quarry. Tyrrell reported in 1888 that two pits dug by prospectors showed much *anhydrite,* and suggested that the whole ridge might be composed of this material. The pit at the top of the hill showed 7 feet of hard, compact, bluish white anhydrite, more or less nodular. Fifteen feet lower down the hill, the other pit showed white nodular anhydrite overlain by 2½ feet of white clay derived from decomposed anhydrite.

The largest crystals of *selenite* found in the **Gypsumville** area are those from the "Elephant Hill" deposit (Map F). As this location is separated from the main quarry by swampy terrain, it has been worked only in the winter months. The trail from Whippoorwill Hill passes over some swampy ground which may at times be difficult to traverse. The deposit is noted for its large masses of transparent and colourless selenite with many cleavage plates over 1 foot square. These are best exposed on the east wall of the central pit, located on

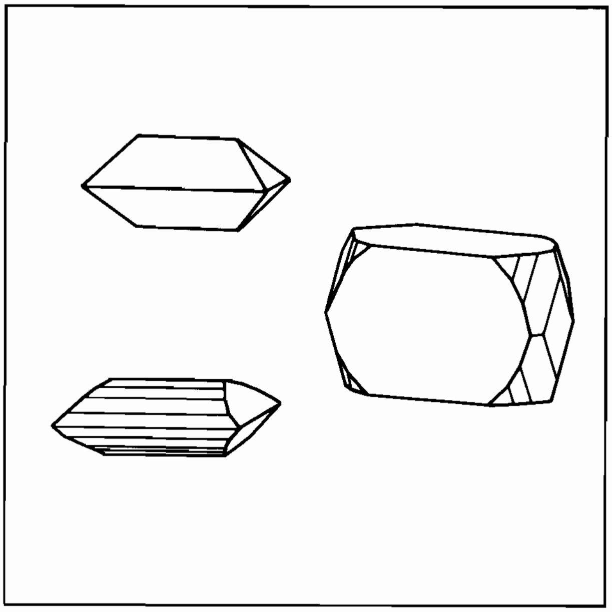


Fig. 14: Anhydrite

the south side of the hill. The pit to the west showed, at the top, thick beds of gypsum with anhydrite cores. Beneath this, thinly bedded white gypsum is separated by a clay band from a bed containing large platy crystals of selenite; the selenite bed graded abruptly in one place into massive anhydrite. At the bottom of this quarry, some gypsum beds showed anhydrite cores. The large third pit, on the southeast side of Elephant Hill, is characterized by very clean white gypsum of the *alabaster* variety; these beds are one to five inches thick and in places are separated by thin films of red clay; a few selenite crystals are present.

An interesting locality for *anhydrite* has been described at "Anhydrite Hill" (Map F). Although only 3 miles north of gravel road 513, access to Anhydrite Hill is normally very difficult, except in winter months, owing to deep swamps. From time to time however, new roads or tracks are built to reach new quarries or for other purposes; up-to-date information can best be obtained from the company office in **Gypsumville.** Much of the rock on the hill is covered by a thin soil cover, but holes sunk during the first World War passed through 86 feet of anhydrite beds without reaching their lower contact. An exposed face, 17 feet in height, showed bluish white, fine-grained anhydrite cut by irregular joints. Along the joint planes the anhydrite has been partially altered to gypsum. The anhydrite of this deposit is a hard variety that would lend itself to polishing, suggesting possible use as an inside decorative stone of attractive appearance.

References: Bannatyne 1959; Davies *et al* 1962, pp.172-173; Traill 1970.

26) Olivine basalt (Museum)

27) Peridot gemstone (Museum)

28) Olivine phenocrysts (serpentinized) in peridotite from Bird River Sill

Olivine, Serpentine and Talc

These three minerals belong to three quite different groups but all are rich in magnesium and are so closely associated with each other in Manitoba that it is hardly possible to describe occurrences of olivine or talc without referring to serpentine. The close association between olivine and serpentine involves pseudomorphism. We have already seen (Silica Minerals) how fossilized trees have been preserved by silicification, a process in which the wood has been replaced by silica without change of shape. In the same way, many olivine crystals have been replaced by serpentine without change of shape — the serpentine is thus pseudomorphic after olivine. The main difference between the two processes is that the silica was not derived from the wood itself, whereas the elements of which the serpentine is composed were largely derived from the olivine. Olivine is a strongly ferromagnesian silicate; there are iron-rich and magnesium-rich olivines, but the general composition is $2(Mg,Fe)O{\cdot}SiO_2$. Serpentine forms at a lower temperature than olivine, often in a cooling magma, and it requires water from an external source; therefore it is said to be a hydrothermal mineral, and its composition is $3MgO{\cdot}2SiO_2{\cdot}2H_2O$.

Olivine (fig. 15) is one of the first minerals to crystallize from magmas that are rich in magnesium and iron. It is found in some gabbros and basalts (plate 26), and is a major constituent of peridotite and dunite. It crystallizes in the orthohombic system, usually as small olive-green to brownish grains. The magnesium end-member (forsterite) of the olivine series is generally some shade of yellow, while the iron end-member (fayalite) is either dark brown or black. *Peridot* (plate 27) is a bright, transparent, yellowish green variety that has been valued as a gemstone for thousands of years. In peridot, the ratio of magnesium to iron is about 5 to 1, and the green colour is due to the iron. Although not particularly hard (6½ to 7), peridot is tough because it does not split easily along cleavages. Most of the gems, which must be free from alteration, are found in dark lava-rocks such as basalt or picrite. In Precambrian rocks olivine is much more likely to be altered to serpentine and iron oxides.

Among the least altered specimens of *olivine* in Manitoba are those of the **Cuthbert Lake** dyke-swarm (Map Q) which consists of peridotite and gabbro. The peridotite contains from 15 to 60 per cent olivine, and the largest dyke, less than ¼ mile in width, strikes northeasterly for more than 40 miles from the south-eastern bay of Wintering Lake (near Thicket Portage) through Payntor, Cuthbert, Partridge Crop, Natawahunan, Buckingham and Begg Lakes. Through much of its length the dyke is concealed either by overburden or by water, but small outcrops appear on shorelines. The peridotite is dark greenish grey but weathers dark brown. It is quite coarse-grained, and abundant olivine grains up to ½ cm in diameter are visible in hand specimens. Olivine can be clearly seen in some of the associated gabbro dykes. Further information about the Cuthbert Lake dyke-swarm is given under Pyroxenes.

Olivine has also been reported from the Thompson nickel mine and the Manibridge nickel mine (a few miles east of Dunlop). About 15 miles south of Thompson, olivine phenocrysts up to 1 cm in diameter can be seen in outcrops of fine-grained picrite around **Ospwagan Lake** (Map Q). The phenocrysts make up from 10 to 30 per cent of the rock which is of volcanic origin; outcrops can be recognized by their pitted appearance where the olivine phenocrysts have weathered out. Weathered surfaces are olive-green or light greenish grey, but the unweathered rock is dark grey, and shows egg-shaped or lenticular, reddish brown olivine phenocrysts, many of which are severely fractured and iron-stained. Detailed study shows that some of the olivines are completely serpentinized but others are only altered around their rims.

Far to the northeast in the **Fox River** ultramafic sill (Map Z), drilling has revealed pyroxenite bands containing tiny olivine crystals, but unaltered olivine is rarely seen in outcrops. In southeast Manitoba, accessible outcrops of peridotite in the **Bird River** sill (Maps B & C) show bands containing high concentrations of near-white, rounded phenocrysts up to a few millimeters in diameter; these buff-weathering phenocrysts (plate 28) are *olivine* replaced by serpentine.

References: Davies *et al* 1962, p.62; Dawson 1952; Patterson 1963; Quirke *et al* 1970; Sabina 1972; Scoates 1971c, 1975; Stephenson 1974; Trueman 1971.

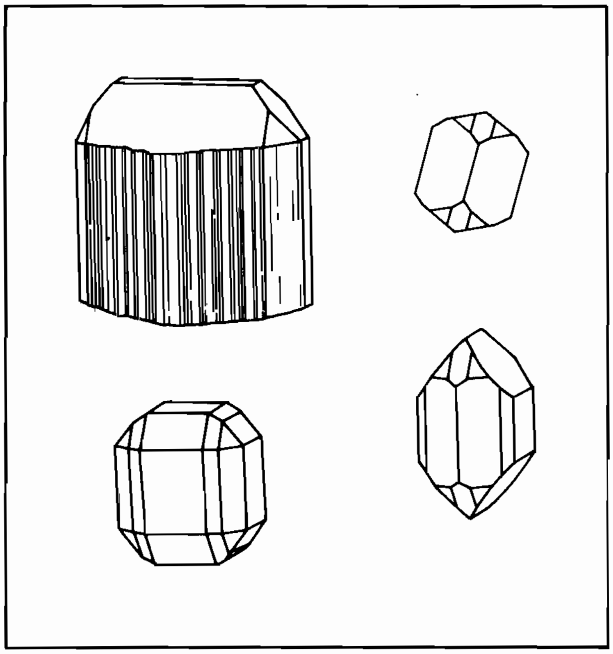


Fig. 15: Olivine

Serpentine (plate 29) is a secondary, hydrothermal mineral formed as a result of the alteration of rocks rich in magnesium, such as peridotite and picrite. It is quite abundant in Manitoba and is well known in the Nickel Belt. Serpentine does not form crystals, but occurs in massive, granular or fibrous forms, with many compositional and colour variations. Hardness varies from 2½ to 5 and specific gravity from 2.2 to 2.6. The predominant colours are green to olive, but yellow, orange, red, brown and many combinations are also common. Some of the harder varieties are used in jewellery, such as the bright green beads of *williamsite.* A compact, granular, translucent variety *(bowenite)* has been extensively used in Chinese carvings as "new jade". A waxy, translucent yellow variety called *retinalite* is also used for ornaments. *Verde antique* is a classic dark green rock long used as an ornamental and decorative building stone. Serpentine in Manitoba occurs principally as the main constituent of the rock *serpentinite,* some of which may show colour banding and mottling, which suggests possible ornamental applications. World-wide, suitable deposits of fibrous serpentine *(chrysotile)* are mined as asbestos (plate 30), a very important industrial mineral. Canada produces most of the world's *asbestos,* mainly from Quebec. Although all the Canadian output is chrysotile, fibrous amphibole was in fact the original asbestos. The usefulness of asbestos is due to its slender fibrous shape and other physical properties, its chemical stability and general durability. It resists fire, acids, corrosion, weather, mildew and vermin; it insulates against heat, vibration, electricity and sound. The principal world usage is as a filler in asbestos-cement products; it is also used as a filler in rubber and asphalt. The fibres can be spun or woven into asbestos cloth and are also used for filtration of acids, alkalies and other corrosive liquids. Finely ground fibres can be sprayed, moulded with plastics or glass, or dispersed in fluids, adhesives and sealing compounds.

The **Fox River** sill (Map Z), which is about 7,000 feet thick, consists of many alternating layers of various mafic and ultramafic rocks, including numerous layers of *serpentinite* from 115 to 750 feet thick; one outcrop occurs on the west shore of the Fox River, ½ mile downstream from its confluence with the Gowan River (Map Z). Much more accessible occurrences are those of the **Manitoba Nickel Belt** (Moak Lake to Setting Lake); nickel deposits are associated with some of the numerous *serpentinite* bodies, the largest of which are several thousand feet long and a few hundred feet wide. These lenticular-shaped bodies are composed dominantly of serpentine minerals, mostly pseudomorphic after olivine. Because these rocks are soft and easily weathered, good outcrops are scarce and the serpentinites are known mostly from drilling. The serpentinite of **Mystery Lake** (5 miles northeast of Thompson) crops out, however, around the southwest bay and nearby island (Map Q). It is a greenish black serpentinized peridotite that weathers dark grey and brown (due to iron oxides). The rock is crossed by irregular joints which have been filled with a variety of minerals including white and reddish chert, coarse white calcite crystals, iron oxides and white fibrous *serpentine.* This rock contains nickel minerals and is on the property of the International Nickel Company of Canada Limited. Similar rock contains orebodies at the Moak Lake, Pipe and Soab Mines (Map Q) owned by this company. Veins of serpentine *asbestos* are found at some of these locations, respectively 17 miles northeast, 20 miles southwest, and 45 miles southwest of **Thompson.** The green serpentinite at the Pipe open-pit (Map Q) is noteworthy as a potential *ornamental stone,* and for its abundant asbestos veins. Owing to mining operations, however, visitors are not permitted except by prior arrangement with the operating company's Thompson office. At the south end of the Nickel Belt, dark green serpentinite is host-rock at the **Manibridge** nickel mine (near Clarke Lake) of Falconbridge Nickel Mines Limited.

References: Davies *et al* 1962, pp.62, 105; Gill 1951; Manitoba Mines Branch 1965; Quirke *et al* 1970; Scoates 1969, 1971a, 1971c.

In the **Grass River Provincial Park** (Map **I**), *serpentinites* occur in a continuous zone extending south from the Grass River and through Iskwasum Lake, where they are exposed on the shore and on numerous islands. Outcrops are mostly sheared, altered and schistose, and weather dark brown to orange; further information is given under Talc. Fibrous serpentine-rich rock forms a narrow band along the northwest shore of Iskwawum Lake. Within this band there are many veins and patches of brittle *fibrous serpentine* (asbestos) up to 4 inches in width, cutting across the massive serpentine which forms the bulk of the rock. The serpentinites show attractive colour variations in shades of green, also mottling and veining effects, which suggest suitability for use as *ornamental stone.*

References: Hunt 1970; Hunt & Denison 1971.

In eastern Manitoba, serpentinized ultramafic rock is exposed on a few small islands immediately south of the southeastern tip of Linklater Island (Map V) in **Island Lake.** This greenish black rock is composed largely of *serpentine* and is criss-crossed by thin veinlets of pale, greenish grey *serpentine-asbestos;* these veinlets, which rarely exceed ½ cm in width, make up about 5 per cent of the rock.

References: Davies *et al* 1962, p.20; Godard 1963.

Twenty-five miles southeast of Bissett, the **Garner Lake** ultramafic body (Map D) includes much serpentinized peridotite which weathers orange-buff to brown; many outcrops are characterized by narrow veinlets of fibrous *serpentine* (including some cross-fibre asbestos) cutting across the serpentine-rich groundmass. The southern half of a large island in the south-central part of the lake is composed of this rock which extends for over ½ km from the west to the east shore. Fifty miles or so to the west-northwest, serpentinite east of **Clangula Lake** (Map D) was quarried around 1950, by Manitoba Marble Quarries Limited, as a source of *ornamental stone.* The quarries are about 600 yards east of the lake and can be reached on foot by following the old tram-line from the lakeshore. Access to Clangula Lake is by boat southwestward up the Wanipigow River, from the vicinity of Lake Winnipeg. Some of the quarries are now under water but some rock-faces can still be seen. The main rock-mass is peridotite, but in the quarries it has been sheared and altered to a *serpentine* rock. This rock, where fresh, is light grey, greenish grey or pale yellow-green. Fractures contain iron oxides, carbonates and quartz, and in some places a bright green nickel mineral. More serpentine rock occurs southwest of the quarries. Abandonment of the quarries was apparently due to the friable nature of the rock which detracted from its value as an ornamental stone. Fifty miles to the southeast, *serpentine* schist and short-fibre asbestos can be found locally in the **Bird River** sill (Map C), associated with serpentinized peridotite.

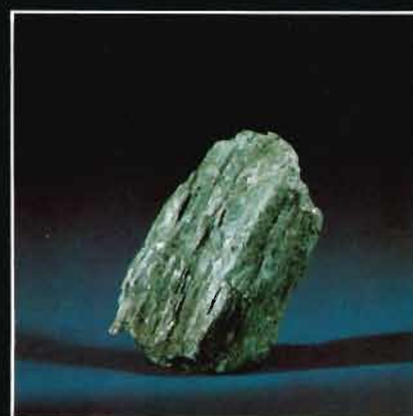
References: Davies *et al* 1962, p.52; Russell 1949; Scoates 1969, 1971b; Weber 1971c; Wright 1932a.

Talc is a hydrated magnesium silicate ($3MgO{\cdot}4SiO_2{\cdot}H_2O$) formed as an alteration product of some magnesium-rich minerals including pyroxene, serpentine and dolomite. It may occur in compact masses (plate 31), as in soapstone, and individual crystals (monoclinic) are rarely seen. Its excellent cleavage causes it to appear in thin plates and flakes (plate 32), well seen in talc schist. The colour is typically apple-green or white, but where massive it appears dark green or grey. Talc feels greasy and can be easily scratched with the finger-nail. It is the softest of all minerals and has long been used for marking cloth ("tailor's chalk") and making crayons. Other familiar applications are in talcum powder, cosmetic lotions, soaps and face creams. Talc powder of high purity is used as a filler in medical tablets and pastes, and also for some kinds of food-processing. An important use for high-grade talc is in the ceramics industry: finely ground powder, which must be free from discolouring impurities, is used to increase the toughness and transluscence of finished products and to resist cracking in the glazing. Major amounts of high-grade talc are also used as an extender-pigment in paints; the talc must be as near white as possible, and low in carbonate impurities. High-grade talc is important as a

29) Platy green serpentine from Flin Flon

30) Fibrous (asbestiform) serpentine (Museum)

31) Massive talc from Flin Flon



32) Flaky green talc (Museum)

filler material for making paper of superior quality; the talc must be free of chemically active or abrasive impurities. Large tonnages of low-grade talc are used as dusting agents for asphalt roofing and gypsum boards, and again as a filler for dry-wall sealing compounds. Similar grades are used as carriers for insecticides, and also in the rubber industry. Other applications are for electric cable coatings and in the manufacture of linoleum and floor tiles; also in adhesives, auto-body compounds and some polishes (as for leather and soft metals); again in some plastic products and foundry facings. *Soapstone* is the massive and impure talc-rock that can be quarried and sawn off in blocks. Its well known use is for Eskimo carvings but it has also been used for acid-proof flooring, laboratory table-tops and electrical switchboards. Soapstone finds only limited use nowadays in making refractory bricks, but after being strongly heated (calcined), talc becomes harder than steel, and can be tooled and threaded for use in electrical insulators and gas-tips. Because of its heat-resistance, soapstone is still used by metal-workers as marking crayon.

In Manitoba *talc* is found in some greenstone belts and is often closely associated with altered pyroxenite or serpentinite; it occurs to a lesser extent with certain gabbros. The gabbroic host-rock at the **Lynn Lake** mine (Map T) is altered to talc and serpentine in the vicinity of the nickel-copper orebodies. At the **Flin Flon** copper-zinc mine, some rocks within the ore-zone are altered to talc schist. White to yellow massive and fibrous talc is associated with copper ore that occurs in chlorite schist at the Pine Bay mine (Map H), on Sourdough Bay, ten miles due east of Flin Flon.

References: Davies *et al* 1962, pp.27, 72; Sabina 1972.

About 5 miles north of Flin Flon, *talc* can be seen in two small ultramafic bodies at **Embury Lake** (Map H). The first is intrusive pyroxenite with an outcrop area of 200 x 300 feet, at the northwest end of the lake. The outcrop rises some 45 feet above the surrounding terrain and is two or three hundred yards north of the lakeshore. A 2-foot-wide zone of talc-carbonate schist represents the altered northern contact of the pyroxenite intrusion. The second outcrop area (400 x 500 feet) is 1¾ miles east of Annabel Creek and ¼ mile north of Embury Lake. The outcrops show an orange-buff to light grey weathered surface. The central part of the intrusion consists of altered pyroxenite and serpentinized peridotite, but the north and south contacts have been altered to talc-carbonate serpentinite and are marked by sheared breccia. The northern contact zone is about 100 feet wide and its outer margin includes a 2-foot-wide zone of talc schist containing up to 70% *talc* and 25% carbonate.

Reference: Scoates 1969.

Forty miles or so to the southeast, outcrops of talc schist, associated with serpentinite, occur along the Grass River near its inlet into Iskwasum Lake (Map I) and for several miles upstream. This lake and river fall within the **Grass River Provincial Park,** accessible from provincial road 391. The serpentinite bodies are ellipsoidal in shape, some of them a mile or two in length, and they appear to have intruded the volcanic country rocks. Their margins have been altered to talc and talc-serpentinite schists to an estimated thickness of 50 to 200 feet. The strong red colouration of some of these schists is due to red iron oxide. Good exposures have been recorded in cuttings along the railway (Map I) west of the Grass River railway bridge: serpentinite is seen from 100 to 150 yards west of the river and, a few yards beyond this, talc schist is exposed with much red rock for about 50 feet. Outcrops with abundant *talc* occur over a distance of about 5 miles downstream from the bridge; two miles south of the bridge a small lake, half a mile east of the river, was nicknamed "talc lake" (Map I). Much talc was recorded on three small islands in the north part of Iskwasum Lake and again near the lake's northwest end. Rare platy crystals of apple-green talc have been found in veins at a few locations, such as the dead-end bay in Grass River east of the main stream, 2 miles north-northwest of Iskwasum Lake (Map I).

References: Hunt 1970; Hunt & Denison 1971; Scoates 1969.

In southeast Manitoba, several outcrops of talc schist and talc-serpentine schist have been noted on two adjacent islands east of Black Island in **Lake Winnipeg** (Map D). The larger of the two, about 500 feet in length, is located in the large bay about a mile northeast of the mouth of the Wanipigow River; the islands are about 200 yards off-shore from the mainland.

References: Davies 1951; Scoates 1969.

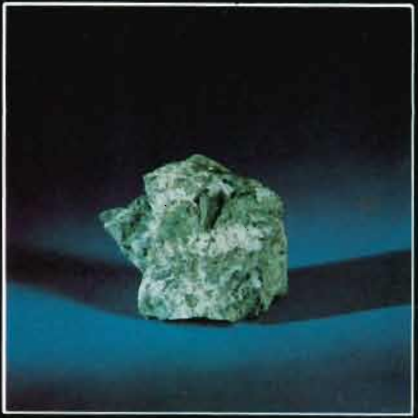
The Pyroxenes

33) Pyroxene porphyry from Snow Lake

34) Hypersthene phenocrysts in gabbro from Prudhomme Lake

35) Green diopside crystals (Museum)

36) Black augite crystals (Museum)



37) Diopside from Bird River

The pyroxenes are an important group of rock-forming ferromagnesian minerals of widespread occurrence in Manitoba. In general composition they are silicates of iron, magnesium and calcium, with or without aluminum, occasionally with sodium, and rarely with lithium. Some of the commonest pyroxenes are primary igneous minerals, major constituents of ultramafic rocks such as pyroxenite, and abundant in basic rocks such as gabbro and basalt. Certain pyroxenes are however of metamorphic origin. Pyroxenes that crystallize in the monoclinic system are called *clinopyroxenes*, and those that crystallize in the orthohombic system are called *orthopyroxenes.* In both cases the crystals, many of which appear dark green or almost black, tend to be stubby, with either four-sided or eight-sided cross-sections (plate 33). All the pyroxenes have two principal cleavages intersecting almost at right angles (fig. 16). This is one of the readiest means of distinguishing pyroxene from amphibole which may be somewhat similar in appearance; both have approximately the same hardness as feldspar (with some variations). Other differences of form and association are referred to under Amphiboles. There are about a dozen varieties of pyroxene, some of them quite rare; jadeite for example is a rare alkali-pyroxene (sodium aluminum silicate) highly valued as the ornamental stone, jade. The following pyroxenes are well known in Manitoba:

(i) HYPERSTHENE (fig. 17), an orthohombic iron-magnesium silicate, $(Fe,Mg)O \cdot SiO_2$, which grades to the magnesium-rich ENSTATITE ($MgO \cdot SiO_2$), less common in Manitoba* (plate 34).

(ii) DIOPSIDE (fig. 18), a monoclinic calcium-magnesium silicate, $CaO \cdot MgO \cdot 2SiO_2$ (plate 35).

(iii) AUGITE (fig. 19), the most abundant of the pyroxenes; it is monoclinic and its composition is variable, but can be regarded approximately as diopside with the addition of iron-aluminum silicate in various chemical combinations, e.g. $CaO \cdot MgO \cdot 2SiO_2 + FeO \cdot Al_2O_3 \cdot SiO_2$ (plate 36).

(iv) SPODUMENE, a rare, lithium-bearing clinopyroxene ($Li_2O \cdot Al_2O_3 \cdot 4SiO_2$) found in certain granitic pegmatites; occurrences are described elsewhere under the heading of Pegmatitic Minerals.

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* Near Russell Lake however, certain ultramafic rocks contain clusters of orthopyroxene identified as *bronzite*, an iron-bearing variety of enstatite (McRitchie 1975). A bronzite-garnet rock near Thompson is described under Garnet.

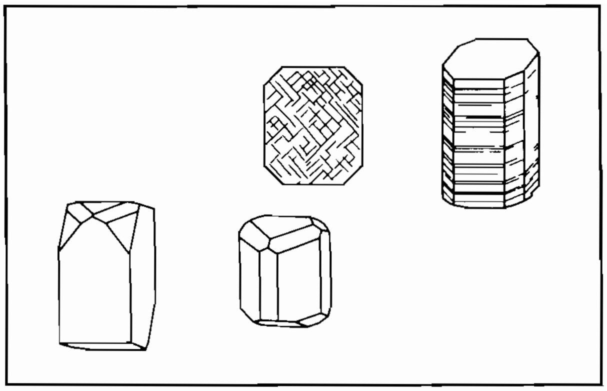


Fig. 16: Pyroxene

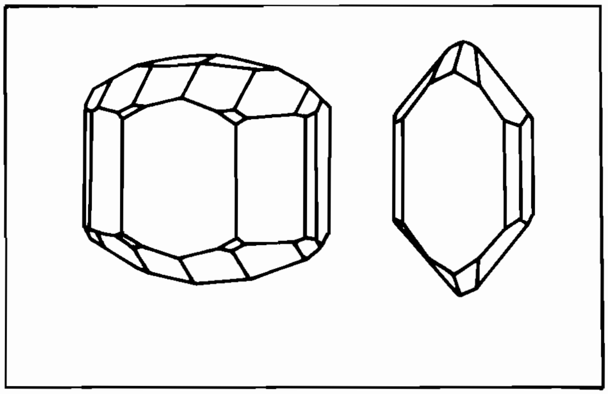


Fig. 17: Hypersthene

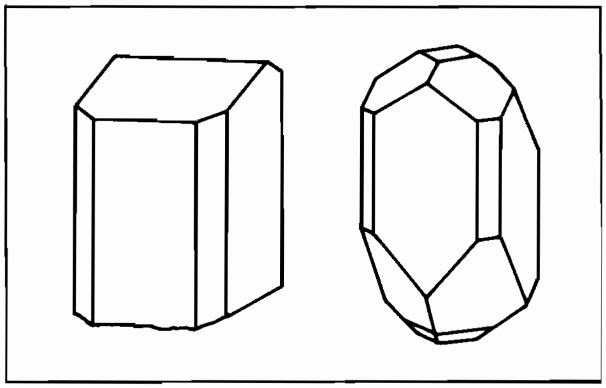


Fig. 18: Diopside

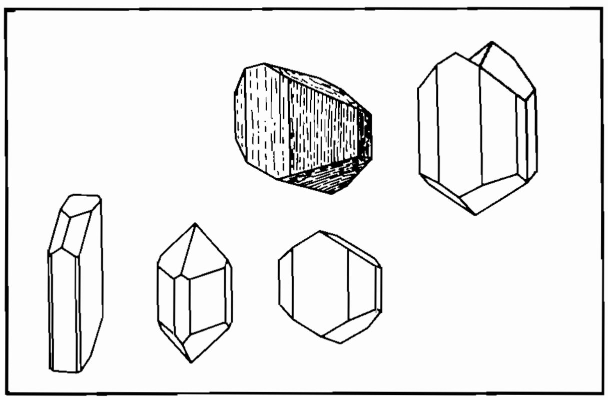


Fig. 19: Augite

Some of the pyroxenes may provide interesting and occasionally valuable gemstones. *Jadeite* falls into the latter category because of its rarity and great durability, which is due to its finely crystalline texture: a typical specimen consists of thousands of minute, interlocking crystals; although they are not outstandingly hard (6½ to 7), this texture imparts great tenacity, so that jadeite can be carved and sawn, even into thin slices, without breaking. Imperial jade is an intense, translucent emerald green; but rich red, mauve, yellow and black varieties are also valuable. Pure white, translucent jadeite is rare and correspondingly valuable, while the greyish white and dark green varieties are relatively cheap. Worldwide, jadeite is generally found associated with albite in serpentinized rocks; it appears to have formed through metamorphism of soda-rich rocks at relatively high temperatures, whereas the serpentine must have formed later as temperatures declined. Initial findings of jadeite boulders that have weathered out of serpentinite, often in mountainous terrain, have in some cases led to discovery of the source rock (Burma, Guatemala, California, Japan, Celebes). Some Mexican jadeite grades in composition toward diopside and is described as diopside-jadeite. Elsewhere, crystals of the mineral *diopside* can provide hard, durable gemstones; attractive colours are rare but green, transparent, faceted gems are well known. The *enstatite-hypersthene* orthopyroxenes have limited gemstone potential: enstatite is noted for clear green specimens of facet grade found in South African diamond mines. Hypersthene is rarely clear, but translucent varieties showing a metalloid sheen are sometimes cut into cabochons by collectors. The sub-metallic lustre is best displayed in *bronzite,* an iron-bearing enstatite. The gemstone potential of spodumene is discussed under Pegmatitic Minerals; good specimens of this pyroxene can be found in Manitoba.

Four miles northwest of West Hawk Lake in the **Whiteshell Park,** pyroxenite is exposed intermittently for a length of half a mile and a width of 500 feet. This rock is composed almost entirely of **Hypersthene**. The outcrops, 2 miles west to west-northwest of McGillivray Lake (Map A), trend northwest-southeast. Ninety miles to the north, near the Ontario border, there is at **Garner Lake** (Map D) an ultramafic intrusion composed of alternating layers of peridotite and pyroxenite. The latter rock consists of dark green interlocking crystals of pyroxene about 3 mms in length; microscopically the pyroxenes are seen to be partially replaced by an amphibole mineral (tremolite), but the replacement is pseudomorphic and is not easily seen in hand specimens. The pyroxenite layers form high, massive outcrops that weather dark grey, contrasting in height with the low outcrops of peridotite. The large island in south-central Garner Lake that has already been noted for its serpentine also shows, along its northern shoreline, outcrops of the pyroxenite. Other pyroxenite outcrops can be seen on islands to the northeast. Forty-five miles to the northwest at **English Lake** (Map D) there is another pyroxenite body, composed of *hypersthene.* It is distinguished from associated rocks by its coarse grain-size and brownish black colour; around its outer contact the pyroxenite grades to a soft talcose rock. The outcrops extend about 100 yards along the southeast shore of the lake. The pyroxenite attracted interest many years ago because it was found to contain a little copper-nickel mineralization; its outcrop area is semicircular with a radius of about 100 feet inland. The surrounding rocks that form most of the southeast shore of the lake are largely greenstones, while the opposite (northwest) shore consists mainly of granitic rocks. English Lake is about 11 miles east of the serpentinite quarries at Clangula Lake, and is about 5 miles northeast of provincial road 304.

References: Russell 1949; Scoates 1971b; Springer 1952; Weber 1971c.

Various pyroxene localities have been recorded in and near the **Manitoba Nickel Belt:**

Augite is the principal constituent of a dense, medium to coarse-grained, greenish black pyroxenite found at the north end of Ospwagan Lake, just west of the narrow entrance to the Manasan River (Map Q). Short tabular crystals of augite, 2 to 3 mm in length, give the rock an interlocking texture. Peridotite of the **Cuthbert Lake** dyke-swarm (Map Q) contains abundant *pyroxene* crystals (up to ½ cm long) as well as olivine. Outcrops have a dark brown to black, finely pitted, weathered surface, and the rock is extremely tough and hard to break. Typical outcrops are low, smoothly rounded, and elongated parallel to their strike (northeast). The rock may appear at first sight to be fine-grained, but is generally medium to coarse-grained. The major minerals are olivine, hypersthene, augite and diopside. The associated gabbro dykes almost invariably contain pyroxene and some outcrops are characterized by abundant phenocrysts of green *clinopyroxene* up to half an inch long, set in a groundmass of plagioclase (labradorite to bytownite), which generally makes up nearly half of the rock. The gabbro dykes vary in width from one foot to two hundred feet but are mostly less than twenty feet wide. Their outcrops are dark green to greenish black, and the rock is generally medium-grained. Other information is given under Olivine. Hypersthene-cordierite granulite at **Paint Lake** is described under Cordierite.

References: Patterson 1963; Stephenson 1974.

Diopside (plate 37) is the lime-rich pyroxene characteristically found in limestones that have been altered to skarn – a rock that typically consists of calcite and various lime-silicate metamorphic minerals (see section I). Skarn occurs with other rocks of sedimentary origin in the Manitoba Nickel Belt, but outcrops are rare and it is best known at the **Thompson** mine (where guided tours can be joined by prior arrangement with the International Nickel Company of Canada Limited). Skarn at the mine may be either thinly banded or quite massive. It contains prominent coarse crystals of diopside and silky phlogopite mica in a carbonate groundmass.

Reference: Quirke *et al* 1970.

About 25 miles southwest of Thompson (Map Q) a few small outcrops of skarn-rock have been described from the vicinity of **Paint and Joey Lakes.** These rocks are fine to medium-grained with granulose texture; they are pale grey and buff, becoming green where more altered. They occur as remnant bands, 20 or 30 feet thick, within granitic gneiss. Their weathered surfaces are roughly pitted. The least altered skarn-rocks consist essentially of coarsely crystalline calcite with subordinate *diopside* and microcline. The more altered varieties consist of pyroxene and plagioclase with only minor carbonate; the pyroxene may include hypersthene as well as diopside, and coarse black flakes of biotite may also be present. One outcrop-locality is on the west shore of Joey Lake, one mile from the south end of the lake.

Reference: Godard 1966.

Seventeen miles east of Sherridon, *diopside* can be seen around **Batty Lake** (Map O), especially the southwest shore, where thinly scattered outcrops of impure, crystalline limestone occur among the gneisses. Narrow limestone-quartzite bands are common elsewhere in the area. The limestone beds weather greyish brown to white, with granular, ridged surfaces. Rounded, dark green crystals of diopside can be found by hammering into the fresh rock beneath the weathered surface; microscopic studies have shown that the diopside is partially altered to green amphibole. Some of the associated quartzo-feldspathic gneisses also contain diopside. Hand specimens show a granular texture and are flecked with small black biotite flakes; bright green glassy diopside crystals give the gneiss a striking appearance. Microscopically the diopside shows some alteration to green amphibole.

References: Davies *et al* 1962, p.94; Robertson 1953.

Dark honey-brown *diopside* has been described from the **Rat Lake** area (Map S), about 30 miles south of Leaf Rapids. The crystals are prominent against a background of white calcite-skarn rock at a few isolated localities. One occurrence is a mile south of the Suwanee River, but the outcrops are of minor extent and the area has been subjected to flooding.

Reference: Schledewitz 1972.

The Amphiboles

38) Hornblendite from Sherridon

39) Black hornblende crystals in nickel ore from Dumbarton Mine

40) Actinolite (Museum)

41) Tremolite (Museum)

42) Anthophyllite schist from Batty Lake

The amphiboles are another group of rock-forming ferromagnesian minerals that are very widespread in Manitoba, more plentiful in fact than the pyroxenes which they resemble in some respects. Amphiboles that are common in Manitoba crystallize in the monoclinic and orthohombic systems and are mostly comparable in hardness (5 to 6) and colour (usually dark green) to the pyroxenes. Amphiboles have slightly lower specific gravities than the corresponding pyroxene varieties, but the readiest means of distinction in the field is by observing the cleavage and general shape of the crystals (fig. 20). Instead of intersecting at about right angles, the two amphibole cleavages intersect at 54°. Bladed or elongated crystals are much more common and they generally taper off with three faces (instead of two as in the pyroxenes). Another strong clue is that amphibole cross-sections are usually six-sided, never eight-sided like the pyroxenes. Chemically, the two groups are approximately parallel in composition: the amphiboles are complex silicates of iron, magnesium, calcium and sometimes sodium, with or without aluminum silicate. A significant difference however is the presence of hydroxyl in amphiboles, indicating that the elements of water were present during crystallization. Also alkalies (mainly sodium) tend to be more prominent in amphiboles, while the calcium-magnesium ratio tends to be lower than in the pyroxenes. There are half a dozen principal varieties of amphibole, and other sub-varieties that grade into them. The following amphiboles are well known in Manitoba:

(i) HORNBLENDE (fig. 21), the commonest of the amphiboles, a complex monoclinic silicate of calcium, magnesium and iron, together with sodium and aluminum silicates; the composition can be represented approximately as $CaO{\cdot}3(Mg,Fe)O{\cdot}\ 4SiO_2(OH)$ with $Na_2O{\cdot}\ Al_2O_3{\cdot}\ 4SiO_2$ and $(Mg,Fe)\ O{\cdot}Al,\ Fe)_2O_3{\cdot}SiO_2$.

(ii) TREMOLITE (fig. 22), a monoclinic magnesium-rich amphibole, approximately $CaO{\cdot}3MgO{\cdot}4SiO_2(OH)$; also distinguished by relatively high calcium content, and thus comparable in composition with diopside.

(iii) ACTINOLITE (fig. 22), approximately $CaO{\cdot}3(Mg,Fe)O{\cdot}4SiO2{\cdot}(OH)$, also calcium-rich, and grading in composition from tremolite owing to an increased iron content at the expense of magnesium.

(iv) ANTHOPHYLLITE, an orthorhombic magnesium-iron amphibole, approximately $(Mg,Fe)O{\cdot}SiO_2$ with minor hydroxyl.

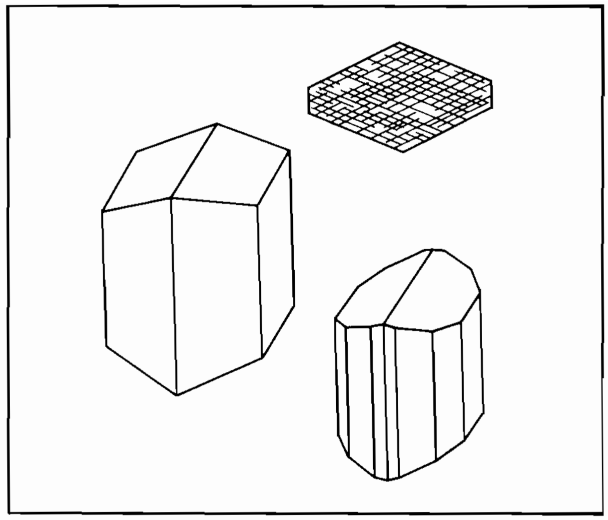


Fig. 20: Amphibole

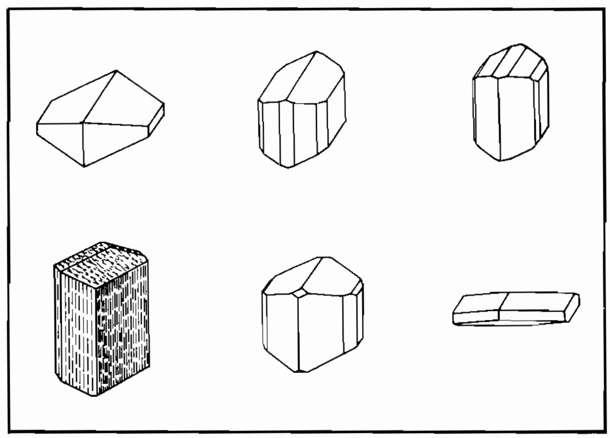


Fig. 21: Hornblende

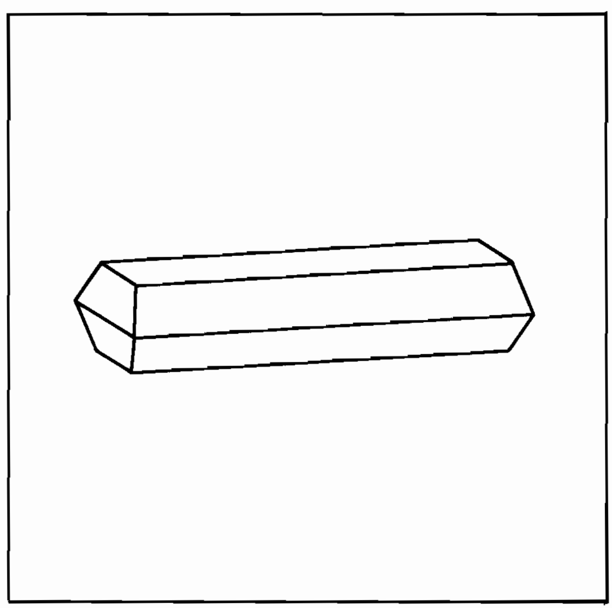


Fig. 22: Tremolite - Actinolite

The principal gemstone interest of the amphiboles is as a source of *nephrite*, one of the two kinds of *jade* from which valuable ornamental carvings are made. Nephrite is a tough, massive variety of tremolite-actinolite and is composed of very compact, densely packed, minute fibres of the amphibole. Tremolite gives whitish varieties of nephrite, actinolite green. The most valuable nephrites are the bright greens from Wyoming and New Zealand. Nephrite is believed by some authorities to have been the classic jade of the ancient Chinese. It is less rare than jadeite (see Pyroxenes). Most discoveries have been of smoothly worn pebbles or boulders derived from veins or lenses of nephrite in various metamorphic rocks, including altered ultramafics. Apart from nephrite, the amphiboles have only minor gemstone potential. Small dark green crystals of *actinolite* from Madagasgar have been cut as "collector's gems"; they are hard but easily cleaved. Clear crystals of *tremolite* can be similarly faceted. Finely fibrous masses of tremolite, actinolite or *anthophyllite* can be rounded and polished in such a way as to provide *catseyes*; this effect is due to light reflected in a narrow band across the fibres. Also, anthophyllite sometimes displays a bronze-like irridescence, and certain material from Greenland is said to exhibit vivid colours reminiscent of ornamental labradorite.

The main commercial use of the amphiboles is as a source of *asbestos*. Although all Canadian asbestos is obtained from fibrous serpentine (chrysotile), the term asbestos in its strictest sense was originally applied to fibrous *actinolite*. This type of asbestos has little commercial value at present, but some actinolite and tremolite are ground up for insulating purposes. *Amosite*, mined only in South Africa, is an iron-rich variety of anthophyllite that occurs in unusually long, splintery, coarse fibres, some of which can be spun but which are used chiefly as a binder for heat insulators. *Crocidolite*, the "blue asbestos", also from South Africa, provides long, coarse, flexible spinning fibre with low fusibility, and (like the other fibrous amphiboles) it has high resistance to acids. Crocidolite is a fibrous variety of *riebeckite*, a blue sodic amphibole. In certain metamorphic rocks crocidolite has been infiltrated by silica and altered to a golden yellowish brown colour, giving rise to the ornamental stone known as *tigereye*.

Hornblende (plate 38) occurs in a wide variety of rock types and is the major constituent of hornblendite (igneous) and amphibolite (metamorphic). As a primary igneous mineral, hornblende is found typically in diorite, syenite, gabbro, andesite and basalt; and as a metamorphic mineral in hornblende schist and hornblende gneiss. Its colour is frequently dark green, black or brownish (see also plate 50). Hornblende can be found at many localities throughout the Precambrian regions of Manitoba, especially in the greenstone belts. The following are some occurrences of mainly coarse-grained hornblende, beginning with southeast Manitoba.

References: Manitoba Mines Branch 1965; Phillips 1975.

In the southern **Whiteshell Park** (Map A), hornblende is prominent in the outer zones of the Falcon Lake stock: in coarse, mottled black and white diorite the dark minerals (25%) are mainly hornblende, accompanied by white plagioclase. The associated coarse black gabbro contains more hornblende than plagioclase. Between West Hawk and Falcon Lakes the fine-grained andesite has been locally recrystallized (along shear zones) to a coarser rock with long narrow leaves of hornblende, some in radiating patterns. Further north in the Whiteshell Park (Map C), a small body of coarse gabbro less than ½ mile northwest of Greer Lake shows large green *hornblende* crystals. Ten miles or so to the north and about 2 miles west of Bird Lake (Map C), coarse hornblendite occurs in the **Bird River** sill near its contact with the granite. Some of the hornblende crystals are as much as an inch in length. Some hornblendite is host-rock for nickel and copper mineralization in this general area (plate 39) which includes the Dumbarton Mine (Map B). Also present in the Bird River sill is some very coarse-grained mottled gabbro in which patches of feldspar are separated by clusters of large hornblende crystals.

References: Davies 1954, 1955, 1957; Gibbins 1971; McRitchie 1971b.

About fifty miles further north, some of the basalt found with other volcanic rocks near the south shore of **Wanipigow Lake** (Map D) has been coarsely recrystallized to a dark rock that strongly resembles gabbro; the weathered surface has a knobbly appearance due to large crystals of *hornblende* set in a fine-grained groundmass. Hornblende diorite is extensive one to five miles north of the lake, e.g. in the vicinity of Beaver Creek. It is a coarse-grained grey rock composed mainly of white feldspar, green hornblende and some glassy quartz; the hornblende appears fresh and unaltered.

References: Davies 1949; McRitchie 1971b.

Another accessible area where hornblende is abundant is the **Grass River Provincial Park.** One to three miles west of Iskwasum Lake (Map I) a broad zone of volcanic rocks contains much pillow-lava. Within these dark greyish green rocks, which extend northwards west of the Grass River, are a few thin flows of porphyritic basalt containing large phenocrysts of *hornblende*. These can be seen near the west shore of the river at the rapids, ¼ mile south of the railway; associated volcanic rocks reach the shoreline for another 3 miles downstream. Porphyritic basalt also occurs at mile 13 on the railway line (Map I). The basic volcanic rocks extend north to the area around **Elbow Lake** (Map M) which lies near the north boundary of the Grass River Park, about 10 miles north of the railway. Recrystallization near granitic contacts has given rise to amphibolite containing *hornblende* crystals up to an inch in length, e.g. south of Webb Lake, 5 miles north-northwest of Elbow Lake. These rocks are associated with well-banded hornblende-plagioclase gneiss. Coarse amphibolite also occurs 11 miles northwest of Elbow Lake, around Paton Lake (Map M); the amphibolite bands grade eastward into basic lavas.

References: Hunt 1970; McGlynn 1959.

Fine-grained hornblende schists derived from basic volcanic rocks can be seen in the western part of **Reed Lake** (Map J). The schists are finely banded and are black where the *hornblende* content is high, grading to grey hornblende gneiss where feldspar is the predominant mineral.

Reference: Rousell 1970.

About two miles east of provincial road 391, between Nelson House and Leaf Rapids, there is a small pear-shaped body of hornblende syenite about 1½ miles long, tapering out to the northwest. Its location is about 3 miles north of the **Suwanee River** (Map S). Weathered surfaces show a pink feldspathic groundmass, distinctly spotted with greenish black *hornblende* and veined by fine-grained granite. The syenite can be distinguished from the surrounding granite (which it otherwise resembles) by the absence or rarity of quartz in hand specimens. Twenty miles or so further north, a gravel road from **Leaf Rapids** to Southern Indian Lake passes through an extensive sequence of volcanic rocks east and northeast of Ruttan Lake (Map S), the site of a large open-pit, copper-zinc mine. About 10 per cent of these basic lava-rocks are porphyritic, and the phenocrysts are mainly hornblende, 2 to 6 mms in length.

References: Schledewitz 1972; Steeves & Lamb 1972.

Gabbros and associated rocks of the **Lynn Lake** region (Map T) contain major amounts of hornblende, as well as other varieties of amphibole and a certain amount of pyroxene. The most accessible outcrops are (i) at Lynn Lake, (ii) south of Dunphy Lakes and (iii) between the Barrington and Hughes Rivers (Map S). The hornblende content of these rocks (collectively known as the Lynn Lake gabbro) is from 40 to 80 per cent. The large *hornblende* prisms (up to ½ inch long) are usually surrounded by a groundmass of feldspar which may have a greenish appearance owing to its content of fine-grained amphibole. Hornblende-rich phases of the gabbro weather dark grey or greenish grey to black. Feldspar-rich phases weather white to greenish, speckled or mottled with dark hornblende. On some outcrops the hornblende crystals stand out to give the weathered surface a stucco-like roughness. The fresh surface of the gabbro is usually dark grey to brownish black, but the feldspar may impart a greenish or bluish cast. Hornblende-rich specimens have a porphyritic appearance, emphasized by the flashing cleavage-faces of the hornblende phenocrysts.

Reference: Milligan 1960.

Actinolite (plate 40) is a common amphibole arising from the alteration of pyroxene or hornblende. It is characterized by its green colour and long, slender, blade-like or fibrous crystals. In Manitoba dense masses of tiny crystals occur in some of the green schists derived from basalt or andesite, but sizeable crystals can best be seen in certain gabbros. Actinolite is recorded at the Flin Flon, Chisel Lake and Anderson Lake copper-zinc mines, and at the Manibridge nickel mine.

Reference: Sabina 1972.

One of the basic igneous rocks in the **Bird River** sill (Map B) is a type of gabbro (anorthositic) that is composed mainly of coarse plagioclase, seen as greyish white areas on the weathered surface. The spaces between the plagioclase may be occupied by densely packed blades of dark green *actinolite.* In places the actinolite is scattered in small clumps, or occasionally in rounded aggregates. Such rocks have been described at the Chrome and Page properties (Map B), respectively 2 miles southwest and 1½ miles north of the road junction (314 and 315).

References: Scoates 1971c; Trueman 1971.

Fifty miles to the northwest (Map D), altered, medium to coarse-grained gabbro contains dark green *hornblende* accompanied by paler green, fibrous *actinolite.* The rock is dark green to black (often brownish on outcrop surfaces) and thus lacks any colour contrast that would make the amphiboles easy to distinguish. Outcrops are located near the east shore of **Lake Winnipeg** opposite Black Island. The best exposures are just south of the mouth of Wanipigow River; other outcrops are located north of the Manigotagan River. Both of these general areas (Map D) are within a few miles of camp or picnic sites on provincial road 304 and can be approached along minor roads, or alternatively by boat.

Reference: Davies 1951.

In the **Grass River Provincial Park** (Map J) actinolite occurs in some of the altered gabbros in the western part of Reed Lake. These are grey to greenish grey rocks, usually fine-grained, but locally coarse-grained; their *actinolite* content varies from 20 to 80 per cent. The actinolite is usually greener and more elongated than the darker and stubbier *hornblende* crystals that predominate in many of the gabbros (Map J). Ten miles to the west, in the Iskwasum Lake area (Map I), actinolite accompanies serpentine in the Grass River serpentinites but the crystals are usually less than 1 mm in length. Slightly larger crystals of fibrous actinolite occur with serpentine and altered plagioclase along the east shore of Barb Lake (Map I) and southward to Iskwasum Lake. This altered igneous rock (known as the Barb Lake mafic intrusion) is medium-grained (1 to 5 mm), and dark green where fresh, weathering brownish.

References: Hunt 1970; Rousell 1970.

Actinolite also occures in the Thompson and Lynn Lake regions. At **Mystery Lake** (Map Q), diorite sills have been partially converted to feldspar-actinolite schist containing about 60 per cent fine-grained *actinolite.* The main outcrop-area is on a small peninsula on the west shore of the lake. In the **Lynn Lake** gabbro (Map T) some of the hornblende and pyroxene has been pseudomorphically altered to secondary green amphibole sometimes called *uralite.* Where this mineral takes the form of larger, bladed crystals it can often be identified as actinolite. The gabbro at Lynn Lake has been described as uralite gabbro in which *actinolite* is the predominant ferromagnesian mineral, ranging in size from minute fibres to large blades visible in the hand specimen.

References: Gill 1951; Milligan 1960.

Tremolite crystals (plate 41) are similarly elongated, blade-like or fibrous, but their colour is usually white or grey rather than bright green. Tremolite is found in metamorphic rocks rich in calcium and magnesium, such as dolomitic marble or altered peridotite. In Manitoba the principal occurrences are in altered igneous rocks. In the southeast, occasional tremolite-rich patches have been noted in very coarse-grained gabbro on the south side of the **Winnipeg River** north of Greer and Waddell Lakes (Map C). In the **Bird River** sill (Map B), outcrops of rusty-weathering altered pyroxenite have a coarsely knotted appearance due to *tremolite* which has replaced pyroxene. Similar replacement has occurred in peridotite where ¼ inch crystals of pyroxene have been converted to tremolite. Occurrences have been described from the Chrome and Page properties (Map B); the close proximity of various rocks is due to the fact that the Bird River sill is a multiple layered intrusion.

At the east end of **Bird Lake** (Map C), fibrous *tremolite* accompanies large (½ inch) garnets in silicified greywacke near the south shore. Some 2½ miles northeast of **Long Lake** (Map D), an interesting dyke (locality 5) of coarse cortlandite (an amphibole-rich variety of peridotite) contains large areas of pale *tremolite,* as well as much *hornblende* and serpentinized olivine which are the predominant minerals. The dyke (known as the Dove Lake cortlandite) is about 50 yards wide and trends southeast for 2½ miles. About 8 miles east-southeast of Long Lake, the **Garner Lake** ultramafic body (Map D) includes pyroxenite layers, some of them several hundred feet thick. The pyroxenites in the northeast corner of the lake have been massively converted to *tremolite-rock.*

References: Campbell 1971; Davies 1956, 1957; Scoates 1971c; Trueman 1971; Weber 1971b.

At the Chisel Lake Mine near **Snow Lake** (Map L), *tremolite* is one of the common gangue minerals that accompany the copper-zinc ore. It occurs in talc-tremolite schist and dolomite-tremolite rock. Green fibrous aggregates of tremolite-actinolite are reported, and also a coarse massive rock composed mainly of green *actinolite* prisms. Other gangue minerals at this mine include quartz, muscovite, biotite and chlorite.

References: Davies *et al* 1962, p.88; Sabina 1972; Williams 1966.

Fifteen miles from Thompson (Map Q), the altered picrite lava-rock at **Ospwagan Lake** (already described under Olivine) contains much fine-grained tremolite in its groundmass; some picrite-breccia consists almost entirely of small laths (1 to 3 mms) of pale green *tremolite,* with only minor amounts of chlorite.

Reference: Stephenson 1974.

Twenty-five miles southwest of Lynn Lake and a mile or so south of **Dunphy Lakes** (Map T), altered pyroxenite shows narrow zones of a tough grey rock composed of radiating *tremolite* needles with flaky *talc.* Outcrops, 2 or 3 miles east of Fox Lake mine, are near the northeast end of Wolf Lake and, nearby, about ¼ mile north of provincial road 396; and again, immediately northeast of Snake Lake.

Reference: Stanton 1949.

Few outcrops of *tremolite-marble* are known in Manitoba, but one has been reported with coarse skarn-rock near Misty Lake in the **exteme northwest** (see section I).

References: Schledewitz 1975; Weber *et al* 1975.

Anthophyllite, a comparatively uncommon amphibole, is found in anthophyllite schist (plate 42) or gneiss, and also as an alteration product in ultramafic rocks. It is essentially a metamorphic mineral, usually occurring in prismatic or needle-like aggregates, or in radiating fibres. The principal occurrence in Manitoba (Map O) is about 17 miles east of Sherridon: outcrops are scattered along one mile of shoreline on the north shore of **Batty Lake.** The rock contains numerous radiating groups composed of dark brown blades of *anthophyllite,* accompanied by cordierite and much biotite. The origin of this metamorphic rock is uncertain, but it may be an altered tuff. The outcrops on the lakeshore are very similar to those 3 miles to the northeast which are part of a long narrow band of anthophyllite-rock, 50 to 100 feet wide and striking generally northwest-southeast for 10 or 15 miles. Remnants of this band persist for at least 8 miles southeast of Limestone Point Lake (Map O), and a striking occurrence of anthophyllite gneiss has been described along the **File River** a mile or two north of its entry into this lake; the anthophyllite is light to dark brown and is seen as radiating bladed crystals from ½ inch to 4 inches in length. A similar band curves westerly from the southwest bay of **Star Lake** (Map O). The rock here is composed mainly of yellowish brown *anthophyllite* in large radiating crystals, some of which are 4 inches long. The amphibole is accompanied by a little quartz, biotite and garnet. Further information about the anthophyllite-bearing rocks of the Batty Lake area is given under Garnet and Cordierite.

References: Davies *et al* 1962, p.97; Kornik 1968; Robertson 1953.

Anthophyllite occurs with cordierite in **east Manitoba** (Utik Lake) and **north Manitoba** (Rat Lake). Both occurrences (Maps S and Y) are described subsequently under the heading of Cordierite.

References: Milligan & Take 1954; Schledewitz 1972.

Minor amounts of *anthophyllite* are found at some copper-zinc mines around **Snow Lake** – as brown prismatic aggregates at Osborne Lake, Stall Lake and Anderson Lake (Map K).

Reference: Sabina 1972.

Monoclinic amphiboles of similar composition to anthophyllite have also been identified in **northern Manitoba.** *Cummingtonite* (Magnesium-rich) occurs as one-inch crystals in a quartz-garnet-plagioclase-amphibole metamorphic rock on the south shore of the east arm of Russell Lake. *Grunerite* (iron-rich) has been found as one-inch crystals in coarse amphibole-plagioclase gneiss in the central part of Mynarski Lakes.

References: Baldwin 1974; Elphick 1972.

Epidote and other Lime-rich Minerals

43) Epidote veins in quartzite from Anderson Lake

44. Crystalline intergrowth of epidote (Museum)

45) Epidote in polished specimen from Ruttan Lake

46) Zoisite with quartz (Museum)

47) Scapolite crystals (Museum)

48) Cleavage block of green scapolite (Museum)

Altered lime-bearing rocks in which new (silicate) minerals have developed may be described as calc-silicate rock, lime-silicate rock or skarn; the latter term is frequently met in geological descriptions of the Thompson nickel mine. We have already seen how the calc-silicate minerals, diopside and tremolite, can develop in metamorphosed limestone and dolomite. Other minerals found in lime-rich environments in Manitoba include: –

Epidote-Clinozoisite, hydrous calcium aluminum silicate ($4CaO \cdot 3Al_2O_3 \cdot 6SiO_2 \cdot H_2O$) in which ferrous iron takes the place of some of the aluminum to cause a gradation from clinozoisite to epidote (plate 43). Both minerals occur in well formed monoclinic crystals (fig. 23) with strong basal cleavage. They are transparent to translucent with vitreous lustre, and hardness between 6 and 7. Epidote is characterized by its attractive yellowish green colour but may also be dark green (plates 44 & 45). Clinozoisite lacks this characteristic and is usually more weakly coloured, often greyish white or brownish. *Zoisite,* a less common, orthorhombic form of clinozoisite, usually occurs as minute grains resulting from the breakdown of lime-rich plagioclase, and is rarely found in large crystals (plate 46). *Epidote* may provide fine crystal specimens from quartz veins and pegmatites. Facet-grade crystals are cut by collectors but, although hard and attractively coloured, their gem value is low because they have little reflectivity. Massive epidote is cut into cabochons however, and a coarse rock named *unakite,* composed of green epidote, pink feldspar and quartz (found with granite), can look very attractive when polished. *Piedmontite* is a relatively rare, manganese-rich variety of epidote that may be purplish red or deep rose; sizeable crystals are very rare but massive piedmontite can provide attractive cabochons. Clear brown crystals of *clinozoisite* are cut only as collector's gems. A fine-grained, pink variety of zoisite, called *thulite,* is sometimes used for cabochons, and massive material can be polished ornamentally if reinforced by the presence of finely intergrown quartz.

Scapolite (plate 47), a rock-forming mineral of variable composition: the lime-rich end-member *(meionite)* has the composition of 3 molecules of anorthite (see Feldspars) combined with one of calcium carbonate, while the soda-rich end-member *(marialite)* consists of 3 albite plus sodium chloride. Scapolite crystallizes in the tetragonal system (fig. 24) and may show square cross-sections with four cleavages. It is generally colourless, white or grey, and transparent to translucent, with vitreous lustre and hardness of 5 to 6. Some varieties are brownish, greenish or otherwise coloured (plate 48).

Although somewhat soft, clear yellow, blue and violet specimens from the Grenville limestone of eastern Canada have provided small but attractive faceted gems.

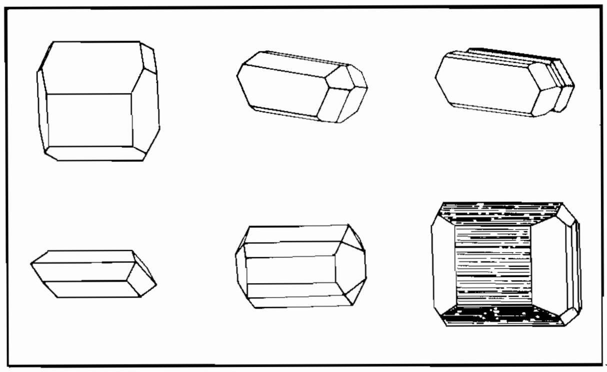


Fig. 23: Epidote

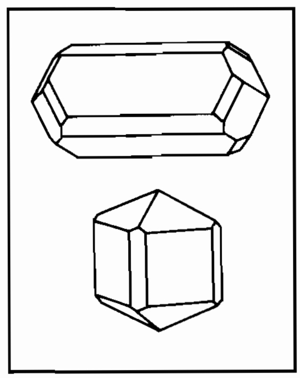


Fig. 24: Scapolite

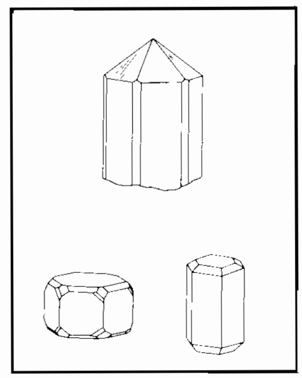


Fig. 25: Apatite

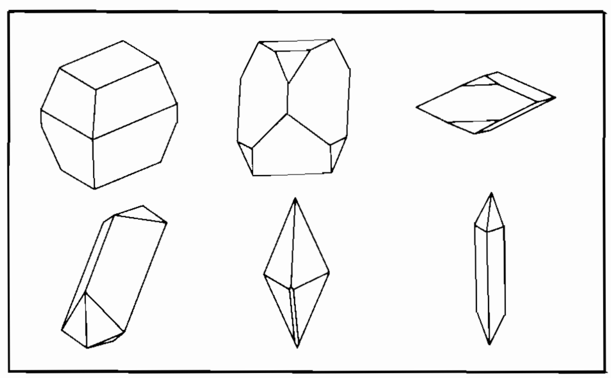


Fig. 26: Sphene

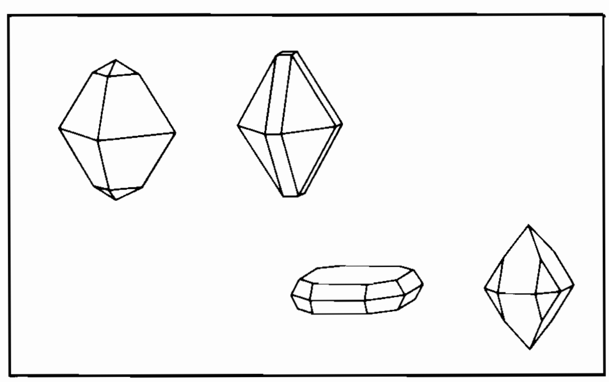


Fig. 27: Scheelite

Very attractive *catseye* gems have been made from white, pink and blue scapolite, and a greyish Grenville variety can be similarly cut. The catseye effect is due to numerous minute cleavage cracks parallel to the four prism faces, and to oriented rodlike inclusions of a dark mineral in the scapolite.

Apatite, a phosphate of calcium combined with either calcium fluoride, $Ca_5F(PO_4)_3$, or calcium chloride, $Ca_5Cl(PO_4)_3$: well formed hexagonal crystals (fig. 25) can be found, often greenish or bluish, also brown or colourless; they are subresinous or vitreous and may be transparent or opaque; the hardness is 5. Striking crystals are to be seen in mineral collections (plates 49 & 50), and the fluorine-bearing variety *(fluor-apatite)* is cut as a collector's gem of considerable brilliance and in various colours, especially green, yellow, purple and blue. The fragility and low hardness are unfavourable for extensive jewellery use however. The best specimens are found in pegmatitic cavities but others are embedded in metamorphic limestone or with calc-silicate rocks. In the late 19th century, metamorphic apatite deposits were extensively worked in eastern Canada as a source of phosphate fertilizer, before giving way to low-cost sedimentary phosphates from Florida.

Sphene or titanite (plates 51 & 52), a titanate and silicate of calcium ($CaO{\cdot}TiO_2{\cdot}SiO_2$), that tends to form wedge-shaped (monoclinic) crystals (fig. 26): these are usually brown and may be nearly opaque, though transparent yellow and green gem varieties are known elsewhere; the lustre is adamantine or resinous, and the hardness 5¼ . As a gemstone, sphene is favoured by collectors because clear crystals show intense light-dispersion to give the sparkle so desirable in gems. Brittleness and relatively low hardness limit its use in jewellery, but sphene is nevertheless much sought as a collector's gem, especially because of the rarity of good gem material. Its general mode of occurrence is similar to that of apatite. Sphene also occurs as an accessory in some major titanium ore deposits, but rarely in sufficient concentration to acquire economic significance.

Scheelite, calcium tungstate ($CaWO_4$), is a tungsten ore-mineral and is included here because it is associated in Manitoba and elsewhere with epidote and other lime-rich minerals. At Canada's principal scheelite mine located at Tungsten, N.W.T., the ore-body occurs in a flat-lying skarn-zone sandwiched between altered limestone and chert. Crystals (fig. 27) are tetragonal pyramids, often 4-sided but occasionally octahedral. Scheelite has an opaque waxlike appearance varying from white to pale yellow or brown. It is fluorescent in ultra-violet light (see Fluorite), showing colour effects from blue to white and yellow. The specific gravity (approximately 6) is unusually high for a mineral with non-metallic lustre. Fractured surfaces look glassy to resinous but the lustre in some specimens can be almost adamantine. With a hardness of about 5, scheelite can be scratched with a knife. In spite of its softness and the ease with which it fractures, scheelite is nevertheless much sought after by collectors, and some very attractive faceted gems have been cut from colourless and orange-yellow scheelite; some colourless gems sparkle almost like diamonds owing to the considerable light-dispersion effects. The uses of tungsten are based upon the fact that it has the highest melting point of all metals (6,170° F), and that tungsten carbide is almost as hard as diamond. Over half of the total tungsten consumption in North America is as carbides, made by the chemical combination of metallic tungsten powder with finely divided carbon. This compound is then compacted and sintered to make carbide cutting tools and wear-resistant parts such as reamers, punches, drills and valve-seatings; carbide-tipped rock-drill bits are widely used in the mining industry for drilling through rock. Familiar applications are as tire-studs and tips for ball-point pens. Tungsten is an important alloy-metal for high-speed cutting steels which must retain their hardness even at red heat, and also for guns, projectiles and armour-plating. The tungsten is normally added to steels in a form known as ferrotungsten, but for some purposes raw *scheelite* can be added. As a "space-age" metal, tungsten is used in some of the superalloys where great strength is required at high temperatures; one of the cobalt-based superalloys contains a considerable amount of tungsten. High-tungsten alloys are used in jet and rocket engines, turbine blades, combustion-chamber liners and many other such applications. Metallic tungsten, in addition to its high melting point, also has good electrical conductivity. Hence tungsten wire is used in incandescent lamps, fluorescent lamps and vacuum tubes, and also for de-icing purposes in automobile windshields.

In southeast Manitoba, fine-grained *epidote* is common in the volcanic rocks between West Hawk and Falcon Lakes (Map A). North of Star Lake, pale narrow bands in dark tuff consist almost entirely of fairly coarse-grained, fresh-looking epidote and tremolite-actinolite. Sheared pillow lavas between **West Hawk** and Barren Lakes contain small lenses composed of coarse epidote, calcite, amphibole and garnet with much quartz. Brown to white *scheelite* (plate 53) occurs in some of these lenses, and may at first sight resemble the quartz unless an ultra-violet lamp is used to show up its fluorescence; a hardness test will also distinguish the two minerals. Old prospector's trenches are located ½ mile northwest and 1 mile north-northwest of Barren Lake. They fall within a zone of north-easterly shearing parallel to the main granite-greenstone contact (Map A).

Clinozoisite is abundant at the Huron pegmatite (Map C) in southeast Manitoba, as described under Pegmatitic Minerals.

References: Davies 1954; Springer 1952.

In the Bissett area, lime-bearing rocks have been altered to calc-silicate rocks at **Turtle Lake** (Map D). This rock, which is exposed on an island and near the north and south shores of the lake, is in places quite coarse-grained and contains amphibole, diopside, plagioclase and apatite; some of the bluish green *apatite* crystals are ½ cm or so in diameter.

Reference: McRitchie & Weber 1970b.

In eastern Manitoba, granite and granodiorite on the shores and islands of **Bear Lake** (Map Y) show prominent crystals of *sphene* (½ cm). At the east end of the lake, on the south side of the Bigstone River, epidote is also present in a few places, in amounts up to 3 per cent of the rock. Development of these lime-rich minerals is probably related to the presence of numerous basic volcanic xenoliths in the granitic rocks.

References: Milligan & Take 1954; Weber 1974.

At the Osborne Lake copper-zinc mine, near **Snow Lake,** brown crystals of *sphene* in white quartz reach diameters of over 1 cm. The site is not open to the public except by special permission of the mine authorities.

Reference: Sabina 1972.

In the **Grass River Provincial Park,** green schists containing epidote, sphene, plagioclase and actinolite are characteristic of the Iskwasum Lake area (Map I). In this area also, alteration products of the Barb Lake mafic intrusion (see Amphiboles) include much *epidote,* and some small rounded blebs of *sphene.* About 15 miles to the northeast, gabbros around **Sewell Lake** (Map M) contain rods of *apatite* up to 1 cm in length.

References: Hunt 1970; McGlynn 1959.

One mile north-northeast of **Sewell Lake** and immediately east of Preaston Lake (Map M), a sill-like body is composed of tremolite (60%) and *clinozoisite* (40%); it is a massive, speckled-weathering greenish rock and may be a highly altered gabbro. Twenty-five miles to the northwest, hornblende-gneiss a mile or two southwest of **Batty Lake** (Map O) appears intensely epidotized, as is also the case to the southwest of Nokomis Lake. Laboratory study showed however that the apparent epidote is in fact orthorhombic and should therefore be called *zoisite;* quartz-zoisite rock has been formed in this way.

Reference: Robertson 1953.

About 30 miles northeast of Flin Flon, extensive paragneisses west of **Kississing Lake** (Map X) contain thin layers of calc-silicate rock which have a characteristic yellow-green colour due to their *epidote* content (average 15%), and may be speckled dark green or reddish brown due to diopside, hornblende, garnet and *sphene.* The groundmass contains much quartz and either plagioclase or *scapolite,* with local concentrations of up to 25 per cent carbonate minerals.

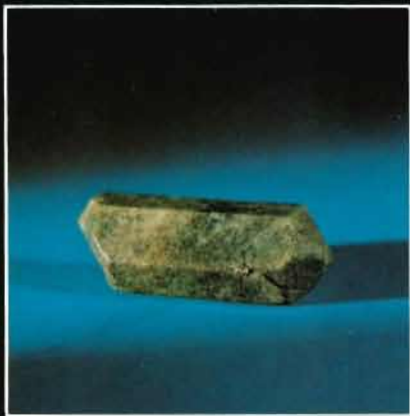
Reference: Pollock 1964.

Skarn-rocks containing lime-rich minerals also occur from place to place in the Thompson-Lynn Lake regions. Skarn at the **Thompson** Mine (Map Q) contains diopside, tremolite and *clinozoisite;* associated quartzite contains *apatite* and *sphene.* Calc-silicate rocks occur 75 to 100 miles to the northwest in the Rat Lake-Granville Lake region (Map S). Rare outcrops near the southwest shore of **Rat Lake** show a distinctive ribbed appearance due to alternating calcite-rich and hornblende-diopside-rich layers. Dark, honey-brown crystals of diopside and scattered amber-coloured granules of *sphene* are prominent against the white calcite. Access to these particular outcrops is now dubious owing to flooding, as noted in the Pyroxene (diopside) section. More accessible outcrops occur about 5 miles north of the **Suwanee River** (Map S) where provincial road 391 crosses a zone of (Sickle-type) arkosic rocks a mile or two in width. Calc-silicate minerals occur in bands from a few feet to several hundred feet thick within the arkoses. These bands are characterized by their greenish colour, often streaked with yellow and purple; streaks of yellowish green *epidote* are numerous. Hand specimens show a massive rock consisting of quartz, feldspar, amphibole, epidote, biotite and some carbonate; some specimens contain diopside and garnet. The arkosic and calc-silicate rocks strike northwest from the main road to crop out along the northeast side of **Costello Lake,** and they appear locally along the southwest shore. Similar rocks are abundant a few miles to the west where the Churchill River flows into **Granville Lake** (Map S).

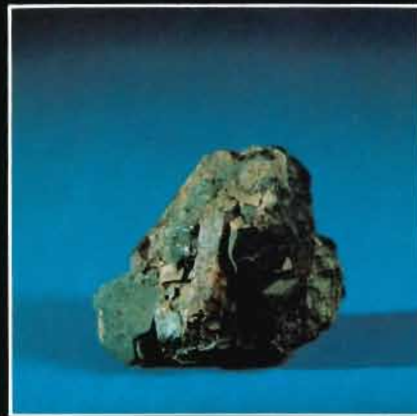
References: Barry 1965; Barry & Gait 1966; Sabina 1972; Schledewitz 1972.

Twenty miles north of Leaf Rapids (Map S), large lenses of *epidote* occur in paragneisses along the south side of **Barrington River** about 5 miles west of Opachuanau Lake. Five miles south-southwest of **Lynn Lake** (Map T), many lenses (up to 3 feet long) of quartz and *epidote* occur in dark tuffs which crop out at a few localities between the railway line and the south end of Eldon Lake.

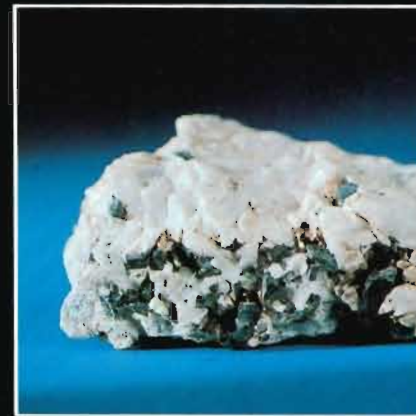
References: Emslie & Moore 1961; Kilburn 1956.



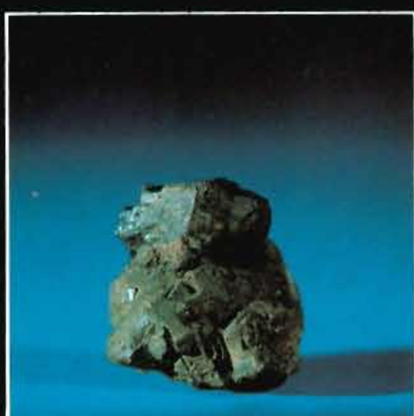
49) Apatite crystal (Museum)



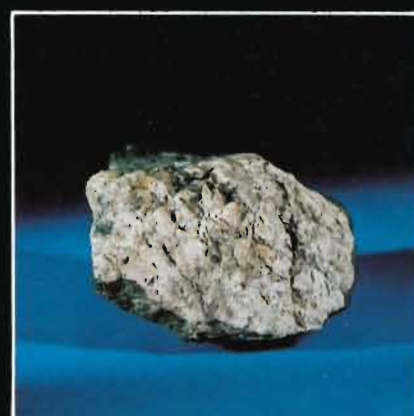
50 Pink apatite intergrown with dark hornblende (Museum)



51) Dark sphene crystals with pale scapolite (Museum)



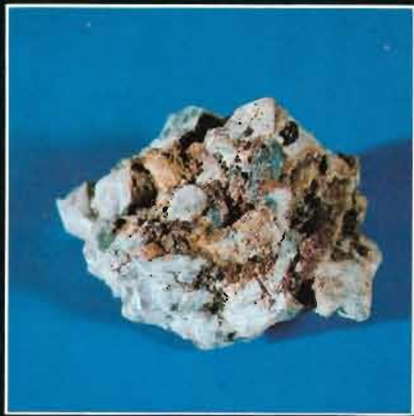
52) Large sphene crystal (Museum)



53) Pale scheelite with dark lava-rock from West Hawk Lake area

Some coarse-grained calc-silicate rock has recently been described in the **extreme northwest** of Manitoba. Pegmatitic development of *scapolite* and clinopyroxene is reported in an outcrop on the southwest arm of Misty Lake, which is about 50 km north of Lac Brochet; and again 2½ km west of the point where the Cochrane River enters Misty Lake. At the latter locality the scapolite-pyroxene rock is associated with tremolite marble.

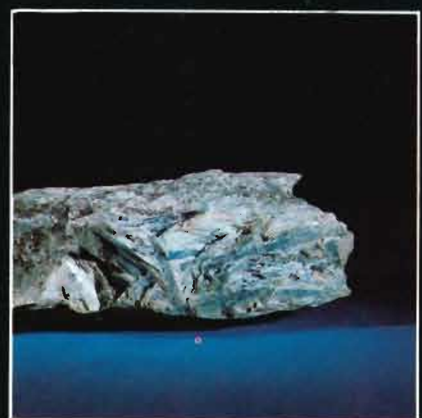
References: Schledewitz 1975; Weber *et al* 1975.



54) White andalusite crystals stained brown by iron oxides and accompanied by miner blue lazulite (Museum)

Andalusite, Kyanite and Sillimanite

55) Green kyanite with muscovite flakes in quartzo-feldspathic groundmass, Herb Lake



56) Blue kyanite is quartz-sericite schist from Anderson Lake

57) Elongateol knots or dusters composed of sillimanite, quartz and feldspar stand out on weathered surface of paragneiss near Russell Lake

58) Large sillimanite crystal in altered sedimentary rock from Bear Lake

These metamorphic minerals are alumino-silicates found mainly in schists and gneisses that were originally argillaceous sediments such as shale or mudstone. All three minerals have the same chemical composition ($Al_2O_3{\cdot}SiO_2$) and all occur in Manitoba, but sillimanite is the most abundant. Andalusite is formed at relatively low temperatures and pressures; sillimanite develops at higher temperatures, and kyanite is a high-pressure mineral.

Reference: Weber *et al* 1975, fig. 28.

This group of minerals provides commercially the high-alumina refractories utilized for their heat-resisting qualities. At a furnace temperature of 1,545 °C all three minerals are converted to silica (SiO_2) and *mullite* ($3Al_2O_3{\cdot}2SiO_2$). This material, stable up to 1,810 °C, makes excellent refractory porcelains which are used for spark plugs, electrical, chemical and laboratory porcelains, enamelware, thermocouple tubing and other such items. Refractories containing mullite are also used for glass tanks, crucibles, furnace linings, fireboxes and high-temperature cements. The alumino-silicate minerals are not mined in Canada, but there are important kyanite and sillimanite deposits in India (Bihar State), and kyanite is extensively mined in Kenya. Sillimanite ore is mined in southwest Africa and andalusite in South Africa. There are large deposits of all three minerals, especially kyanite, in the southeast United States.

Andalusite (plate 54) is an orthorhombic mineral, crystallizing in elongated prisms with square cross-sections (fig. 28). It has a vitreous lustre and a hardness of 7½; its colour is usually greyish white or reddish brown. Clear specimens of andalusite make excellent hard durable gems showing an interplay of green-red or brown-red hues; large gems are rare and valuable, and have not been found in North America. Much more common is *chiastolite,* an impure variety containing black carbonaceous impurities that form cross-like patterns on prism-ends. Chiastolite typically occurs in cigar-shaped crystals showing no flat faces. Cross-sections can be sliced off and polished to show the chiastolite-cross patterns, popular as curiosities. Chiastolite is much softer (4) than pure andalusite. *Andalusite* crystals large enough to be seen with magnification are quite rare in Manitoba, but there is one locality in the southeast where andalusite is fairly abundant in crystals of up to 1 or 2 cm; their form is however very imperfect and they contain numerous inclusions of other minerals. The area is a mile or two south and southwest of Tooth Lake (Map D). The gneisses and schists in which the andalusite occurs crop out around the north shore of **Flintstone Lake,** and on a nearby island.

Reference: McRitchie & Weber 1970d.

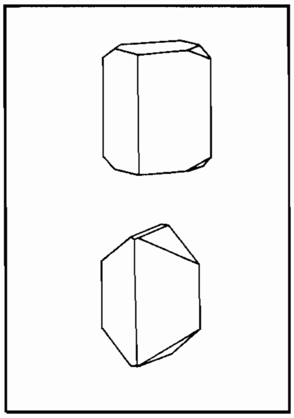


Fig. 28: Andalusite

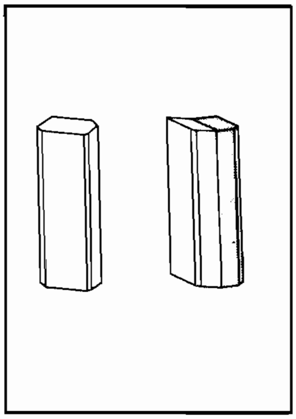


Fig. 29: Kyanite

In eastern Manitoba, Elbers (pers. comm.) has observed greyish crystals of *andalusite,* up to ½ cm across and containing many inclusions, in garnet schist at the east end of **Goose Lake** (north of Island Lake).

Kyanite is a triclinic mineral forming long, bladed crystals (fig. 29) that are usually blue or greyish blue to white with a pearly lustre. They have the unusual property of variable hardness: crystals can be scratched with a knife lengthwise but not crosswise. This property and the strong prismatic cleavage cause the mineral to shatter into splinters when extricated, unless great skill and patience are exercised. Rarely, blue or green kyanite (plate 55) is made into faceted gems, greatly valued by collectors but lacking durability. The mineral is not abundant in Manitoba but is well displayed at a few localities, one of which is Anderson Lake, a mile or two south of **Snow Lake** (Maps K & L). The best specimens of *kyanite* (plate 56) are those found on the waste dump at the Anderson Lake mine, but entry can only be gained with the permission of the mine authorities. Light blue to greyish green and grey kyanite is common there in coarse, bladed aggregates; individual crystals are up to an inch wide and several inches long. White-weathering kyanite can be seen in outcrops of silvery-looking sericite schist next to the railway about ¼ mile east of the mine, and also in schist outcrops near the southeast tip of Anderson Lake (Map L). *Kyanite* has also been reported 4 miles south-southeast of **Lynn Lake** Mine, near the southwest shore of McVeigh Lake (Map T); the outcrops are grey quartzitic rocks of sedimentary origin with minor schist; abundant kyanite was found in one of the schist layers, but the exact location is not clear.

References: Emslie & Moore 1961; Russell 1957; Sabina 1972.

Sillimanite is more abundant than either andalusite or kyanite in Manitoba. It occurs in long slender orthorhombic crystals; they are often needle-like or fibrous, and are usually white or colourless but may be greyish or brownish. *Fibrolite* is a variety of sillimanite that may form compact masses composed of minute fibrous crystals. The toughness of such material was known to American Indians who made use of fibrolite pebbles as hammer-heads. Waterworn pebbles of transparent sillimanite from the gem-gravels of Burma are collectors' gems; they are pale blue with high lustre but, although hard, they are difficult to work with because of their strong prismatic cleavage. In Manitoba *sillimanite* generally occurs within nodular clusters along with quartz, and sometimes feldspar or muscovite mica. These knots or nodules, which may be several inches in length, stand out on weathered outcrop-surfaces (plate 57). In southeast Manitoba good examples can be seen in altered sedimentary rocks on the northern shoreline of **Big Clearwater Lake** (Map D). The sillimanite needles in these nodules can only be seen under a microscope however.

Reference: McRitchie & Weber 1970.

In northern Manitoba, *quartz-sillimanite knots* are prominent in schist and gneiss outcrops between **File and Corley Lakes** (Map N), located west of Snow Lake and north of Reed Lake; access is explained under Staurolite. Twenty miles to the north-northwest, paragneisses at Limestone Point Lake (Map O), contain sillimanite-rich quartz lenses up to 2 inches long and occupying as much as one fifth of some outcrop-surfaces. In the coarse gneiss of the **Limestone Point-Batty Lakes** area *sillimanite* is visible without magnification as shiny white fibrous flakes forming lens-like aggregates; these are widespread on the peninsula between Limestone Point Lake and File River. In sheared rock ½ mile west-northwest of **Walton Lake** (Map O) blade-like sheaths of *sillimanite* are abundant, occasionally reaching a length of 3 inches. Forty miles to the west, around the northeast side of **Kississing Lake,** the paragneisses contain flattened nodules up to 6 inches in length; under the microscope they show fibrous, felted sillimanite, winding around the quartz grains.

References: Bailes 1971c, 1972; Harrison 1949; Kornik 1968; Pollock 1964; Robertson 1953.

At **Bear Lake,** about 100 miles northeast of Norway House, relatively large *sillimanite* crystals can be seen. The greenstone belt that strikes east-west through the western part of Bear Lake is in contact to the north with gneisses that contain sillimanite crystals (plate 58) up to two inches in length. Owing to their mode of occurrence, these crystals were at first taken for kyanite but were identified as sillimanite in the laboratory. Two outcrops are known about a mile north of the large island at the west end of the lake (Map Y).

Reference: Weber 1974.

Another locality where sillimanite can be easily seen is in shoreline outcrops* in **Burntwood Lake** (Map P), where sillimanite is intergrown with cordierite in migmatitic greywacke-gneiss. The *sillimanite* occurs as long white sheaves elongated parallel to the cordierite crystals. The latter are described under Cordierite.

References: McRitchie 1971; McRitchie *et al* 1971.

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* Longitude 100°18'; latitude 55°21' and 55°23' (approx.).

59) Garnet crystals from Chisel Lake

60) Well-formed garnets in schist from File Lake

The Garnets

Garnets occur widely in metamorphic rocks throughout the Precambrian regions of Manitoba. They can be recognized by their hardness, lack of cleavage and strongly crystalline forms, appearing as sub-rounded, many-sided, isometric crystals (fig. 30). They are usually red or brown but can be almost any colour except blue. Garnets vary in composition but the most abundant is an iron-aluminum garnet, *almandine*. Less common types contain calcium, magnesium, manganese or chromium. Garnets vary in hardness from 6½ to 7½ and in specific gravity from 3.5 to 4.3. The principal garnets and their typical modes of occurrence are:

Almandine	$3FeO \cdot Al_2O_3 \cdot 3SiO_2$	: mica schist and gneiss
Pyrope	$3MgO \cdot Al_2O_3 \cdot 3SiO_2$	: ultramafic rocks
Spessartite	$3MnO \cdot Al_2O_3 \cdot 3SiO_2$	: pegmatite, rhyolite, quartzite
Grossular	$3CaO \cdot Al_2O_3 \cdot 3SiO_2$	: skarn
Andradite	$3CaO \cdot Al_2O_3 \cdot 3SiO_2$	: skarn, chlorite-schist, serpentinite
Uvarovite	$3CaO \cdot Al_2O_3 \cdot 3SiO_2$	: chrome-rich serpentinite

Gems have been cut from all types of garnet except uvarovite which occurs as tiny green crystals too small to cut. Most abundant are the brownish red *common garnets* (almandine) which often occur in large (but usually cracked) crystals; unshattered deep red to violet-red transparent varieties are the *precious garnets* known since Biblical times. Carbuncle is the name applied to cabochon gems of this type, but faceted gems are also cut. Deep red to nearly black *pyrope* is often used in jewellery, especially as small faceted gems; a blood-red gemstone, *Bohemian garnet*, is sometimes misleadingly called Cape (or Arizona) ruby. *Rhodolite* is an attractive rose-red gemstone intermediate in composition between almandine and pyrope. *Spessartite* may (rarely) provide clear brilliant gems ranging in colour from orange-yellow to deep red, but is seldom seen in jewellery because of its erratic (pegmatitic) occurrence. At the Silver Leaf pegmatite in southeast Manitoba (Map C), spessartite is associated with apatite and blue tourmaline (see Pegmatitic Minerals). *Grossular* occurs in a wide range of colours, frequently in well-shaped crystals; faceted gems are mostly some shade of orange, and are known as *cinnamon-stone* or hessonite. Massive green grossular from South Africa is known as "Transvaal jade" and can be cut in cabochons. *Andradite* is often brown or black but a rare yellowish to emerald green variety called *demantoid* is the most valuable of all the garnet gems, noted for its colour and sparkling brilliancy; it is found in serpentine.

Industrially, garnet (mainly *almandine)* is used as an abrasive because of its hardness and its splintery fracture which provides sharp cutting edges. Some garnet-bearing rocks make good grindstones, and garnet-mica schist has been much used as a sharpening stone. Extremely fine-grained garnet rocks have even been used for razor blades. Garnet grains are used as an abrasive, particularly for hard woods; garnet paper (with a cutting power several times that of sandpaper) is employed for finishing hard surfaces. For some of these purposes, artificial material may replace garnet in the more industrialized countries, but garnet remains particularly suitable in such applications as coated abrasive papers and cloths, and as loose grains for sandblasting and polishing.

Garnet localities in **southeast Manitoba** include:

(1) Scattered outcrops of pillow lava eastward along the south shore of the **Winnipeg River** (Map C) from a point 3 miles east of Lamprey Falls (sections 21, 28, 29, range 16, township 16): *garnet* occurs as well-developed, deep red crystals up to half an inch in diameter, making up 75 per cent of the rock in places; other exposures are at the west end of a large island in the Winnipeg River in section 24, range 16, township 16.

Reference: Sabina 1963.

(2) Along and near the south shore of **Bird Lake** some outcrops of dark schistose greywacke contain pink garnets up to 2 inches in diameter; in places (Map C) *garnet* constitutes up to 75 per cent of the rock; the outcrops are on and near a small island about 2 miles east of the outlet of Bird River. This locality is also noteworthy for the presence of cordierite (described subsequently). Similar rocks east of Tulabi Lake contain some beds, a foot or so in width, that are packed with large garnets up to an inch in diameter.

References: Davies 1955, 1956; Sabina 1963.

(3) Gneissic and altered sedimentary rocks near the west and east shores of **Garner Lake** (Map D) contain *garnets* that have developed in the thermal aureole of the Garner Lake ultramafic intrusion; these rarely exceed ½ cm in diameter, but are well formed and free of inclusions.

References: McRitchie & Weber 1971a (p.267), 1971b; Scoates 1971b, p.192; Weber 1971a (p.86), 1971c.

In **northern Manitoba,** garnets are abundant west of Wekusko Lake (Map K) and around **Snow Lake** (Map L); some examples can be seen in outcrops along provincial road 392 between Anderson Creek and the Stall Lake turn-off (Map L). Immediately north of the creek, biotite schist and gneiss contain pink *garnet* crystals about ½ cm in diameter. Less than half a mile further north, garnet appears in chlorite schist. One tenth of a mile north of the Stall Lake turn-off, chlorite, hornblende and biotite schists and gneisses contain deep red, well-formed garnets up to ½ cm in diameter; these crystals are prominent on weathered surfaces and can be seen along the roadside for at least half a mile. Crystals of deep red garnet up to 5 cm in diameter have been noted in schist at the Chisel Lake Mine (plate 59) and good specimens are found on other mine-dumps in the Snow Lake area (Maps K & L), but collecting is not normally permitted at the operational mines. As garnet is commonly associated with staurolite in this area, other garnet localities are noted under Staurolite.

Reference: Sabina 1972.

An excellent garnet locality 13 miles west of Snow Lake is **File Lake** (Map N; for access see Staurolite). Deep red, almost perfectly formed *garnet* crystals (plate 60), from ½ cm to 2 cm across, stand out on the weathered surface of staurolite-sillimanite schist and paragneiss (Map N, locality 4). A few miles to the northwest, in the **Batty Lake** area (Map O), some of the pegmatites contain fresh garnets with no sign of alteration, but many garnets north of Batty Lake are sheared and partly altered to dark green chlorite. Unaltered, reddish brown garnets, up to 2 cm across, are abundant however in anthophyllite gneiss (see Amphiboles) along the File River, a mile or two north of Limestone Point Lake; some bands of the gneiss contain 25 to 40 per cent *garnet*. About 17 miles west of this locality, large reddish garnets are prominent in white quartz-gneiss north of Elken Lake (Map O); garnet crystals and three-inch clusters give this rock a plum-pudding appearance. Somewhat similar rock can be seen, and specimens collected, from rock dumps in the vicinity of the old workings at the disused **Sherridon** mine. Red garnet is abundant in the gneissic rocks that contained the copper-zinc orebodies; individual crystals measure half an inch, and garnet-quartz nodules over an inch across.

References: Bailes 1971a,b,c; Harrison 1948, 1949; Kornik 1968; Robertson 1953; Sabina 1972.

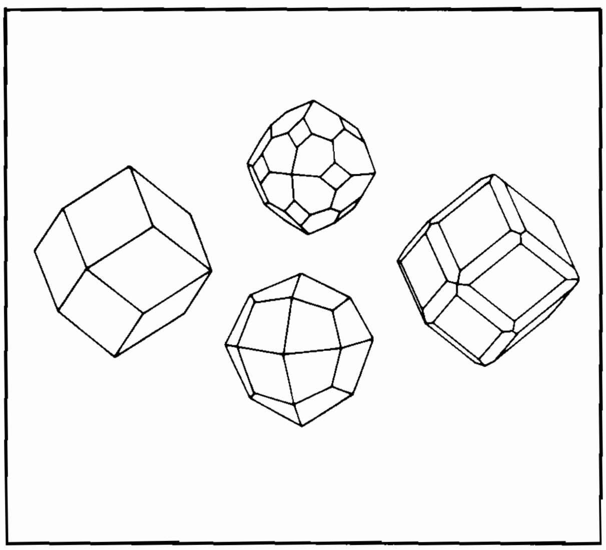


Fig. 30: Garnet

There are some interesting garnet-bearing rocks about 2 miles southwest of **Lynn Lake** (Map T), where interlayered volcanic and sedimentary rocks form a prominent peninsula on the southwest shore of Sheila Lake. On, and southwest of, the peninsula, a banded amphibole-carbonate rock (which is interbedded with greywacke) contains generally about 85 per cent fibrous amphibole and 15 per cent *garnet.* One 10-foot layer however contains about 50 per cent garnets, up to 12 mm across, set in a groundmass of radiating amphibole and biotite. The amphibole-garnet layers trend southwest for over a mile with intermittent outcrops towards, and south of, Margaret Lake. The garnets are pale purple. Less than 30 miles southwest of Lynn Lake, and about 1 mile south of provincial road 396, garnet-bearing rock occurs on the east shore of **Snake Lake** (Map T). The rock is a light grey to brown garnet-biotite gneiss containing well-formed pink to red garnets, occasionally an inch in diameter, set in a quartzose groundmass. Further mention of this locality is made under Staurolite.

References: Emslie & Moore 1961; Stanton 1949.

About 18 miles south of Thompson (Map Q) there is an unusual garnet-bearing gneiss on the south shore of Mid Lake, in the **Paint Lake Provincial Park.** The gneiss, which is dark greenish grey and mottled, contains 30 to 50 per cent pink *garnets,* many of them well formed and several millimetres in diameter. They are intergrown with coarse pyroxene identified as *bronzite,* a variety of enstatite.

Reference: Stephenson 1974.

61) Some staurolite crystals (Museum)

62) Elongated staurolite crystals and rounded garnets in schist from File Lake

Staurolite

Staurolite is a metamorphic mineral found in certain schists and gneisses of sedimentary origin, often accompanied by garnet. Staurolite is an interesting mineral to collect as it forms hard, weather-resistant crystals with characteristic shapes (fig. 31). Crystals may be either singletons or twins. Some twins consist of two crystals intergrown in the form of a cross, which may be either right-angled or with arms at about 60° to each other. These cruciform twins, especially the right-angled ones (which are comparatively rare), have long been sought as lucky charms called fairy-stones or fairy-crosses (plate 61). Clear facet-grade crystals of staurolite are very rare but small, dark gems are cut from them in Switzerland.

Staurolite is a hydroxyl-bearing iron aluminum silicate (approximately $2FeO{\cdot}5Al_2O_3{\cdot}4SiO_2{\cdot}H_2O$), found almost exclusively in metamorphosed argillaceous rocks. It forms prismatic orthorhombic crystals that are usually brown and translucent. The crystals are brittle and have the same hardness as quartz (7). Cruciform twins are common. Although normally dark and almost opaque, transparent crystals are occasionally found. The principal staurolite occurrences in Manitoba are in the Snow Lake region, but the mineral is also recorded in the Lynn Lake area. In the southeast, small brown tabular crystals of staurolite occur in mica schist interbedded with quartzite along the **Manigotagan River** near Lake Winnipeg.

References: Bailes 1971a, b; Davies 1951; Davies *et al* 1962; Milligan 1960.

Near the town of **Snow Lake** there are several localities (Map L) where good staurolite crystals can be found. One is 2 miles east of the town, where highway 392 crosses Snow Creek. Dark brown *staurolite* crystals several inches long are abundant in outcrops of biotite schist along the creek. The crystals, some of them cruciform, stand out prominently on outcrops. On the north bank of Snow Creek, about 100 feet below its outlet from Snow Lake, large untwinned crystals up to 7 inches long occur in greywacke-gneiss. The crystals are dark reddish brown and some are reported to be of "gem quality" (Traill, 1970). Good outcrops of staurolitic greywacke-schist, with garnets, also occur at the north end of Snow Lake (less than a mile west of the town), and at the southeast end of Snow Lake (north shore of the "East Narrows"). Dark brown *staurolite* crystals, 2 to 4 inches long, can also be found on rock dumps at the disused Nor Acme Gold Mine (Map L) in Snow Lake. Other minerals at this locality include pink to purplish red garnet, hornblende, pyroxene, tremolite (in pale green aggregates), epidote, tourmaline, chlorite, calcite, feldspar, serpentine and gypsum (white rosette encrustations).

References: Russell 1957; Sabina 1972; Traill 1970.

On the east side of **Wekusko Lake,** crystals of brown staurolite up to 4 inches long are abundant in chlorite schist on the shores and islands of Crowduck Bay (Map K). *Staurolite* (some in cruciform twins), dark red garnets (generally less than ½ inch across) and small prisms of tourmaline (see Pegmatitic Minerals) are all

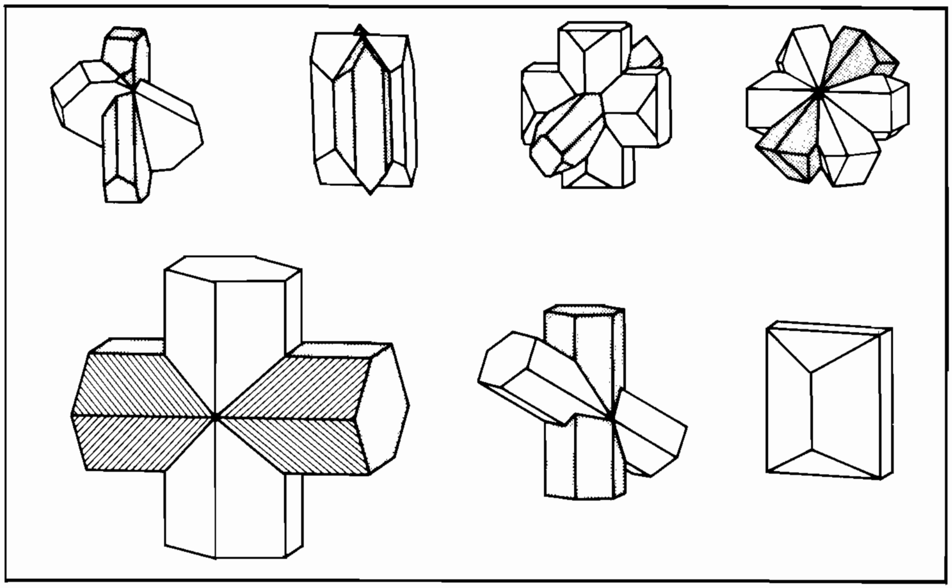


Fig. 31: Staurolite

prominent on outcrop surfaces. Staurolite-bearing schists are well exposed on islands at the south end of Crowduck Bay and nearby; also along the west shore of the narrows connecting Crowduck Bay with Wekusko Lake; and on Ballard and Campbell Islands (Map K) near the mouth of Crowduck Bay. Crowduck Bay is accessible by boat from Government Dock (Map L) on the west side of Wekusko Lake. The 14-mile trip across the lake is extremely hazardous on windy days.

Reference: Sabina 1972.

Another excellent staurolite (and garnet) locality is the west and northwest part of **File Lake** (Map N), located 12 miles west of Snow Lake. A 2-mile long, north-trending peninsula at the west end of File Lake is composed of interbedded schist and paragneiss containing much staurolite and garnet (plate 62). The best specimens are found towards the north end of the peninsula. Immediately northeast of the peninsula, the same rocks (altered sediments) crop out for a mile along the lakeshore. In many of the beds staurolite and garnet occur together, standing out conspicuously on the weathered surfaces. *Staurolite* crystals, up to 3 centimetres in length, contrast with the smaller rounded garnets. Some of the best staurolite outcrops are on a point that juts southward into File Lake ¼ mile northeast of the peninsula. Access to File Lake is from the south via Reed Lake. Boats can be transported by truck from the north end of Reed Lake to the south end of Morton Lake (by arrangement with Grass River Lodge). There is a short, easy portage from the north end of Morton Lake to the west shore of File Lake. A cabin and boat on File Lake can be rented through Grass River Lodge (provincial road 391).

References: Bailes 1971c, 1972; Harrison 1948, 1949.

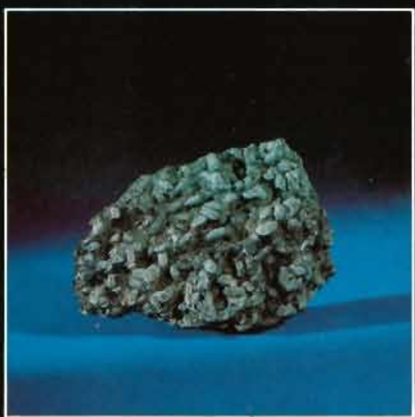
Similar *staurolite* and garnet schists have been described south and west of Duval Lake, west of the south end of **Kississing Lake** (Map X). The schists, as much as 2,000 feet thick in places, have been traced 20 miles to the Saskatchewan border.

Reference: Pollock 1964.

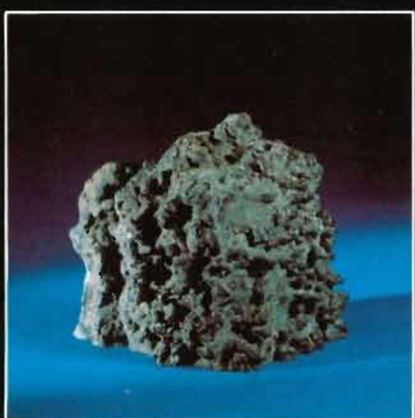
The staurolite localities in the **Lynn Lake** region (Map T) are not as thoroughly documented as those of Snow Lake. Gneisses of variable composition, including some staurolite gneiss, are well exposed on the islands in the central part of **Snake Lake**, on the east mainland immediately opposite, and again half a mile further south. The staurolite gneiss is a light grey rock with sugary texture, containing abundant biotite and numerous brown, diamond-shaped crystals of *staurolite* (½ inch long), all set in a quartzose groundmass. Garnet, sillimanite and tremolite gneisses have also been recorded in the same vicinity; other information is given under Garnets. Ten miles to the northeast, staurolite schist has been found sparsely between **Wilmot Lake** and the main road. The *staurolite* occurs in diamond-shaped crystals up to half an inch in length. Garnet gneiss is more common than staurolite schist in this vicinity. Both are local variations from the predominant hornblende-biotite gneiss or schist. Minor amounts of sillimanite schist have also been recorded at this locality, with sillimanite needles (rare) up to 3 inches in length.

References: Oliver 1952; Stanton 1949.

63) Blue cordierite with quartz from Rat Lake



64) Well-formed cordierite crystals on weathered surface of schist from Utik Lake



65) Raged cordierite stands out on weathered surface of metamorphic rock from Bear Lake

Cordierite

Cordierite is a complex silicate of magnesium and aluminum with hydroxyl and variable amounts of iron, approximately $4(Mg,Fe)O \cdot 4Al_2O_3 \cdot 10SiO_2 \cdot H_2O$. It is typically found as a metamorphic mineral either in contact hornfels (especially near granitic contacts) or regionally in cordierite schist and gneiss. In Manitoba it is frequently accompanied by garnet in altered sedimentary (occasionally volcanic) rocks, and is also found in pegmatites that have intruded them. The crystals (fig. 32) are orthorhombic, often six-sided, and usually some shade of blue (plate 63). Cordierite seldom shows good crystalline form however. Generally it contains many impurities, and often shows signs of alteration, especially on weathered surfaces. The alteration is usually to some form of mica, chlorite or talc, causing the cordierite to appear greyish or greenish; the alteration products are collectively called pinite. This is one property that helps to distinguish cordierite in the field. Another distinctive property is sector-twinning, seen, where present, as pseudo-hexagonal crystals divided into distinct segments.

Cordierite has some gem-potential because of its attractive colours, hardness (7¼) and lack of easy cleavage; moreover, although brittle, it does not fracture easily. A transparent, intense blue variety of cordierite from Ceylon is known to jewellers as *saphire d'eau,* but gem material is hard to find because of impurities. Owing to the rarity of good, clear crystals, angular fragments broken from nodules or lenses of cordierite are utilized if the quality is suitable. Faceted gems are cut from clear violet to blue material, which is rare owing to abundant veil-like inclusions. *Cordierite* is remarkable for its strong pleochroism which can be seen by holding a sliver of the mineral up to the light and rotating it: colour changes can be seen from blue to dark blue and straw yellow. This property was known to the Vikings and used by them to locate the sun through overcast skies for navigational purposes: the colour changes are more distinct where the light is strongest. Cordierite is relatively abundant in Manitoba; it can be seen at one or two places in the southeast, but the best localities are in the east and north; "gem-quality" cordierite has been reported from the Sherridon-Batty Lake area (described subsequently).

In southeast Manitoba (Map C) dark grey quartz-biotite rock interbedded with greywacke along the south shore of Bird River (near Bird Lake), shows egg-shaped clumps (1½ x ½ inch) of very impure *cordierite* riddled with inclusions of quartz, biotite and garnet. Cordierite-bearing rock can also be seen in places along the south shore of **Bird Lake.** Provincial road 315 gives direct access to these locations, and there are some excellent garnet occurrences nearby as already described.

References: Davies 1955; Sabina 1963.

One of the most striking cordierite localities in Manitoba is 130 miles northeast of Lake Winnipeg, at **Utik Lake** (Map Y), some 35 miles northwest of Oxford House. Distinctive bands of cordierite schist (plate 64), interlayered with altered sedimentary and volcanic rocks, strike east-northeast and are exposed at numerous localities on the northern shoreline and on islands in the central part of the lake. In places, the cordierite is accompanied by rosettes of pale brown anthophyllite (see Amphiboles). The rock, which is considered to be metamorphosed basalt, weathers dark brownish grey and contains from 15 to 70 per cent *cordierite,* standing out as large crystals on outcrop surfaces. These often appear as sub-rounded nodules, but where crystals lie parallel to the surface they appear as rod-shaped forms, some of them an inch or so in length; they weather grey like the groundmass of the rock (plate 65), but fresh surfaces show dark blue crystalline cordierite. Microscopically these are found to contain tiny inclusions of quartz, biotite and chlorite.

References: Milligan & Take 1954; Weber 1974, 1975.

Similar cordierite schist has been described fifty miles to the southeast at **Island Lake:** outcrops have been recorded near the south shore of Cochrane Bay (Map V). The schist is dark brownish grey and is packed full of nodules about half an inch long which stand out like pebbles on the weathered surface. Each nodule is actually a single crystal of *cordierite* containing numerous microscopic inclusions of other minerals.

Reference: Goddard 1963.

"Gem-quality" cordierite has been documented from a locality (Map O) about 9 miles northeast of **Sherridon** and approximately ¾ mile west of Walton Lake, where a series of lenticular quartz blebs coalesce into an 8-foot, roughly spherical pod containing "gem" *cordierite* in well-formed crystals up to 3 inches in length. The cordierite is an iron-rich variety and when studied microscopically was seen to be free of the usual inclusions. Two or three miles further west, cordierite is very common in the quartz-rich rocks around Finger Lake and near the railway line. Five and a half miles to the south, cordierite-rich gneiss again occurs, 3 to 4

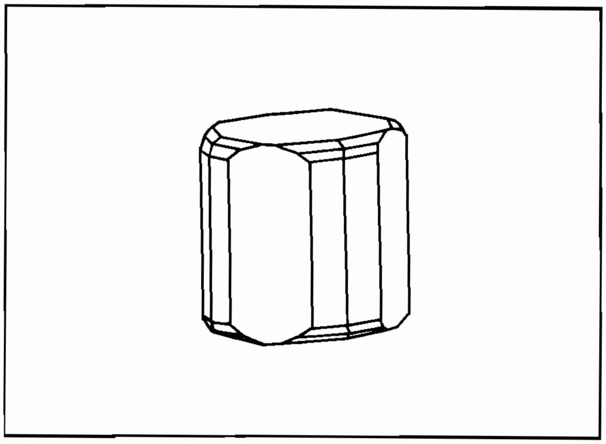


Fig. 32: Cordierite

miles east of the railway along the track of the power-line (Map O); half a mile north of the power-line, bright blue cordierite is found in quartz-rich pegmatite stringers that impregnate the gneiss.

References: Robertson 1953; Traill 1970.

At **Batty Lake** (Map O), cordierite is a constituent of the anthophyllite gneiss (see Amphiboles) that occurs on the north shore and also in a narrow band northwest of the lake. Although abundant, the cordierite is in stringers and blebs rather than discrete grains, and is partially altered to chlorite, especially north of Batty Lake. The other constituents of the rock are quartz, plagioclase, biotite and almandine garnet. The anthophyllite gneiss strikes southeast along the peninsula that forms the northeast shore of **Limestone Point Lake,** and shows striking outcrops along the File River (Map O), a mile or so north of this lake. The *cordierite* occurs as violet-tinged grains (lacking crystalline form) between the anthophyllite blades; it is accompanied by reddish garnets up to an inch in diameter.

References: Kornik 1968; Robertson 1953.

Unusually coloured cordierite is reported from some of the copper-zinc mines of the **Snow Lake** area (Maps K & L). Dark, smoky green cordierite has been recorded with the metallic minerals at Stall Lake Mine, and smoky greenish blue *cordierite* occurs in some schists at the Anderson Lake Mine. Owing to mining operations, casual visits are not convenient to the mine authorities, but pre-arranged visits are permissible.

Reference: Sabina 1972.

About 17 miles south of **Thompson** (Map Q), there is an unusual cordierite-bearing rock at Paint Lake. The outcrop surfaces are irregular and roughly pitted. The rock is medium to coarse-grained and varies in colour from dark grey to mottled yellowish green and black. Grains of blue *cordierite,* red garnet, dark pyroxene (hypersthene), glassy quartz and yellowish green-brown feldspar can be seen on fresh surfaces. Only two outcrops are known (localities 2 and 3), and, as this occurrence falls within the **Paint Lake Recreational Park,** removal of specimens is not permitted unless approved by the provincial park authorities. Extensive gneiss outcrops, from which excellent cordierite and garnet specimens can be obtained, are located west of Birchtree Mine (Map Q). The host-rock is a grey paragneiss consisting mainly of quartz, plagioclase, biotite and garnet. To the southwest the gneiss is characterized by mauve-coloured garnets (up to 2 cm in diameter) making up 5 to 20 per cent of the rock; good outcrops extend several miles up the **Burntwood River.** The best *cordierite* occurrences are to the north (localities 15 to 18) and to the west along **Birchtree Brook** -- in this area the paragneiss becomes migmatitic, and deep blue cordierite is prominent in the quartzo-feldspathic (granitic) material that has permeated the gneiss; both the cordierite and associated garnet are in well formed crystals up to 2 cm.

References: Godard 1966; Stephenson 1974.

Cordierite is common in the gneisses and pegmatites west and northwest of Thompson, but pure, well-formed crystals are rare. Typical examples can be seen in the **Nelson House** area, where massive blue cordierite and garnet occur in migmatitic gneiss and white pegmatite at the southwest end of Footprint Lake, northwest of Threepoint Lake, and along the Rat River south of Wapisu Lake (Map R). Some cordierite also occurs in gneisses cut by pegmatite along the Rat River, between the road bridge and the north end of Wapisu Lake. Fifty miles to the southwest, at **Burntwood Lake** (Map P), *cordierite* is prominent as outstanding rectangular crystals (2 to 10 cm) on outcrops of migmatitic greywacke-gneiss. Sillimanite is visibly intergrown with the cordierite which occurs in well-defined layers of argillaceous origin.

References: McRitchie 1971; McRitchie et *al* 1971.

About 40 miles northwest of Nelson House (Map S), cordierite-sillimanite-anthophyllite-biotite gneiss strikes northwest across **Rat Lake** for at least 15 miles (24 km) in a narrow band generally less than a mile in width. Many of the outcrops that were studied have since been submerged owing to the rise of water level at Rat Lake. Buff-coloured outcrops were described, with ribbed surfaces due to differential weathering; discontinuous layers and thin lenses vary in composition as follows:

- (a) (grey to buff) biotite-feldspar-quartz with variable garnet, cordierite and sillimanite
- (b) (grey-green) cordierite-garnet-anthophyllite
- (c) (dark grey) biotite-cordierite-quartz-plagioclase
- (d) (grey-brown) tremolite-bearing amphibolite

Cordierite crystals of unusually good quality were described by Baldwin from a granitic contact on the west shore of Rat Lake (plate 63), 2¼ miles north of the (1970) mouth of the Suwanee River (Map S). The best cordierite specimens, found within an area of 200 x 90 feet, were from a very coarse cordierite-feldspar rock in which the crystals were from ½ inch to 3 or 4 inches across. Although these particular outcrops are now largely under water, the mode of occurrence is worthy of note.

References: Baldwin 1971; Schledewitz 1972.

Pegmatitic Minerals

66) Amblygonite from Bernic Lake

67) Large beryl crystal from Winnipeg River area

68) Green beryl with pink feldspar from Greer Lake area

69) Dark crystals of cassiterite in quartz-muscovite rock from Winnipeg River area

70) Black columbite with cleavelandite (Museum)

Granitic pegmatites are characterized by large well-formed crystals of various minerals and are an important source of certain gem minerals such as tourmaline, topaz, beryl, spodumene and others. Pegmatites are of great interest to mineral collectors and have supplied innumerable specimens for museums throughout the world. The vast majority of simple pegmatites consist predominantly of *quartz, feldspar* and *mica*, as found abundantly throughout the Precambrian regions. These major granitic minerals have already been described, as have certain other minerals, such as apatite, calcite, clinozoisite and garnet, that may also be found in some pegmatites. In some unusual, complex pegmatites, the major granitic minerals are accompanied by rarer minerals, such as those containing lithium, beryllium, tantalum and tin at the Bernic Lake TANCO Mine (Map C), which has been systematically described by Crouse and Cerny (1972). Pegmatites containing various uncommon minerals, especially beryl and spodumene, are known at a number of localities in the southeast and a few in north-central Manitoba. The following are some notable minerals, some of them quite rare, found in these complex pegmatites; they are first introduced in alphabetical order. Subsequent pages contain field descriptions of their occurrences in Manitoba.

Amblygonite (plate 66) is a rare lithium aluminum fluo-phosphate, $Li(F,OH)AlPO_4$*, found in large white cleavable masses. The flat cleavage faces are prominent and the mineral is often difficult to distinguish in the field from feldspar, as there is little difference in hardness (6); but specific gravity (3 to 3.1) is slightly higher. Crystals are triclinic but well-formed examples are small and rare. Where found, however, clear transparent crystals have provided faceted gems since pale greenish yellow specimens were found in Maine about 1940; as the gems lack brilliancy and are only moderately hard, their main value lies in their rarity. Nevertheless, amblygonite, where found in workable concentrations, is a potential source of lithium, which is an important light-weight alloy metal for aluminum, magnesium and zinc, and is also used in metal bearings, copper electrodes and lead sheathings. It also serves as a deoxidizer and purifying agent in the refining of various metals and alloys. Lithium compounds are widely used in photography, pharmaceutics, dentistry, meat-curing, gas purification and for many other purposes. The hydroxide is used in electric batteries, and the chloride in air-conditioning and industrial dyeing. Lithium supplies the red colour in signal rockets, flares and fireworks. Further information about lithium is given under Petalite.

Beryl (plate 67) is a silicate of beryllium and aluminum ($3BeO·Al_2O_3·6SiO_2$), occurring in well-formed hexagonal crystals (fig. 33), often large. White, pale green and colourless varieties are found in Manitoba, more rarely deeper green (plate 68) and golden yellow. Beryl is distinguished from apatite by its hardness (8), but may be confused with quartz unless distinctively coloured. Beryl has provided classical gemstones since the dawn of history; the name *emerald*, for the rare, deep green, precious stone (not confined to pegmatites), was derived through ancient Greek from an old Persian word. The less rare *aquamarine*, the colour of blue-green sea-water, is also well known. Other beryl gems are similarly distinguished by their colours; they include *morganite* (rose, pink or lilac) and *goshenite* (colourless) which are found in lithium pegmatites, and the golden yellow *helidor*. The best developed crystals are likely to be found within cavities in pegmatites. Beryl thus provides a variety of first-class gemstones. The industrial uses of beryl, practically the only commerical source of the metal beryllium, have come to the forefront in recent years. Much of the production is from pegmatites or associated rocks, and total world output is relatively small. This is because practically all of it comes from small-workings requiring intensive hand-sorting which can only be done economically in countries where labour-costs are low. Beryllium is a light-weight metal (S.G. 1.85) that can substitute in many respects for aluminum which is heavier (S.G. 2.70). Beryllium, therefore, finds many uses in aircraft, missiles and space vehicles, where light weight is an important factor. It is also used in nuclear reactors and X-ray equipment because it does not obstruct radiation. Beryllium is a valuable alloy metal, especially in beryllium-copper which possesses great strength and resistance to corrosion; it is also alloyed with nickel, cobalt and aluminum for various applications.

Cassiterite (plate 69) is tin oxide (SnO_2), the principal ore mineral of tin; known occurrences in Manitoba are restricted to local disseminations in a few pegmatites. The crystals are tetragonal, often in stubby prisms with flat brilliant faces; elbow-shaped twins are not uncommon (fig. 34). The colour is usually brown or black, and the streak white. The hardness is 6 to 7 and the specific gravity (about 7) is unusually high for a mineral with non-metallic lustre. Transparent crystals of cassiterite, especially if colourless, have elsewhere furnished beautiful and durable faceted gems, but these are rare. Much less valuable is the massive or nodular variety

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* Some authors give the name *montebrasite* to the hydroxyl end of the series and amblygonite to the fluorine end: mineralogical details of specimens from the TANCO pegmatite are described by Cerna, Cerny and Ferguson (1972).

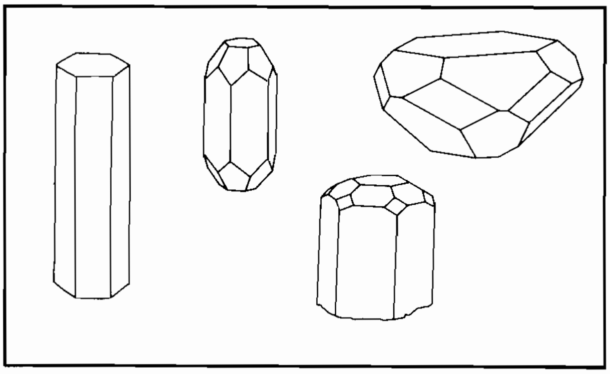


Fig. 33: Beryl

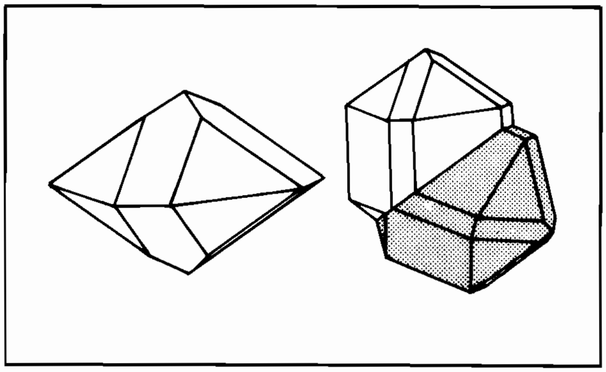


Fig. 34: Cassiterite

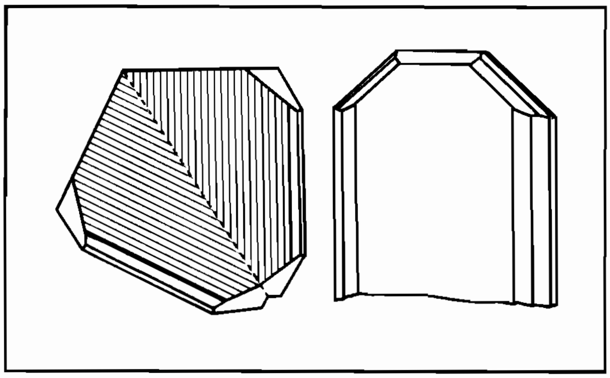


Fig. 35: Columbite

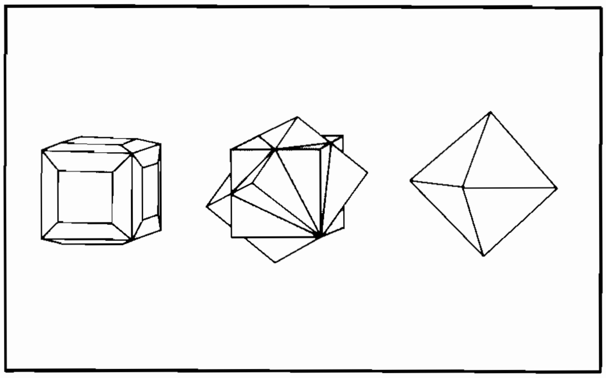


Fig. 36: Fluorite

called *wood tin* because of its colour and concentric banding (like the grain in dark wood), brought out by cutting and polishing. Tin was one of the first metals utilized by early man. Phoenician traders obtained tin from the Cassiterides ("tin islands") between 1000 and 2000 B.C. The location of the tin deposits was Cornwall at the southwest tip of Britain. Pure cassiterite is easily smelted as it is only necessary to eliminate the oxygen by burning charcoal, coal or coke. Cassiterite "pebbles" *(stream tin)* found in stream beds and alluvial deposits are suitable for this treatment. In modern practice, various impurities in tin ore require special processing. Copper minerals are often present and the smelting of mixed tin and copper ores led to the creation of bronze by ancient civilizations thousands of years ago. Bronze was used for cooking utensils, implements, weapons and ornaments; by mediaeval times, bronze armour, bell castings and pewter (tin-lead alloy) were being made. In modern times tin has been chiefly used in tin-plate for coating sheet iron; also in solders, and for various alloys such as gun-metal, bearing-metals and phosphor bronze. Because commercial tin deposits are comparatively few, and notably lacking in North America, various substitutes for tin have been developed in recent years.

Columbite (plate 70) is ideally an oxide of columbium (= niobium), ferrous iron and manganese, $(FeMn)Nb_2O_6$, but in practice variable proportions of tantalum take the place of niobium, causing an ultimate gradation to the mineral tantalite; the two end-members can only be distinguished by laboratory tests and in most cases the combined name *columbite-tantalite* is appropriate. Crystals (fig. 35) are orthorhombic, usually black, with square to rectangular cross-sections; they may be thin and tabular, or short and stubby, sometimes appearing rounded if the ends are modified. The lustre is submetallic and the streak is dark red to black. The mineral is brittle because of numerous internal fractures, and crystals are difficult to extract without breaking. The tin-bearing granites and pegmatites of Nigeria are among the world's main sources of columbite, which is a major ore-mineral of niobium, a metal used in alloys that must withstand high temperatures, as in jet engines and gas turbines. In recent years the steel industry has made increasing use of niobium for stainless steels and for high strength, low alloy, carbon steels, suitable for oil and gas pipelines and large structures such as stadiums and bridges. There is also an increasing demand in the automotive industries, and new uses for niobium are being developed in superconductor magnets, electric transmission lines and thermonuclear reactors.

Fluorite (fluor-spar) is calcium fluoride (CaF_2), found as isometric crystals (fig. 36) of vitreous lustre and various colours, especially green, yellow or purple, more rarely blue, pink or brown (plate 71). The mineral can be scratched with a knife (hardness 4) and has good octahedral cleavage. The property of fluorescence, by which certain minerals glow in the dark under the rays of an ultra-violet lamp, was first described after experiments made in 1852 with *fluor-spar* in England. In spite of its softness, cleavages and other drawbacks, fluorite is widely used for ornamental purposes because of its clarity and attractive colours. Transparent green fluorite has been carved into delicate statuettes in China. A fibrous blue and white banded variety *(Blue John)* from Derbyshire, England, has, since Roman times, been turned into handsome bowls, cups and other items; this has also been done at various localities in North America. Faceted gems are cut only as collectors' items as they are too fragile for normal jewellery purposes. Minor quantities of clear, transparent, colourless fluorite (rarely found) are used in optical equipment. Although found sparsely in a few Manitoba pegmatites, the main occurrence of fluorite elsewhere is in veins, such as the lead veins of Derbyshire. Fluorite is an essential raw material and large deposits are worked for use as flux in metallurgical (especially steel) and related industries; in open-hearth furnaces the flux cleanses the steel of phosphorous and sulphur. Fluorite is also used for the manufacture of hydrofluoric acid and other chemicals, including sodium aluminum fluoride for aluminum refining. Fluorite is used in the refining of uranium ores and concentrates. In the ceramics industry it has been used in the manufacture of enamels, in opalescent and coloured glass, and in facings for bricks.

Two non-pegmatitic occurrences of fluorite may be mentioned here. In **northwest Manitoba,** two stocks of quartz monzonite, described by Weber *et al* (1975), contain accessory fluorite in small purplish grains up to 3 mm in diameter; locally the fluorite constitutes up to 2 per cent of the rock. Although the stocks form prominent hills, outcrops are generally sparse, but some can be seen 1 to 2 miles northeast of Chekask Lake, which straddles the Saskatchewan border at latitude 59°46'. In **southeast Manitoba,** small purple fluorite crystals (up to 1 cm) have been recorded (McRitchie & Weber 1970b) at Happy Lake, immediately southeast of Manigotagan Lake; the crystals form irregular clusters in chloritized biotite paragneiss.

Lithiophilite (plate 72) is a rare manganese-rich phosphate of lithium, Li $MnPO_4$; with increase of iron at the expense of manganese, lithiophilite grade into triphylite. Crystals (orthorhombic) are very rare (fig. 37); the usual occurrence is in compact cleavable masses (two cleavages at right angles) or aggregates, with hardness of 4½ to 5. Lithiophilite is typically salmon-pink or clove-brown, with vitreous to resinous lustre; it readily breaks down to various alteration products.

Monazite is a phosphate of so-called rare-earth metals such as cerium, lanthanum and yttrium, and usually contains about 5 per cent thorium, giving a typical formula such as $(Ce,La,Y,Th)PO_4$. Crystals (monoclinic) are small, scattered and isolated, though larger examples can occasionally be found in granitic pegmatites; they are often flattened, with wedge-shaped terminations (fig. 38). Granular masses are more common. Monazite is usually yellowish to reddish brown, with resinous lustre. Concentrations in beach sands (e.g. Australia) are an important commercial source of thorium and rare earths. Thorium nitrate has been much used in the manufacture of gaslight mantles. Relatively small amounts of thorium are currently used in thorium-magnesium alloys and certain alloys of nickel, cobalt, tungsten and molybdenum. In the future, a major use of thorium will probably be in the preparation of fissionable isotopes for atomic energy. The rare-earth metals are mainly utilized in metallurgy, as catalysts in petroleum refining, and in glass colouring and polishing. Rare-earth oxides are used in colour-television tubes. An important new market is in cobalt-rare earth permanent magnets of great strength, used in aero-space equipment.

Petalite (plate 73) is a rare lithium-aluminum silicate ($Li_2O{\cdot}Al_2O_3{\cdot}8SiO_2$) found in foliated, cleavable masses, but rarely in crystals (monoclinic). It is usually white, grey or colourless, with vitreous or pearly lustre. Its hardness (6) is the same as feldspar, for which it can easily be mistaken. Petalite also resembles amblygonite but has lower specific gravity (2.4). The strong cleavage causes this mineral to shatter so thoroughly that transparent material suitable for cutting into faceted gems (notable only as curiosities) is very rare. In the TANCO pegmatite at **Bernic Lake,** log-shaped crystals of petalite up to 2 metres in length have been described by Cerny and Ferguson (1972). Few deposits of petalite are large enough to be mined, but where sufficiently concentrated (usually with other lithium minerals), petalite is a commercial source of lithium, a soft white metal that is the lightest element to remain solid at ordinary temperatures. Lithium oxidizes rapidly in air and reacts readily with water. Its unique properties have many applications: in addition to those mentioned under Amblygonite, lithium chemicals are used in lubricating greases, as catalysts, and for generation of oxygen. Lithium carbonate is important in aluminum production. The specialized uses of petalite are similar to those of spodumene (described subsequently).

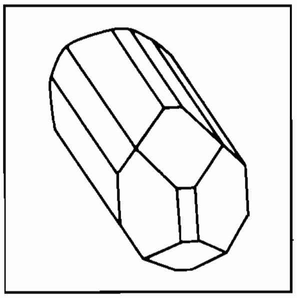


Fig. 37: Lithiophilite

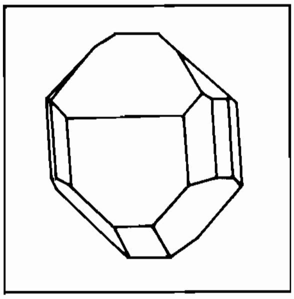


Fig. 38: Monazite

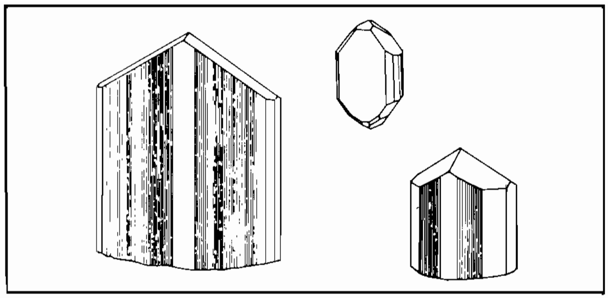


Fig. 39: Spodumene

Pollucite (plate 74) is a rare, pegmatitic mineral that is mined at **Bernic Lake** as a source of cesium; it is hydrous cesium aluminum silicate, $2Cs_2O \cdot 2Al_2O_3 \cdot 9SiO_2 \cdot H_2O$. It is colourless to white, or greyish or pinkish white, and occurs in granular masses. Pollucite is brittle, fairly hard (6½) and lacks cleavage. It breaks with a conchoidal fracture and is difficult to distinguish from quartz in the field, apart from a slightly waxy lustre seen on fracture surfaces. Pollucite is an isometric mineral but crystals (cubic in shape) are extremely scarce. Clear material from Maine has been cut into gemstones, sought by collectors because of their rarity. Transparent material varies from colourless to faintly pink or yellowish, usually with a slight milkiness; internal specks resembling white "snowflakes", only a fraction of a millimetre in diameter, can occasionally be seen. Cesium is the least abundant of the five naturally occurring alkali metals and is mostly found in lithium pegmatites, especially associated with lepidolite. With a melting point of 28.7°C, cesium is one of the few metals (the others being mercury and gallium) to remain liquid at room temperature. In its solid state it is a soft, silvery white, ductile metal. Cesium emits electrons when exposed to light, and it reacts explosively with cold water. Compared with the other four alkali metals, cesium is the most electropositive, has the highest density, highest vapour pressure, lowest boiling point and lowest ionization potential. Because of these properties, cesium is used in space-age research projects involving space-propulsion and energy-conversion. Commercial uses of cesium are restricted owing to its high cost and great reactivity, but there are applications in photoelectric cells, photomultiplier tubes, vacuum tubes, infrared lamps, scintillation counters, magnetometers, pharmaceuticals and in microanalysis.

Purpurite is an iron-manganese phosphate, $2(Fe,Mn)PO_4 \cdot H_2O$, occasionally found in granitic pegmatites as an alteration product of lithiophilite and triphylite. The mineral is orthorhombic but crystals are practically unknown; it occurs instead in small irregular masses with prominent cleavage. A deep rose to reddish purple colour is distinctive, but purpurite is often discoloured by black alteration products. The hardness is 4 to 4½, and the specific gravity 3.4.

Spodumene (plates 75 & 76) is a comparatively rare, monoclinic, lithium-bearing pyroxene ($Li_2O \cdot Al_2O_3 \cdot 4SiO_2$) found in lithium pegmatites; there are some interesting occurrences in Manitoba. Spodumene is of much interest to mineral collectors because of its ability to form large, well-shaped crystals (record length 42 feet in South Dakota) and because of its gem potential. Crystals (fig. 39) are often elongated (lathlike) or flattened (bladelike) and some faces may be striated lengthwise. Cross-sections show the strong pyroxene cleavages intersecting at approximately right angles, and usually a well-developed third parting. The easy cleavability of spodumene requires much time and skill to overcome in gem-cutting, but spodumene is nevertheless a well-established gem mineral with three main colour variations:— *kunzite* is pink, lilac or purplish; *triphane* is colourless to yellow; and *hiddenite* is strictly emerald green, excluding the pale yellowish green varieties. Most spodumene crystals are embedded in quartz or feldspar, but the best gem specimens are usually found in pockets or cavities, often with clay or mineral débris. Undoubted gem varieties have not been recorded in Manitoba but some striking specimens have been found, mostly white or pale green. Cerny and Ferguson (1972) have described lath-shaped crystals of white spodumene up to 1.5 metres in length from the TANCO pegmatite, while pointing out that at least 90 per cent of the spodumene there is in tabular aggregates (up to 2 metres across) of water-clear, fibrous spodumene intergrown with quartz; individual fibres, some of them flattened, range up to 10 cm in length. Apart from its interest to collectors, spodumene is one of the major lithium ore-minerals, and deposits in Manitoba have attracted considerable commercial attention. The TANCO pegmatite at **Bernic Lake** (Map C) includes a high-grade spodumene zone containing 5 million tons of potential spodumene ore; the spodumene has a very low iron content and is suitable for high refractory ceramics and for glassware. Some commercial uses of lithium and its compounds have been mentioned under Amblygonite and Petalite; in general these apply also to spodumene, but spodumene, petalite and lepidolite are particularly utilized in the manufacture of special types of ceramic, glass and enamelware, and in welding and brazing fluxes.

Tantalite, $(Fe,Mn)Ta_2O_6$, is the tantalum-rich end-member of the columbite-tantalite series (figs. 35, 40). It is found in granitic pegmatites, particularly those containing marked amounts of albite, lithium silicate, and lithium-manganese-iron phosphate. Its physical properties are very similar to columbite except that specific gravity increases from a little over 5 (pure columbite) to well over 7 for some tantalite (6.76 at Bernic Lake). The **Bernic Lake** tantalite (plate 77) is a black manganese-rich variety and has a dark brown streak; its occurrence is skeletal between albite blades, and grains rarely reach 1 or 2 mm. Rare larger plates up to 1 cm are actually *pseudo-ixiolite,* a closely related mineral indistinguishable from the tantalite except by X-ray analysis. These minerals from the TANCO pegmatite have been studied and described by Grice, Cerny & Ferguson (1972). The TANCO Mine at Bernic Lake (Map C) is one of the world's major producers of tantalite, which is shipped in concentrates to the United States for extraction of tantalum. Commercial utilization of this metal is based upon four physical characteristics: its high melting point, making it suitable for high temperature parts and alloys; the outstanding (capacitance) properties of its anodic oxide film on the surface of tantalum powder (desirable for capacitors); its extreme resistance to corrosion or chemical attack when used in chemical equipment; and the hardness and high melting point of its carbides. The largest consumer of tantalum is the United States electronics industry, primarily for the manufacture of electrolytic capacitors: millions of these are made for use in computers, telecommunications and instrumentation. Large amounts of tantalum are consumed in the making of sheet, tube and other mill products, mostly for the chemical industry. Cutting tools also account for large quantities of tantalum. Other applications of the metal are as alloy additives, and in tantalum salts and oxides, and also in the tantalum carbide industry.

Topaz, well known as a valuable gemstone, is an aluminum fluo-silicate, $Al_2SiO_4(OH,F)_2$, in which part of the fluorine may be replaced by hydroxyl (OH). It usually occurs as prismatic crystals (orthorhombic), often highly modified (fig. 41), and occasionally in crystalline masses. Though usually colourless to faintly blue (plate 78), topaz may be yellow, greenish, or rarely pink. Its lustre is vitreous and it is more or less transparent. Topaz is distinguished by its hardness (8), strong basal cleavage, relatively high specific gravity, and crystalline form; crystals are often stubby with wedge-shaped terminations. The value of topaz as a gemstone is largely due to its glistening, well-shaped, symmetrical crystals. Good specimens appear as short stubby prisms with diamond or square shaped cross-sections, terminating in blunt ends bevelled by pyramidal planes. Most crystals show evidence of the strong basal cleavage at right angles to the length of the prisms; this often gives rise to a prominent terminal face, but where this is absent the terminations may be wedge-shaped (fig. 41). Perfect crystals are highly lustrous with faces that appear to have been polished, but imperfect crystals often have rough pitted faces due to natural etching processes, and may have lost all trace of their crystalline form. The best crystals are usually found in pegmatitic cavities. Topaz occurs sparsely in Manitoba at localities described subsequently, and at the Birse Lake rose quartz deposit.

Tourmaline is a complex silicate of boron and aluminum but its precise composition is extremely variable, approximately $Na(Mg,Fe)_3Al_6(Bo_3)_3Si_6O_{18}(OH,F)_4$. *Schorlite,* the common, black, iron-rich tourmaline, is often seen in pegmatites, and large crystals (hexagonal) can sometimes be found; local concentrations can give rise to schorl-rock in which the black tourmaline is usually accompanied by quartz. Such rock is well exposed in a coarse-grained pegmatite dyke that forms a cliff on the south shore of the bay at **Pickerel Narrows** settlement (Map S). Some of the schorlite crystals are 18 inches long. This pegmatite also contains 3-foot long feldspars, and biotite books measuring 8 inches across (Barry 1965). Characteristically, tourmaline crystals show triangular cross-sections in which the three sides are slightly curved; some cross-sections are six-sided. Typical crystals are elongated, often striated lengthwise, with different rhombohedral terminations at opposite ends (fig. 42). Needle-like crystals may form radiating groups; massive, compact or columnar forms (plate 79) are also common. The lustre is vitreous, and the hardness is 7 to 7½. Other varieties, on a compositional basis, are *dravite* (magnesium-rich, brown) and *lithia tourmaline* (lithium-rich; blue, pink or green). Tourmaline has the property of pyroelectricity, becoming electrically charged when heated; specimens placed in the sunlight may become covered with dust owing to the electrical attraction thus generated. Tourmaline also has the property of piezoelectricity, developing an electric charge when a thin slice is strongly compressed; this has led to its use in high-pressure gauges. Tourmaline is best known, however, as a gemstone, owing to its hardness, lustre, crystalline form, virtual lack of cleavage and remarkable range of colours. Single crystals, when cut, may show several hues owing to colour zoning. Clear specimens with good lustre can thus be cut into faceted gems of high quality. Ideally, where external zones have spalled off, leaving a core of uniform colour, excellent gems can be cut. Although some gems are obtained from schorlite and dravite, it is the coloured lithia tourmalines that provide the great majority of gem specimens. As with many other gem minerals, the best specimens are often found in cavities or pockets; tourmalines found in this setting may be so

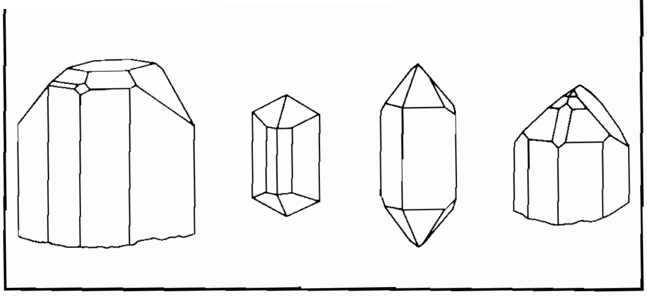


Fig. 41: Topaz

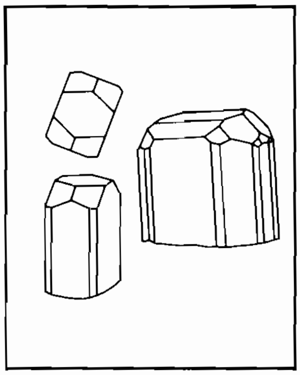


Fig. 40: Tantalite

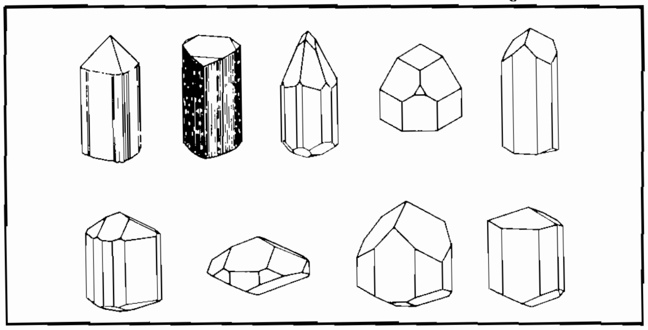


Fig. 42: Tourmaline

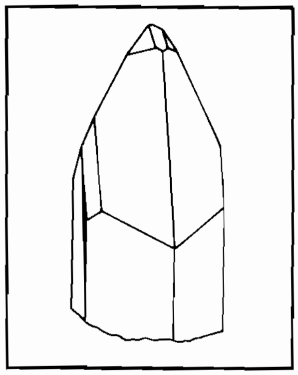


Fig. 43: Wodginite

deeply striated as to appear grooved. The principal gem varieties, named on a colour basis, are *rubellite* (red), *elbaite* (pink), *siberite* (purplish red), *indicolite* (indigo blue) and *achroite* (a rare colourless variety). Somewhat misleading are the trade terms Brazilian emerald (green) and peridot of Ceylon (honey yellow). Greens, reds and pinks are much favoured as gems, but single stones frequently exhibit many shades and colour combinations.

Triphylite (plate 80) is an iron-rich phosphate of lithium, $LiFePO_4$, that grades into lithiophilite with increase of manganese at the expense of iron; its colour is typically bluish grey but the appearance and physical properties of the two minerals (fig. 37) are otherwise very similar.

Uraninite, the dioxide of uranium (UO_2), is (worldwide) an important ore mineral. No economic ore deposits of uranium minerals are yet known in Manitoba, but uraninite in minute amounts has been noted in a few pegmatites. Crystals (isometric) are rare, but tend to have cubic or octahedral forms when found. Crystalline uraninite normally contains several per cent of thorium or rare-earth metals, whereas these are almost negligible in the cryptocrystalline variety known as *pitchblende* (plate 81), which usually occurs in massive, colloform, botryoidal or banded forms. Uraninite is characterized by its high specific gravity (9 to 9.7 for crystals, but may be as low as 6.5 for pitchblende), and strong radioactivity, readily detectable by ratemeter. Its black to brownish colour, brownish black streak, and sub-metallic or pitchy lustre are also distinctive. The mineral readily breaks down to various alteration products, seen as vividly coloured yellow, orange and green haloes. Uranium has been detected in some Manitoban pegmatites by geophysical instruments, but concentrations that can be readily seen in outcrops are very scarce. Currently, the most promising areas for uranium exploration are in the **extreme northwest** of the province, where uranium occurs in certain granites and pegmatites; because of the very extensive overburden in this region, exploration is almost entirely dependent upon geophysical and geochemical methods. Metallic uranium is the heaviest naturally occurring element, and the only one that is readily fissionable: its atoms can be split when their nuclei are struck by neutrons. Uranium is made up of three isotopes (atoms with the same chemical characteristics but different atomic structures); the only readily fissionable isotope (U-235) represents 0.71 per cent of elemental uranium. The most important non-military use for uranium is as fuel in nuclear electric power-plants. Canada's nuclear power program requires natural ceramic uranium dioxide (UO_2), which is produced in Ontario. Other refinery products include natural uranium metal, enriched uranium zircalloy (used as booster fuel), enriched uranium carbide (used in Manitoba's Whiteshell reactor at Pinawa), and depleted uranium metal castings for various applications. Radioisotopes, essentially by-products of nuclear reactors, have important applications in medicine, agriculture, chemistry and industry.

Wodginite was first described in 1963 from Wodgina, Australia, and soon afterwards was identified at **Bernic Lake,** Manitoba (plate 82). The mineral closely resembles tantalite but is monoclinic; at Bernic Lake wodginite occurs in larger and better formed crystals than does tantalite. It is a complex oxide composed mainly of tantalum, with much tin and manganese, and lesser amounts of titanium, iron and niobium. Its formula (at Wodgina) was originally given as $(Ta,Sn,Mn,Ti,Fe,Nb)_{26}O_{32}$. At Bernic Lake (TANCO mine), the mineral is black to brownish and has a pale red-brown streak; well-formed black prismatic crystals (fig. 43) up to 4 mm in length have been found in quartz. More ragged, brownish crystals, containing many inclusions of quartz and muscovite, reach up to 4 cm at this locality. Wodginite is included with the tantalum ore from Bernic Lake. It has been systematically described by Grice, Cerny & Ferguson (1972).

(a) West Hawk Lake – Falcon Lake area

Eight miles west of Falcon Lake and about 3 miles northeast of Glenn, there are two pegmatite dykes containing lithium and beryllium minerals about a mile north of the Trans-Canada Highway (Map A). On the Lucy #1 claim, a trench exposes part of a pegmatite dyke which contains white *spodumene* (plate 75) in crystals up to a foot in length; in the south portion of the dyke almost 25 per cent of the rock is spodumene. Large crystals of pink and white *feldspar* are prominent, accompanied by granular albite and schorlite; there are also some needle-like crystals of blue *tourmaline.* Also present are blue apatite, *fluorite,* pale silvery lithium mica and small scattered crystals of pale green beryl. The second dyke is about half a mile to the southwest on the adjoining claim (Artdon #1) and is exposed for a length of 60 feet over a width of 10 feet. The coarse crystals are again pink and white feldspar and white to pale green *spodumene,* accompanied by *smoky quartz* and biotite; white to pale green *beryl* is also present. Small pegmatite dykes which contain minor amounts of spodumene and beryl have also been noted to the south and west of West Hawk Lake and north of Star Lake, but these minerals are not prominent. Diamond drilling has confirmed that the "Deer" pegmatite which crops out near Crescent Beach, West Hawk Lake (Map A), contains *lepidolite* and some spodumene.

References: Bannatyne 1972; Cerny & Turnock 1971; Davies 1954; Rowe 1956; Springer 1952.

(b) Winnipeg River – Greer Lake area

West of Eaglenest Lake, the **Winnipeg River** passes through a zone that contains many pegmatites, some of which show good *beryl* crystals (Map C). A few beryl dykes crop out along the shores of the river. The most westerly of these (locality 1) is about 2¾ miles west-southwest of Lamprey Falls. The most easterly (locality 2) is at the north end of Eaglenest Lake. Between these two points a pegmatite dyke on the south shore of the Winnipeg River (locality 3) contains numerous small pencil-shaped crystals of beryl. The dyke, part of which is under water, consists of pink feldspar, smoky opalescent quartz, slightly tinted *rose quartz,* and yellowish mica. This pegmatite cuts garnet-mica schist and has an observed width of 12 feet.

The major *beryl* dykes in this area, however, are concentrated around the pegmatitic granite north and northwest of **Greer Lake** (Map C). Access to some of these can be gained along a trail south from the Winnipeg River at a point 6¼ miles east of Lamprey Falls; the trail leads to a pegmatite quarry* at the east end of Greer Lake; *feldspar* was quarried here between 1933 and 1935, and some large books of *mica* (plate 12) have been recovered. Similar pegmatite on the Grace claims, 2,000 feet south of the feldspar quarry, is notable for its *beryl* (plate 18) which is scattered through the dyke in pale green crystals, from less than an inch to almost a foot across; a few are pencil-shaped. The pegmatite is composed mainly of coarse feldspar and *quartz* (white, smoky and black), with some books of mica, a little black *tourmaline* and rare columbite-tantalite.

There are several other interesting pegmatites between Greer Lake and Waddell (formerly Aileen) Lake, 1½ miles to the west (Map C). They can be reached by a trail which leaves the Winnipeg River at a point about 4¾ miles (by boat) east of Lamprey Falls. The **Silver Leaf** lithium property is 1¼ miles south of the river and ½ mile or so northeast of Waddell Lake. The pegmatite on this property (discovered in 1924) is at least 525 feet long and the eastern third of the dyke is exposed for 100 feet down the slope of a rocky ridge. In addition to the *lithium micas* already described (see Lepidolite), fine blades of greyish to white *spodumene* are intergrown with quartz, and *lithiophilite* occurs as salmon-pink to orange, compact cleavable masses. *Topaz* is present as crude, long, grey, blue or green, turbid pyramidal crystals and crystalline masses, rarely as clear sky-blue crystals. There is a little white or very pale *beryl,* and a few pale pink, transparent crystals have been found. Garnet and *columbite-tantalite* are embedded in *zinnwaldite* mica (plate 15), and *amblygonite* is also present.

The **Huron** claim, 600 yards to the east (Map C) is outstanding for its large *beryl* crystals, occurring in albite-quartz-mica pegmatite, which intrudes basalt and is exposed for a length of about 400 feet with a maximum width (as seen in pits) of 10 feet. Very large crystals of pinkish *albite* with patches of white quartz make up the bulk of the pegmatite; some of the albite is in smaller platy crystals *(cleavelandite).* Large crystals of salmon-pink *perthite* are also present. Most of the beryl (as in plate 67) is in large crystals, some a foot or more across (occasionally 18 inches), appearing in various shades of green and yellow. The beryl is accompanied by large vein-like masses of quartz. Other notable specimens obtained from this pegmatite are: flat platy crystals of *columbite-tantalite* (10 x ½ cm), filling fractures in pink feldspar; *clinozoisite,* as dark grey granular masses and as delicate honey-coloured crystals; cinnamon-brown *monazite;* greyish to aquamarine masses of *topaz;* black vitreous *quartz. Uraninite,* though present, is not conspicuous; it was used, however, to establish the age of the pegmatite and associated rocks as 2,500 million years.

The **Annie** claim, located about 1,250 feet north-

* See Feldspar (albite) and Mica (biotite).

northwest of the Huron and 2,000 feet northeast of the Silver Leaf deposit, contains a feldspar-quartz-mica pegmatite at the south edge of the pegmatitic granite, near the volcanic contact (Map C). The coarse, buff pegmatite was formerly worked for *cassiterite* (about 1930). The rock consists mainly of *cleavelandite,* smoky and white glassy *quartz,* grey and lilac *lithia mica,* pale yellow mica, and a few white *beryl* crystals.

References: Bannatyne 1972; Cerny & Turnock 1971; Davies 1957; Rowe 1956; Sabina 1963; Springer 1949, 1950; Traill 1970.

(c) Bernic Lake area

On the north shore of **Bernic Lake** (Map C), Tantalum Corporation of Canada Limited (TANCO) operates a unique pegmatite mine which produces tantalum and cesium minerals and has potential for lithium. The main pegmatite is a complexly zoned, flat-lying dyke that has penetrated into amphibolites derived from altered andesites. The property was originally explored for its tin potential, but although *cassiterite* is locally present, attempts at tin production ceased in 1930. The pegmatite complex consists essentially of *microcline-perthite* (some very large crystals), *quartz* (including some smoky varieties), *albite* (including much *cleavelandite)* and various *micas* (see plates 2, 9, 14). *Tourmaline* is abundant in places as large black crystals, and various uncommon minerals are partially segregated in particular zones. The early underground exploration had revealed an abundance of lithium minerals, and in the 1950's further drilling penetrated a band over 100 feet thick in which small white blades of *spodumene* are intergrown with quartz. Crouse and Cerny (1972) now consider that the spodumene-bearing and spodumene-rich zones constitute nearly half the total volume of this pegmatite. Other lithium minerals in the deposit (see plates 66, 72, 73) are *amblygonite, petalite, lithian micas* and *lithiophilite.* The latter occurs as pink to brownish aggregates associated with cleavelandite, quartz and spodumene. The potential value of the tantalite and pollucite, currently produced by TANCO, was not fully realized until the 1960's when new technologies created new markets. The *tantalite* (plate 77) is confined to an albitic aplite zone, mostly as ragged, formless growths in or between blades of albite; grains as large as 1 or 2 mm across are exceptional. Another tantalate mineral, *wodginite* (plate 82) occurs in fine-grained albite and also in coarse perthitic microcline associated with quartz and mica; it is more prominent than the tantalite, with which it can easily be confused, occurring in well-formed black prismatic crystals several millimetres in length, and in larger more ragged crystals up to 4 cm. The TANCO pegmatite contains one of the largest concentrations of *pollucite* (plate 74) known anywhere at the present time. Crouse and Cerny (1972) have described a pollucite zone approximately 500 feet long, containing lens-shaped masses of pollucite up to 40 feet thick. Most of the pollucite shows a peculiar structure characterized by clear glassy eyelets embedded in a braided white matrix. Specimens of dark grey or massive milky pollucite are exceptional. Other minerals of interest at the mine include the micas *lepidolite* and *zinnwaldite,* also *beryl, apatite* and *rhodochrosite* (see Carbonates). A detailed account of this important mine is beyond the scope of the present work, but a systematic and comprehensive description has been given by Crouse and Cerny (1972). For further information and references, see Amblygonite, Petalite, Pollucite, Spodumene, Tantalite and Wodginite; also Microcline (Feldspar) and Lepidolite (Mica).

At the east end of **Bernic Lake** (Map C), a group of flat-lying pegmatite dykes is located on claims held by Lithium Corporation of Canada Limited. Extensive open workings, now considerably overgrown, can be seen on the Buck Claim about 600 yards east of the lake. A few cassiterite crystals as much as an inch in length were originally reported from this property. There are specimens of tourmaline, spodumene, amblygonite, feldspar and other minerals on the old rock-dumps, and also in the walls of the open cut, at the east side of the Buck claim. The large pegmatite dyke exposed here is about 20 feet thick and dips east at 25 to 30 degrees. It is composed essentially of quartz, albite and mica and has intruded andesite. Several distinct mineral zones are distinguished in the open cut, characterized (from the top downwards) by:

(i) Large crystals of black *tourmaline* with feldspar and quartz.

(ii) Yellowish *lithium mica* in books (3 x 3 inches) with quartz and albite and (at the base) some very large pink *microcline* crystals; pale yellowish green *beryl* crystals (up to an inch across) occur in small amounts.

(iii) *Spodumene* intergrown with much *quartz,* and accompanied by feldspar.

(iv) Crystals of *amblygonite* (up to 6 inches across) associated with radiating platy *albite;* minor *lepidolite.*

(v) *Amblygonite* crystals, up to 2 feet by 1 foot, accompanied by quartz; at the bottom of this zone large masses of grey-green *triphylite,* up to one foot across, occur with the quartz (compare plate 80).

About 250 yards to the southwest a second dyke is exposed on the east side of a hill near the west edge of the Buck claim. The dyke dips northeast at 20 degrees and has been traced along strike for about 125 feet; its exposed thickness above swamp level is 8 feet. The top and bottom zones consist of white quartz, tourmaline and mica, but between them is a 2-foot zone composed mainly of pink *albite* and *quartz* with a considerable amount of deep purple *purpurite,* partly weathered to a dark brownish colour. Some of the *tourmaline* is black and some is deep translucent green. Much of the *mica* is pale yellowish, and grains of clear, dark blue *apatite* are sparsely scattered in the upper zone. Two hundred and fifty yards to the west of this dyke, a smaller dyke on the Coe claim, close to the lake-shore, is remarkable for its high concentrations of *petalite,* associated with quartz and feldspar. Some pale mica, *triphylite,* purpurite and blue apatite are also present. Some mineral specimens have been obtained from a small pit near the shore.

Several pegmatite dykes and quartz bodies near the southeast shore of **Shatford Lake** (Map C) contain white to yellow *beryl* crystals, mostly an inch or so in length. The largest of the dykes strikes east to northeast through basalt about ¾ mile west of the east end of the lake, showing outcrops over a distance of 500 yards. The dyke is also well exposed in trenches. It is composed essentially of coarse pink *albite* and quartz; the feldspar is in the form of large crystals and curved plates. In the main workings (Dyke claims), which date back to the 1950's, large masses of *zinnwaldite* are present (as described under Mica), also biotite and yellowish lithia mica. Several large patches of dark reddish to greyish brown *monazite* were seen in one pit; some concentrations showed surface areas of 10 by 8 inches. The fractured feldspar in which the monazite occurs has been stained red by iron oxide. Small tabular crystals of *columbite-tantalite* also occur in fractured feldspar and quartz. *Topaz* is present only as remnants of large prismatic crystals that have been largely altered to soft micaceous material (pinite). *Beryl* is widespread in accessory amounts, associated with quartz and albite. One deep green crystal of beryl over 1½ feet long has been recorded.

Much of the early prospecting of pegmatites in southeast Manitoba, dating back to the first world-war, was inspired by the search for *cassiterite* (plate 69), the main ore-mineral of tin. This search, which persisted until the 1950's, did not lead to the discovery of a tin mine but did result in the opening and mining of equally valuable pegmatitic minerals at Bernic Lake: minor cassiterite occurs with the tantalite at this mine (TANCO). Small amounts of cassiterite are also present in a group of *tourmaline*-bearing dykes north and west of **Rush Lake** (Map C); these are identified as the Rush, Stannite and Odd claims. Rush Lake is 2 miles northeast of Bernic Lake, but these claims are accessible only from the north, by walking along forestry tracks that leave provincial road 315 near the west end of Bird Lake. As all good specimens have been removed, the journey is not recommended for mineral collection purposes. On the former Odd claim, small grains of cassiterite are scattered through a grey, fine-grained albitite dyke, composed of white *albite,* yellowish mica, clear quartz and small black tourmaline grains. The albitite is part of a pegmatitic suite and it grades westward into coarse pegmatite in which drilling revealed only occasional large crystals of *cassiterite.* The albitite phase is most conspicuous to the east where the dyke narrows to less than 5 feet. Drilling carried out many years ago indicated the dyke had a tin content of 0.35 per cent over a length of 320 feet. Some of the drill core can still be seen at the site, but all the tin-bearing sections have been removed. On the former Stannite property, cassiterite occurs in a narrow contact zone, about one foot wide, between pegmatite and quartz-mica schist. The tin-bearing zone is poorly exposed for a length of only a few feet; within it, crystals of cassiterite up to half an inch across were found in a coarse mixture of pale yellow mica and quartz. The cassiterite, which has now been almost completely removed, was found along the northern contact of the pegmatite near its west end where the dyke is quite narrow. The eastern part of the dyke consists of a coarse-grained, buff-coloured assemblage of quartz, feldspar and mica with a few large crystals of *spodumene* and small amounts of beryl, *triphylite* and *purpurite.* A large pegmatite dyke on the former Rush property is well exposed over a length of about ¼ mile with a width up to 250 feet, but access to this locality is almost impossible at the time of writing owing to a dense coverage of slashed débris from woodcutting operations. The dyke is an *albite* pegmatite dipping steeply south and containing xenoliths of andesite. Cassiterite is present in minute amounts; the only conspicuous accessory mineral is *tourmaline* in crystals up to 3 inches long.

References: Bannatyne 1972; Cerna, Cerny & Ferguson 1972; Cerny & Ferguson 1972; Cerny & Macek 1972; Cerny & Turnock 1971; Crouse & Cerny 1972; Davies 1955, 1957; Davies *et al* 1962; Grice, Cerny & Ferguson 1972; Rinaldi, Cerny & Ferguson 1972; Sabina 1963; Springer 1950; Traill 1970.

(d) Cat Lake area

Several quartz-feldspar-mica pegmatites that were worked for *spodumene* in the 1950's are well exposed within a few hundred yards of Cat Lake (Map C). The Eagle, Irgon and Central properties are readily accessible by road. On the **Eagle** property, a vertical dyke up to 24 feet in width has been exposed for over half a mile. The dyke is narrow at its west end where it tapers out in altered basalt, but it increases in width to the east where it cuts through granite. The principal minerals of the pegmatite are albite, microcline, quartz, spodumene, garnet and muscovite. The *spodumene* is in white to pale green laths, intergrown with quartz. Near its west end this pegmatite is cut by a north-south dyke of similar composition but also containing pink *cleavelandite*, black *tourmaline* and small green crystals of *beryl* (up to 1 inch across). On the F.D.5 claim, east of the Eagle, a very coarse-grained dyke contains *microcline* and *albite* crystals up to a foot in length, with large books of *biotite* evenly scattered throughout. Apple-green crystals of *spodumene* (up to 2 inches long) make up 50 per cent of the rock in places; white *beryl* crystals up to an inch across are also present. The outcrop area is a low knoll about 90 by 45 feet, with four smaller exposures 100 feet to the southeast.

On the **Irgon** claim, another *spodumene* dyke of somewhat similar composition is exposed for ¾ mile, cutting mainly through altered basalt. The narrow west end of the dyke is about 15 feet wide, but the pegmatite broadens to 60 feet near its eastern end before disappearing under muskeg. The dyke is roughly banded parallel to its length, owing to alternations of quartz-spodumene with fine-grained pegmatite. Foliation due to uniform alignment of muscovite flakes contributes to the banded structure.

At the **Central** claim, a zoned pegmatite, dipping 20 degrees west, is exposed on the east side of a low granite ridge. *Spodumene* occurs in sub-equal amounts with *quartz* in a zone traced for 150 feet with a thickness of 10 feet. The quartz-spodumene zone is successively overlain by an *albite*-rich band, then by *quartz-muscovite* rock and albite granite.

References: Cerny & Turnock 1971; Rowe 1956; Sabina 1963; Springer 1950.

(e) Crowduck Bay, Wekusko Lake

Large pale green to white spodumene crystals (plate 76) have been found in pegmatite dykes near Crowduck Bay (Map K), access to which has been explained under Staurolite. Trenching and some drilling were carried out between 1950 and 1956 by companies exploring for lithium. At the **Sherritt Gordon** property, about half a mile west of the Crowduck Bay narrows, three parallel dykes that strike northwesterly within a width of ½ mile were investigated in the 1930's. The central dyke is the largest with a maximum width of 7 m (23 feet); it contains pale greenish white, blade-like *spodumene* crystals up to 45 cm (1½ feet) in length. White to reddish *cleavelandite* and black *tourmaline* are two of the other constituents. A mile or so to the northeast, two white, feldspathic pegmatites cut greywacke and conglomerate on the **Violet** claim (drilled by Combined Developments Limited in 1955-56), located near the east shore about ½ mile north of the narrows. The smaller southerly dyke is exposed in a cliff along the shore; this dyke is 3 m (10 feet) wide and contains clusters of coarse *spodumene*. The larger dyke is 650 yards to the north-northeast and about 100 yards from the shore; its strike is parallel to the shoreline. It contains concentrations of thin-bladed apple-green *spodumene* crystals intergrown with *quartz;* there is much red oxide staining. The **Green Bay** property is 2½ miles southeast of Crowduck Bay and the trail is 4½ miles long. The main dyke strikes north-northwest and is exposed in 16 cross-trenches which show large pink feldspars *(perthitic microcline)*, coarse *tourmaline* crystals, greenish *spodumene* in blades up to 30 cm, and minor *beryl.*

References: Bannatyne 1973; Rowe 1956; Sabina 1972.

(f) Cross Lake area

Pegmatites containing beryl or spodumene have intruded altered sedimentary rocks in the Cross Lake area. Some crystals of pale green *beryl* are several inches long but are not of outstanding quality. Museum specimens of *spodumene* have been collected from a pegmatite that had been trenched south of **Cross Island** (Map U). A detailed examination of this location, on the southwest shore of a two-mile-long island, ¼ mile south of Cross Island, showed two parallel dykes, 6 to 10 feet in width, containing pale greenish white spodumene of excellent crystalline form; the crystals are set in massive *quartz.* The feldspars are coarse *perthite* and fine-grained *cleavelandite.* Large books of greenish *muscovite* are present, as well as blue *apatite* and black *tourmaline.* The latter is abundant in the wall-rocks along the pegmatite contact.

References: Bannatyne 1973; Bell 1962; Rousell 1965.

(g) Oxford Lake – Knee Lake area

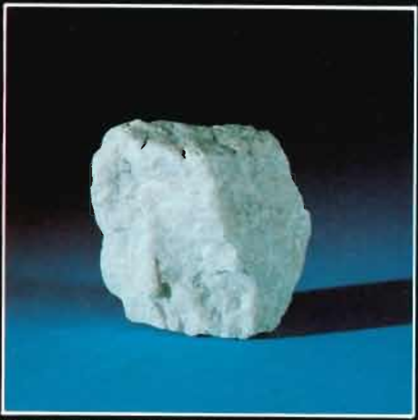
Well-formed stubby crystals (up to 5 x 1½ inches) of greenish *spodumene* occur in a pegmatite dyke at a small lake known as "Lake J", 13 miles south-southeast of Oxford House and 7 miles southwest of Knee Lake (Map W). The dyke, which is approximately 4 feet in width, and has been traced for nearly ¼ mile, strikes easterly across the southerly extension of "Lake J", cutting altered sedimentary rocks. It is very coarse-grained and contains *alkalic feldspar,* minor quartz and pale green *muscovite* in books up to ¼ inch thick. The spodumene is concentrated in clusters towards the north side of the dyke. Other minerals reported are garnet and blue-green *apatite.*

References: Bannatyne 1973; Barry 1959.


71) Fluorite crystals (Museum)


72) Lithiophilite from Bernic Lake


73) Petalite from Bernic Lake


74) Pollucite from Bernic Lake


75) Spodumene from Glenn area


76) Spodumene from Crowduck Bay

77) Tantalite or pseudo-ixiolite in quartz-albite rock from Bernic Lake

78) Water-worn topaz from gravel deposit (Museum)

79) Black tourmaline (Museum)

80) Triphylite from Bernic Lake

81) Pitchblende (Museum)

82) Small black crystals of wodginite with albite from Bernic Lake

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Mineral	Approximate Composition	Approximate		Cleavage	Transparency tp=transparent tl=translucent op=opaque	Lustre	Streak	Colour	Crystalline form and general habit	Remarks	Page
		Specific Gravity	Hardness								
Actinolite	$CaO \cdot 3Mg,FeO \cdot 4SiO_2 \cdot (OH)$	3.1	5½	2 at 56° (prominent)	tp to tl	vitreous	neutral	green	monoclinic: elongated blades or small needles; or fibrous	an amphibole; grades to tremolite	44, 45, 46-47
Agate	SiO_2	2.6	7	none	tl	waxy to vitreous	neutral	variegated	cryptocrystalline: nodular, botryoidal	banded chalcedony; conchoidal fracture	16
Alabaster	$CaSO_4 \cdot 2H_2O$	2.3	2	as gypsum	tl	snow-like	white	white or tinted	monoclinic: in compact masses	very fine-grained gypsum	30, 33
Albite	$Na_2O \cdot Al_2O_3 \cdot 6SiO_2$	2.6	6¼	2 at 93½° (prominent)	tp to tl	vitreous and pearly	white	white, grey, pink, neutral	triclinic: tabular, platy, massively crystalline; lamellar twinning	sodic plagioclase; crystals common; finely striated	17, 18, 19, 72, 73, 74, 75
Amazonstone	$K_2O \cdot Al_2O_3 \cdot 6SiO_2$	2.6	6¼	2 at 89½° (prominent)	tl	vitreous	white	bright green to bluish green	triclinic: blocky, tabular crystals or cleavable masses	variety of microcline; colour distinctive; often perthitic	17, 18
Amblygonite-montebrasite	$Li(F,OH)AlPO_4$	3	6	1 perfect, 1 clear, 1 weak	tl	vitreous and pearly	neutral	white, grey, tinted	triclinic: coarse cleavable masses, microcrystalline	cleavage fragments resemble feldspar	66, 72, 73
Andalusite	$Al_2O_3 \cdot SiO_2$	3.2	7½	1 distinct, 1 weak	tl	vitreous	neutral	red, brown, grey, greenish, pink	orthorhombic: coarse prismatic crystals	square cross-section; hard if unaltered	55
Andesine	Ab_{50-70} (Ab=albite) An_{30-50} (An=anorthite)	2.7	6¼	2 at 93¾° (approx.)	tp to tl	vitreous	white	white, grey, neutral	triclinic: usually massively crystalline; lamellar twinning	intermediate plagioclase; finely striated	19
Anhydrite	$CaSO_4$	2.9	3¼	3 at 90°	tp to tl	vitreous and pearly	white to greyish	white to pale bluish, grey, neutral	orthorhombic: massive, bedded	rectangular cleavage; usually very fine-grained	30, 31, 32, 33
Anorthite	$CaO \cdot Al_2O_3 \cdot 2SiO_2$	2.8	6¼	2 at 94¼° (approx.)	tp to tl	vitreous	white	white, grey, neutral	triclinic: usually massively crystalline; lamellar twinning	lime plagioclase; finely striated	17, 19, 21
Anthophyllite	$(Mg,Fe)O \cdot SiO_2 + (OH)$	3.2	5¾	prismatic: 1 perfect, 2 imperfect	tl	vitreous to silky	neutral or greyish	dark or yellowish brown	orthorhombic: bladed; fibrous aggregates	an amphibole; brown, radiating blades or fibres	44, 45, 47-48, 63, 64
Apatite	$Ca_5F(PO_4)_3$ to $Ca_5Cl(PO_4)_3$	3.2	5	weak (basal)	tl to op	vitreous or sub-resinous	white	pale green, blue, brown, neutral	hexagonal: prisms and pyramids with pinacoids	crystals common; scratched by knife	51, 52, 72, 73, 74, 75
Asbestos (Chrysotile)	$3MgO \cdot 2SiO_2 \cdot 2H_2O$	2.6	2½	parallel to fibres	tl	silky	white	white, grey, yellow, green	monoclinic: fibrous	fibrous serpentine	35, 36, 45

Mineral	Approximate Composition	Approximate Specific Gravity	Approximate Hardness	Cleavage	Transparency tp=transparent tl=translucent op=opaque	Lustre	Streak	Colour	Crystalline form and general habit	Remarks	Page
Augite	$(Ca,Na)(Mg,Fe,Al)(Si,Al)_2O_6$	3.3	5¾	2 at 87° (prominent)	tl to op	vitreous to dull	greyish green	dark green to black	monoclinic: short prismatic crystals, 4 or 8 sided	a clinopyroxene; rectangular cross-section	40,41
Beryl	$3BeO \cdot Al_2O_3 \cdot 6SiO_2$	2.8	7¾	indistinct (basal)	tp to tl	vitreous	white	white, green, golden yellow, neutral, blue	hexagonal: prisms, rarely with pyramid end-faces	may resemble quartz in crystalline form, colour and hardness	66, 72, 73, 74, 75
Biotite	$K(Mg,Fe)_3(Al,Fe)Si_3O_{10}(OH,F)_2$	3	2¾	perfect micaceous	tp to op	splendent, pearly	neutral	black, dark brown, dark green	monoclinic: flakes, books, aggregates	black mica; single flakes smoky, elastic	22, 24, 60, 61, 72, 74, 75
Bronzite	$(Mg,Fe)O \cdot SiO_2$	3.3	5½	2 at 87° (prominent)	tl to op	bronze-like	neutral to greyish	brown	orthorhombic: massive to foliaceous	iron-bearing enstatite; rectangular cross-section	40, 41, 59
Bytownite	$Ab_{10\text{-}30}$ (Ab=albite) $An_{70\text{-}90}$ (An=anorthite)	2.7^+	6¼	2 at >94° (prominent)	tp to tl	vitreous	white	white, grey, neutral	triclinic: massive or granular; lamellar twinning	lime-rich plagioclase; finely striated	19, 21, 41
Calcite	$CaCO_3$	2.7	3	3 perfect; angle = 75°	tp to op	vitreous to earthy	white	white, neutral, tinted	hexagonal: prisms, rhombs, variable	effervesces with cold dilute hydrochloric acid	27, 28, 42
Cassiterite	SnO_2	7	6½	indistinct	tp to op	adamantine	pale brown (or greyish white)	reddish brown to black	tetragonal: prisms and pyramids; elbow twins; also fibrous-reniform	tinstone; high lustre and specific gravity	66, 73, 74
Chalcedony	SiO_2	2.6	7	none	tp or tl	waxy to dull	white	white, grey, blue, brown, black	cryptocrystalline: botryoidal, concretionary	general name for varieties of cryptocrystalline quartz	14, 15
Chert	SiO_2	2.6	7	none	op	dull, sub-vitreous	white	pale grey to black	cryptocrystalline: bedded, nodular	a rock-forming chalcedonic mineral	15-16
Chlorite	$4H_2O \cdot 5(Mg,Fe)O \cdot Al_2O_3 \cdot 3SiO_2$	2.8	2¼	micaceous	tp to tl	vitreous to pearly	neutral to greenish white	green (generally dark) to yellowish	monoclinic: flaky or massive	soft, green, non-elastic	22, 25
Cleavelandite	$Na_2O \cdot Al_2O_3 \cdot 6SiO_2$	2.6	6¼	2 at 93½° (prominent)	tl	vitreous and pearly	white	white	triclinic: lamellar twinning, platy habit	white, platy albite; finely striated	18, 72, 73, 75
Clinozoisite	$4CaO \cdot 3Al_2O_3 \cdot 6SiO_2 \cdot H_2O$	3.3	6¼	1 perfect, 1 prominent	tp to tl	vitreous	neutral to greyish	neutral, grey, yellow, green, pink	monoclinic: prismatic; granular masses	crystals striated; grades to epidote	50, 52, 72
Columbite	$(Fe,Mn)Nb_2O_6$	5.2^+	6	1 distinct, 1 weak	op	sub-metallic (shiny black)	dark red to brown or black	black; (irridescent tarnish)	orthorhombic: thin tabular to square prismatic	brilliant lustre; heart-shaped twins; grades to tantalite	67, 72, 74
Cordierite	$H_2O \cdot 4(Mg,Fe)O \cdot 4Al_2O_3 \cdot 10SiO_2$	2.6	7¼	1 weak	tp to tl	vitreous	neutral	blue or bluish to violet	orthorhombic: pseudo-hexagonal twins; granular, massive	dark blue but alters to pinite (soft)	56, 62-64

Mineral	Approximate Composition	Approximate Specific Gravity	Approximate Hardness	Cleavage	Transparency tp=transparent tl=translucent op=opaque	Lustre	Streak	Colour	Crystalline form and general habit	Remarks	Page
Cummingtonite	$(Mg, Fe)O \cdot SiO_2 + (OH)$	3.3	5½	2 at 56° (prominent)	tl to op	silky	neutral	brown or greyish	monoclinic: fibrous, commonly twinned	a metamorphic amphibole	48
Diopside	$CaO \cdot MgO \cdot 2SiO_2$	3.3	5¾	2 at 87° (prominent)	tp to op	vitreous	white to greyish	green to yellowish, brown, white	monoclinic: short, prismatic; usually granular	a clinopyroxene; often pale green; rectangular cross-section	40, 41-42, 52
Dolomite	$CaCO_3 \cdot MgCO_3$	2.9	3¾	3 perfect; angle = 73¾°	tp to tl	vitreous to pearly	neutral	pink, brown, white, neutral	hexagonal: rhombs, curved faces; also coarse masses	scratched by knife; effervesces in cold dilute hydrochloric acid only if powdered	27, 28-29
Enstatite	$(Mg, Fe)O \cdot SiO_2$	3.3	5½	2 at 87° (prominent)	tl to op	vitreous to pearly	neutral to greyish	grey, green, yellowish brown	orthorhombic: stout prisms (rare); generally lamellar-massive	an orthopyroxene; grades to hypersthene; rectangular cross-section	40, 41
Epidote	$H_2O \cdot 4CaO \cdot 3(Al, Fe)_2O_3 \cdot 6SiO_2$	3.4	6½	perfect basal	tp to tl	vitreous to resinous	neutral or greyish	yellowish green, darker green	monoclinic: tabular or elongated blades; often granular-massive	yellowish-green; crystals striated; grades to clino-zoisite	50, 52,
Fluorite	CaF_2	3.2	4	4 perfect (octahedral)	tp to tl	vitreous	white	purple, blue, green, yellow	isometric; cubes, often intergrown, also octahedral	brightly coloured; cubic; easily scratched with knife	68, 72
Fuchsite	As muscovite, plus Cr_2O_3	2.8	2½	perfect micaceous	tp to tl	pearly	neutral	bright green	monoclinic: flakes and scales	green muscovite mica	23
Garnet (almandine)	$3FeO \cdot Al_2O_3 \cdot 3SiO_2$	4.2	7¼	none	tp to tl	vitreous to resinous	white	red to brownish black	isometric: crystals sub-rounded and many-sided	hardness, colour, crystal-line form distinctive	57-59, 61, 63, 64, 75
Graphite	Carbon	2.2	1½	perfect basal	op	metallic	black	grey-black	hexagonal: flakes, scales, platy masses	marks paper	22, 26
Grunerite	$(Fe, Mg)O \cdot SiO_2 + (OH)$	3.5	5½	2 at 56° (prominent)	tl to op	silky	neutral	brown to grey	monoclinic: fibrous, tabular, prismatic	grades to cummingtonite (amphibole)	48
Gypsum	$CaSO_4 \cdot 2H_2O$	2.3	2	1 perfect, 2 distinct	tp to tl	sub-vitreous and pearly	white	neutral, white, grey	monoclinic: tabular, prismatic, variable; also compact-massive	cleavage, softness and twinning distinctive; forms massive bedded deposits	30-33
Hornblende	$Na,Ca_2(Mg, Fe, Al)_5(OH)_2(Si,Al)_8O_{22}$	3.2	5½	2 at 56° (prominent)	tl	vitreous	neutral	dark green to black or brown	monoclinic: stubby, blocky prisms with 3 end-faces	common amphibole; 6-sided cross-section; note cleavage angle	44, 45-46
Hypersthene	$(Fe, Mg)O \cdot SiO_2$	3.5	5½	2 at 87°, 3rd parting	tl	sub-vitreous or pearly	greyish to brownish	brown, green, grey to blackish	orthorhombic: foliated-massive; prismatic-tabular crystals (rare)	an orthopyroxene; grades to enstatite; rectangular cross-section; prominent cleavage	40, 41, 64

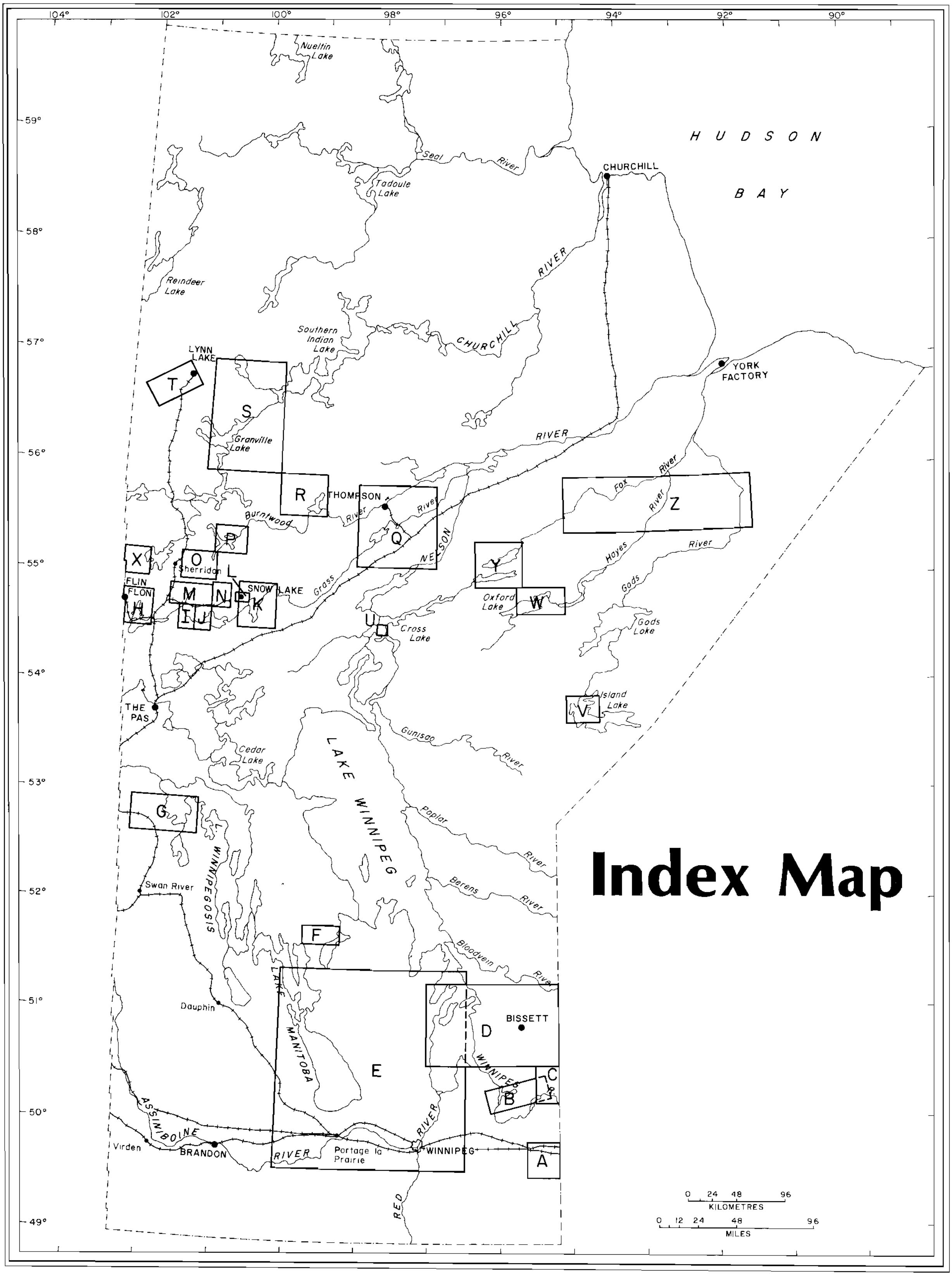
Mineral	Approximate Composition	Approximate		Cleavage	Transparency tp=transparent tl=translucent op=opaque	Lustre	Streak	Colour	Crystalline form and general habit	Remarks	Page
		Specific Gravity	Hardness								
Jasper	SiO_2	2.6	7	none	op	waxy	white	red, brown, yellow	cryptocrystalline: vein-filling, nodular	impure variety of chert, typical with iron-ore	16
Kyanite	$Al_2O_3 \cdot SiO_2$	3.6	4 - 7	perfect lengthwise	tp to tl	vitreous to pearly	neutral	blue, white, grey-green	triclinic: long flat blades and aggregates	soft lengthwise, hard cross-wise	55
Labradorite	$Ab_{30\text{-}50}$ (Ab=albite) $An_{50\text{-}70}$ (An=anorthite)	2.7	6¼	2 at <94° (prominent)	tl	vitreous	white	grey, white, neutral	triclinic: cleavable masses; tabular crystals (rare); lamellar twinning	lime-soda plagioclase; may show play of colours; finely striated	17, 19, 41
Lazulite	$(Mg,Fe)\ Al_2(OH)_2(PO_4)_2$	3.1	5½	1 distinct, 1 indistinct	tl	vitreous	white	deep blue	monoclinic: granular-massive, crystals rare	rare vein-mineral and minor gemstone	15
Lepidolite	$K(Li,Al)_3\ (Si,Al)_4O_{10}(F,OH)_2$	2.9	3	perfect micaceous	tl	pearly	neutral	lilac, pink, greyish white, yellowish, bluish	monoclinic: platy crystals; usually in scaly aggregates	lithium mica; lilac colour typical; grades to muscovite	23, 72, 73
Lithiophilite	$LiMn\ (PO_4)$	3.5	4½	2 at 90° (prominent)	tl	resinous	neutral to off-white	salmon-pink, clove-brown	orthorhombic: cleavable masses; crystals rare	shows brown to black surface alteration; grades to triphylite	68, 72, 73
Microcline	$K_2O \cdot Al_2O_3 \cdot 6SiO_2$	2.6	6¼	2 at 89½° (prominent)	tp to tl	vitreous	white	greyish white, pink, red, cream	triclinic: blocky tabular crystals; cleavable masses; simple and lamellar twinning	abundant potassic feldspar; large crystals common; finely striated	18, 73, 75
Monazite	$(Ce,La,Yt)PO_4$	5.2	5¼	1 imperfect, 1 parting	tp to tl	resinous	white	yellowish to red-dish brown	monoclinic: granular masses; crystals often flat or elongated	not common; large crystals rare	68, 72, 74
Muscovite	$K\ Al_3Si_3O_{10}(OH)_2$	2.8	2½	perfect micaceous	tp	pearly	neutral	neutral or tinted	monoclinic: 6-sided tabular plates and large flakes	primary white mica; often in foliated masses	22, 23, 75
Oligoclase	$Ab_{70\text{-}90}$ (Ab=albite) $An_{10\text{-}30}$ (An=anorthite)	2.65	6¼	2 at >93½° (prominent)	tl	vitreous or pearly	white	grey, white, pinkish	triclinic: cleavable masses; flat tabular crystals; lamellar twinning	an abundant sodic plagioclase; finely striated	19
Olivine	$2(Mg,Fe)\ O \cdot SiO_2$	2.2	6¾	2 very weak	tp to tl	vitreous	neutral	green, brown, yellow, white	orthorhombic: crystals thick, tabular, wedge-ended; usually in rounded grains	a ferromagnesian rock-forming mineral, usually green, often altered	34-35
Opal	$SiO_2 \cdot nH_2O$	2^+	$5½^+$	none	tp to op	vitreous, resinous, pearly, waxy	white	milky, neutral, tinted	amorphous: massive, bot-ryoidal, stalactitic	hydrous silica mineral; gems show striking play of colours	16
Orthoclase	$K_2O \cdot Al_2O_3 \cdot 6SiO_2$	2.6	6¼	2 at 90° (prominent)	tl to tp	vitreous or pearly	white	white, pink, brownish, neutral	monoclinic: blocky with rectangular cross-sections; simple twinning	potassic feldspar; lacks striations; twinning easily visible	17-18
Perthite	Mixture of sodic and potassic feldspars	2.6	6¼	2 at 90° (approx.)	tl to tp	vitreous	white	white, pink	complex intergrowth: external form usually like microcline	microscopic intergrowth of albite or oligoclase in microcline or orthoclase	18, 72, 73, 75

Mineral	Approximate Composition	Approximate Specific Gravity	Approximate Hardness	Cleavage	Transparency tp=transparent tl=translucent op=opaque	Lustre	Streak	Colour	Crystalline form and general habit	Remarks	Page
Petalite	$Li_2O \cdot Al_2O_3 \cdot 8SiO_2$	2.4	6¼	1 perfect, 1 weak	tp to tl	vitreous or pearly	white	white, neutral, grey, yellow	monoclinic: cleavable masses; crystals small and rare	large log-shaped and long tabular crystals at Bernic Lake	68, 73, 74
Phlogopite	$K\,Mg_2AlSi_3O_{10}(OH)_2$	2.9	2½	perfect micaceous	tp to tl	pearly, sub-metallic	neutral	brown, amber	monoclinic: 6-sided flaky crystals and foliated masses	metamorphic magnesian mica; grades to biotite	24, 42
Pitchblende	UO_2	7.7	5	none	op	pitch-like	black	black	cryptocrystalline: massive, botryoidal, banded, colloform	cryptocrystalline forms of uraninite	71
Pollucite	$2Cs_2O \cdot 2Al_2O_3 \cdot 9SiO_2 \cdot H_2O$	2.9	6½	none	tp	sub-vitreous	white	neutral, white, grey	isometric: massive, fine-grained; cubic crystals (rare)	cesium ore; easily mistaken for quartz	69, 73
Purpurite	$2(Fe,Mn)PO_4 \cdot H_2O$	3.4	4¼	1 good, 1 weak	op	dull	reddish purple	deep red to dark brown	orthorhombic: small irregular masses	alteration product of lithiophilite	69, 74
Quartz	SiO_2	2.6	7	very weak; breaks with conchoidal fracture	tp to tl	vitreous	white	neutral, white, smoky	hexagonal: prismatic crystals with pyramid endings; often massive	many variations of form and colour, but generally white or colourless and glassy; note hardness	14-15, 72, 73, 74, 75
Rhodochrosite	$MnCO_3$	3.5	4	3 perfect; angle = 73°	tp to tl	vitreous	white	pink, red, brown	hexagonal: rhombohedral crystals (rare); usually cleavable masses	effervesces in warm hydrochloric acid; colour often distinctive	27, 29, 73
Rutile	TiO_2	4.2	6¼	weak	tp to tl	adamantine	pale brown	reddish brown	tetragonal: prismatic, needle-like; striated; often twinned	often as slender crystals in quartz; note streak	15
Satin Spar	$CaSO_4 \cdot 2H_2O$	2.3	2	1 perfect, 2 distinct	tl	silky	white	white, grey, tinted	monoclinic: fibrous, compact	fibrous form of gypsum	31, 32
Scapolite	$(Na,Ca,K)_4Al_3(Al,Si)_3Si_6O_{24}(Cl,F,OH,CO_3,SO_4)$	2.7	5½	4 at 45° (obscure)	tp to tl	vitreous to resinous	white	white, grey, green, brown	tetragonal: in prisms with square cross-sections; often massive	composition varies from lime-rich to soda-rich; often altered	50-51, 52, 53
Scheelite	$CaWO_4$	6	4¾	1 (not prominent)	tl	vitreous to adamantine	white	yellowish white, brownish, green	tetragonal: often massive; crystals pyramidal, octahedral, tabular	high specific gravity; fluorescent under ultraviolet light	51,
Selenite	$CaSO_4 \cdot 2H_2O$	2.3	2	1 perfect, 2 distinct	tp	vitreous	white	neutral	monoclinic: in flattened crystals and cleavage plates	transparent crystalline gypsum	30, 32-33
Sericite	$K\,Al_3Si_3O_{10}(OH)_2$	2.8	2½	perfect micaceous	tp	pearly	white	neutral, white	monoclinic: scaly masses or scattered flakes	fine-grained metamorphic muscovite	22, 23

Mineral	Approximate Composition	Approximate		Cleavage	Transparency tp=transparent tl=translucent op=opaque	Lustre	Streak	Colour	Crystalline form and general habit	Remarks	Page
		Specific Gravity	Hardness								
Serpentine	$3MgO \cdot 2SiO_2 \cdot 2H_2O$	2.6	2 - 5	none	tl to op	waxy, greasy	white	green to yellow, dark olive, red, brown	monoclinic: platy or formless masses; no crystalline form	soft, usually mottled green; see also asbestos	34, 35-36, 38
Siderite	$FeCO_3$	3.9	4	3 perfect; angle = 73^o	tl	vitreous or pearly	white	brown, buff, reddish	hexagonal: rhombs with curved faces; also massive or granular	effervesces with hot hydrochloric acid; note colour and specific gravity	27
Sillimanite	$Al_2O_3 \cdot SiO_2$	3.2	6¾	1 perfect lengthwise	tp to tl	vitreous to silky	neutral	grey, white, brown, neutral, greenish	orthorhombic: long needle-like prisms; often fibrous	often in quartz-sillimanite knots or clumps within paragneiss	55, 56, 61, 64
Sphene	$CaO \cdot TiO_2 \cdot SiO_2$	3.5	5¼	1 (not prominent)	tp to op	adamantine to resinous	white	brown, yellow, green, grey	monoclinic: wedge or lozenze shaped with sharp edges	thin, wedge-like crystals; high lustre, often brown	51, 52
Spodumene	$Li_2O \cdot Al_2O_3 \cdot SiO_2$	3.2	6¾	2 perfect at 87^o; 3rd parting	tl	vitreous to dull	white	white, grey, greenish	monoclinic: flattened prismatic crystals, vertically striated	a pyroxene; large crystals and cleavable masses in pegmatite	40, 41, 69, 72, 73, 74, 75
Staurolite	$Fe_2Al_9Si_4O_{22}(OH)_2$	3.7	7¼	1 imperfect	tl to op	resinous to vitreous	greyish	reddish brown to brownish black	orthorhombic: short prismatic crystals and cruciform twins	colour, hardness and twins distinctive, but soft where altered	60-61
Talc	$3MgO \cdot 4SiO_2 \cdot H_2O$	2.8	1	perfect, platy	tl	pearly, greasy	white	green, grey, white	monoclinic: massive-foliated; rare tabular crystals	feels greasy, marks cloth	36-38, 47
Tantalite	$(Fe,Mn)Ta_2O_6$	6.8	6	1 distinct, 1 weak	op	sub-metallic to resinous	dark brown	black or brown	orthorhombic: skeletal-interstitial at Bernic Lake	grades to columbite; mangano-tantalite at Bernic Lake	70, 73
Topaz	$Al_2SiO_4(OH,F)_2$	3.5	8	1 perfect (basal)	tp to tl	vitreous	neutral	neutral, greyish, yellowish, pink, bluish	orthorhombic: prismatic; often stubby and wedge-ended	note cleavage and hardness, but soft if altered	15, 70, 72
Tourmaline	$Na(Fe,Mg)_3Al_6(BO_3)_3Si_6O_{18}(OH,F)_4$	3.1	7¼	very weak	tp to op	vitreous to resinous	neutral	black, blue, green, red, brown, white	hexagonal: slender prismatic; often 3-sided with curved faces	also needle-like, rosettes, massive or columnar	60, 70, 72, 73, 74, 75
Tremolite	$CaO \cdot 3MgO \cdot 4SiO_2(OH)$	3.2	5½	2 at 56^o (prominent)	tp to tl	vitreous	neutral	white to dark grey	monoclinic: long slender prisms; also fibrous	metamorphic amphibole, grades to actinolite	44, 45, 47, 52, 53
Triphylite	$Li(Fe,Mn)PO_4$	3.5	4¾	2 at 90^o (prominent)	tl	resinous to vitreous	neutral to greyish	greenish or bluish grey	orthorhombic: cleavable masses; crystals rare	shows brown or black surface alteration; grades to lithiophilite	71, 73, 74

Mineral	Approximate Composition	Approximate		Cleavage	Transparency tp=transparent tl=translucent op=opaque	Lustre	Streak	Colour	Crystalline form and general habit	Remarks	Page
		Specific Gravity	Hardness								
Uraninite	UO_2	9	5½	none normally seen	op	sub-metallic	brownish black	black or nearly so	isometric: massive, botryoidal; cubic or octahedral crystals rare	radioactive; very high specific gravity	71, 72
Wodginite	$(Ta,Sn,Mn,Ti,Fe,Nb)_{26}O_{32}$	7.4	6	none	op	sub-metallic	pale red-brown	black to brownish	monoclinic: prismatic-pyramidal; also skeletal-interstitial	a tantalum ore-mineral at Bernic Lake	71, 73
Zinnwaldite	$K(Li,Al,Fe)_3(Al,Si)_4O_{10}(OH,F)_2$	3.1	3¼	perfect micaceous	tp	vitreous and pearly	neutral	grey, brown	monoclinic: flakes, books, spherical aggregates	iron-lithia mica; grades to biotite	24, 72, 73, 74
Zoisite	$4CaO \cdot 3Al_2O_3 \cdot 6SiO_2 \cdot H_2O$	3.3	6½	1 perfect, 1 weak	tp to tl	vitreous	neutral	grey, white, greenish	orthorhombic: prismatic; often columnar-massive	metamorphic; crystals (rare) striated; compare clinozoisite	50, 52

Index Map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Seal River
Tadoule Lake
CHURCHILL
Reindeer Lake
CHURCHILL RIVER
Southern Indian Lake
LYNN LAKE
YORK FACTORY
Granville Lake
RIVER
NELSON
THOMPSON
Burntwood River
Fox River
Hayes River
Gods River
Sherridon
FLIN FLON
SNOW LAKE
Grass
Oxford Lake
Cross Lake
Gods Lake
Island Lake
THE PAS
Cedar Lake
Gunisao River
LAKE WINNIPEG
Poplar River
Berens River
Bloodvein River
LAKE WINNIPEGOSIS
Swan River
Dauphin
LAKE MANITOBA
BISSETT
WINNIPEG
ASSINIBOINE RIVER
Virden
BRANDON
Portage la Prairie
WINNIPEG
RED RIVER
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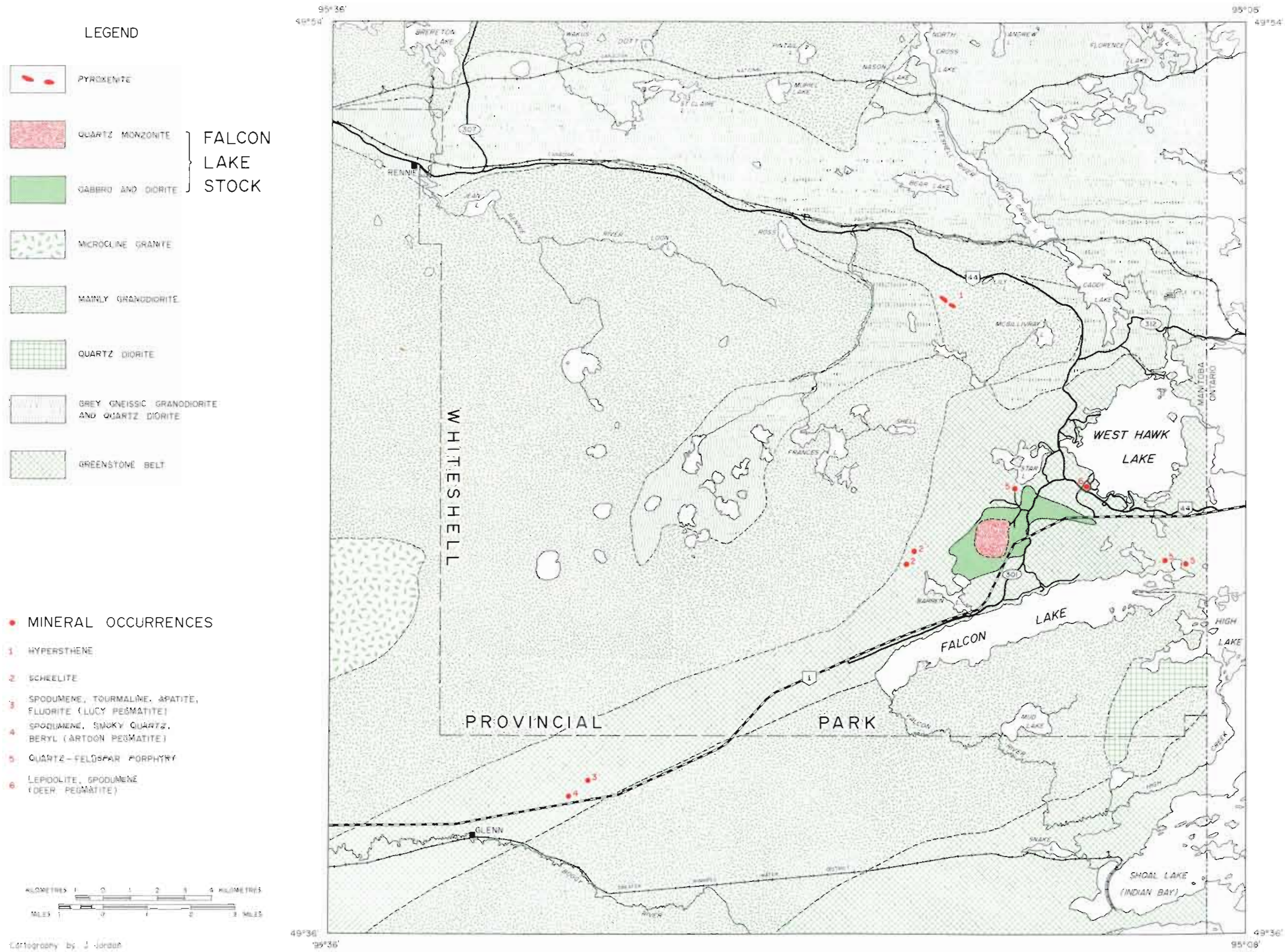
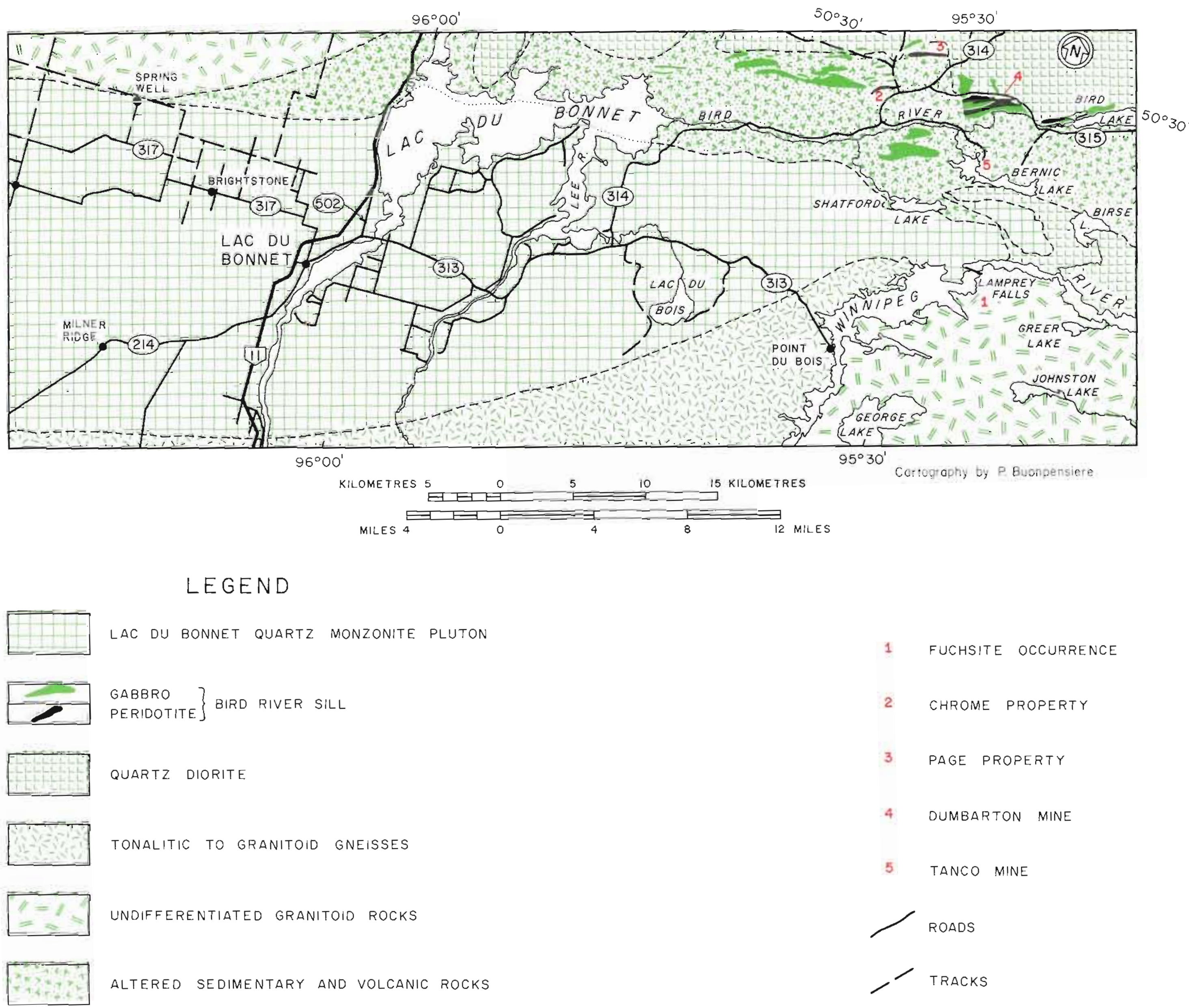
MILES

Whiteshell Park (South)

A

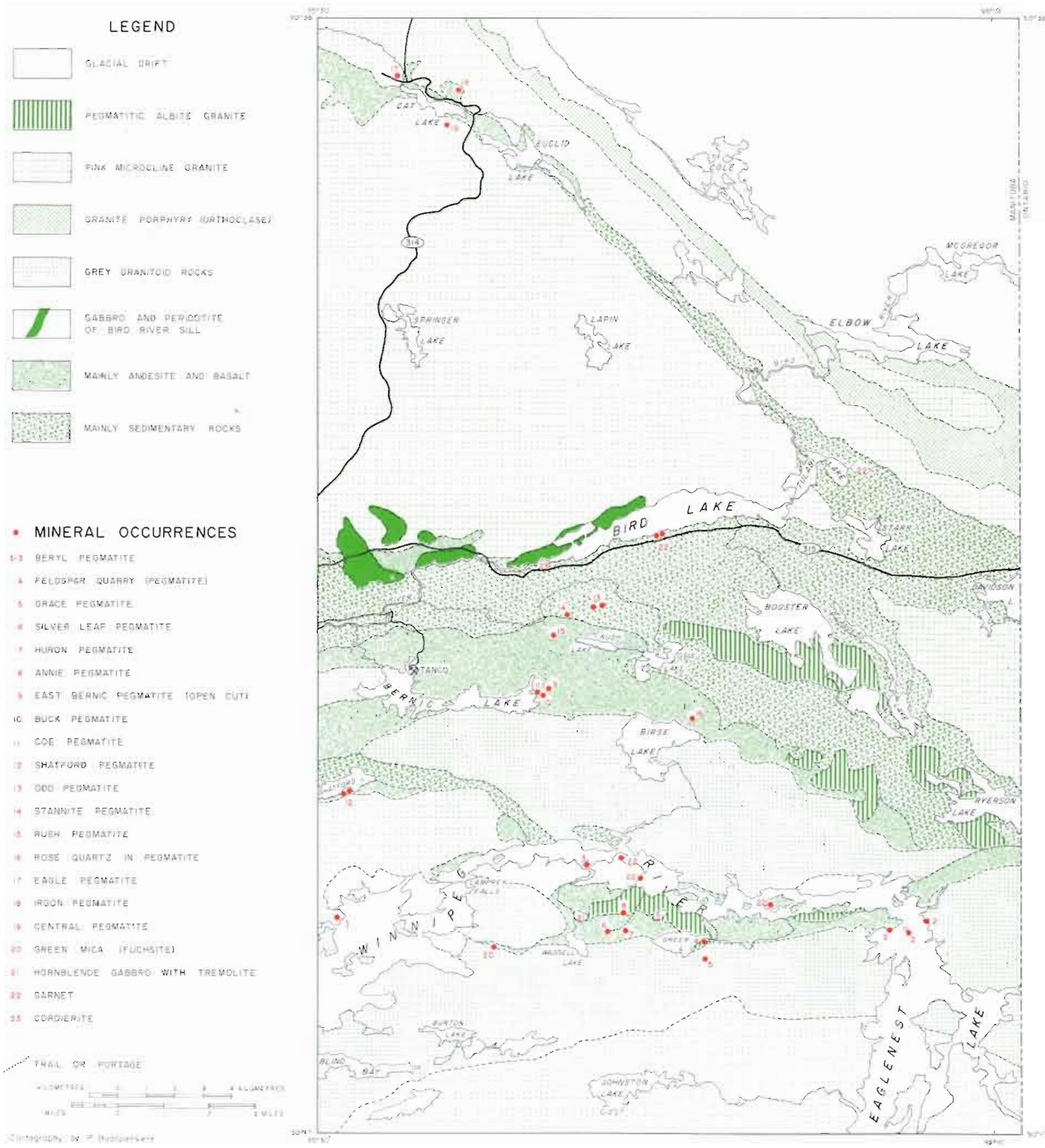


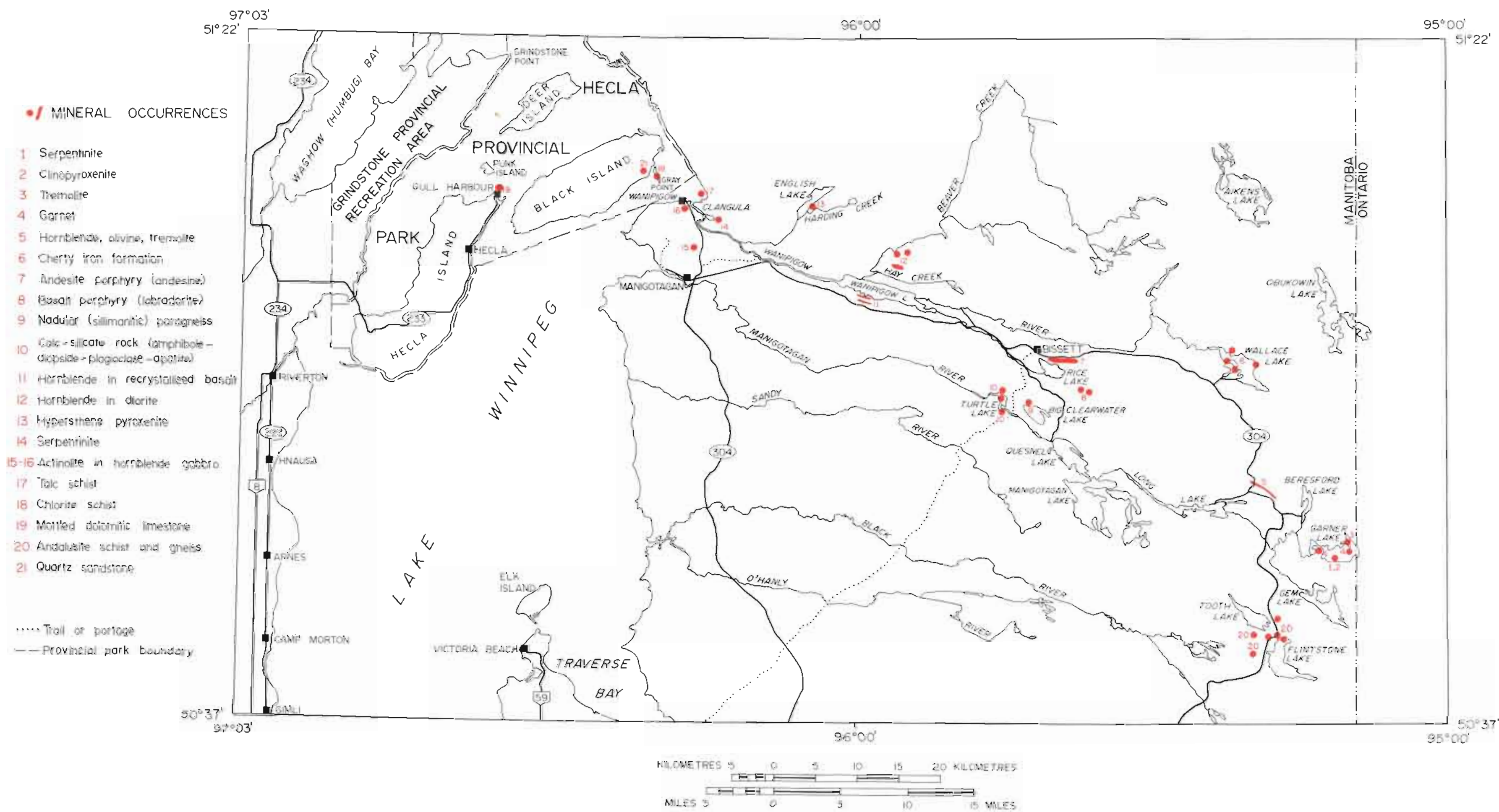


Lac du Bonnet - Bird Lake

Greer Lake - Cat Lake

C





Hecla Island - Garner Lake

D

Winnipeg - Interlake Region

LEGEND

- ACTIVE QUARRY (symbol: X)
- DISUSED QUARRY (symbol: X)

1 STEEP ROCK: LIMESTONE

2 FAULKNER: LIMESTONE

3 SPEARHILL: LIMESTONE

4 ROSEHILL: DOLOMITE

5 LILY BAY: LIMESTONE

6 BOWMAN: LIMESTONE

7 INWOOD: DOLOMITE

8 GUNTON: DOLOMITE

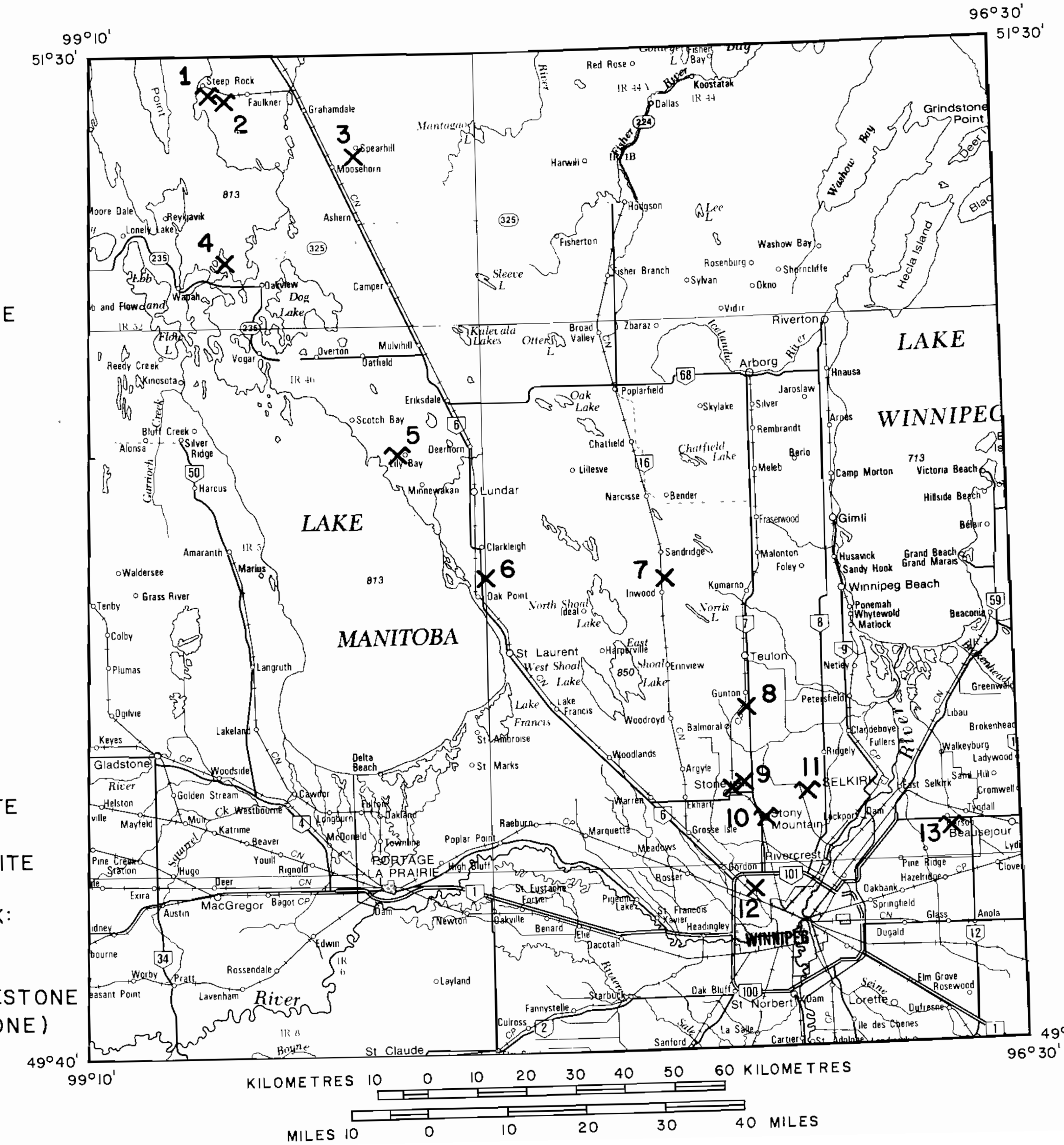
9 STONEWALL: DOLOMITE

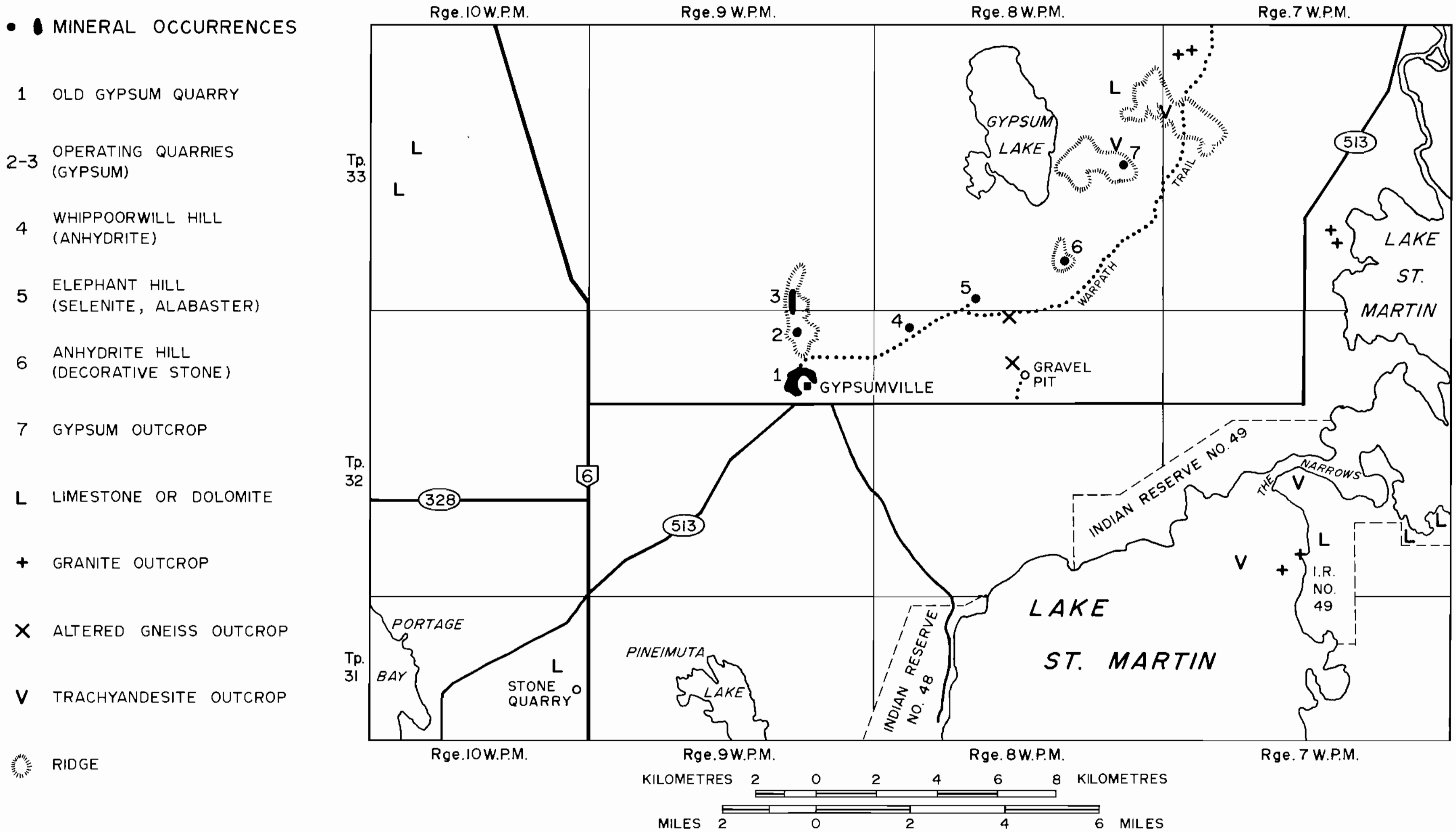
10 STONY MOUNTAIN: DOLOMITE

11 MULDER'S QUARRY: DOLOMITE

12 LITTLE MOUNTAIN PARK: DOLOMITE

13 GARSON: DOLOMITIC LIMESTONE (TYNDALL BUILDING-STONE)

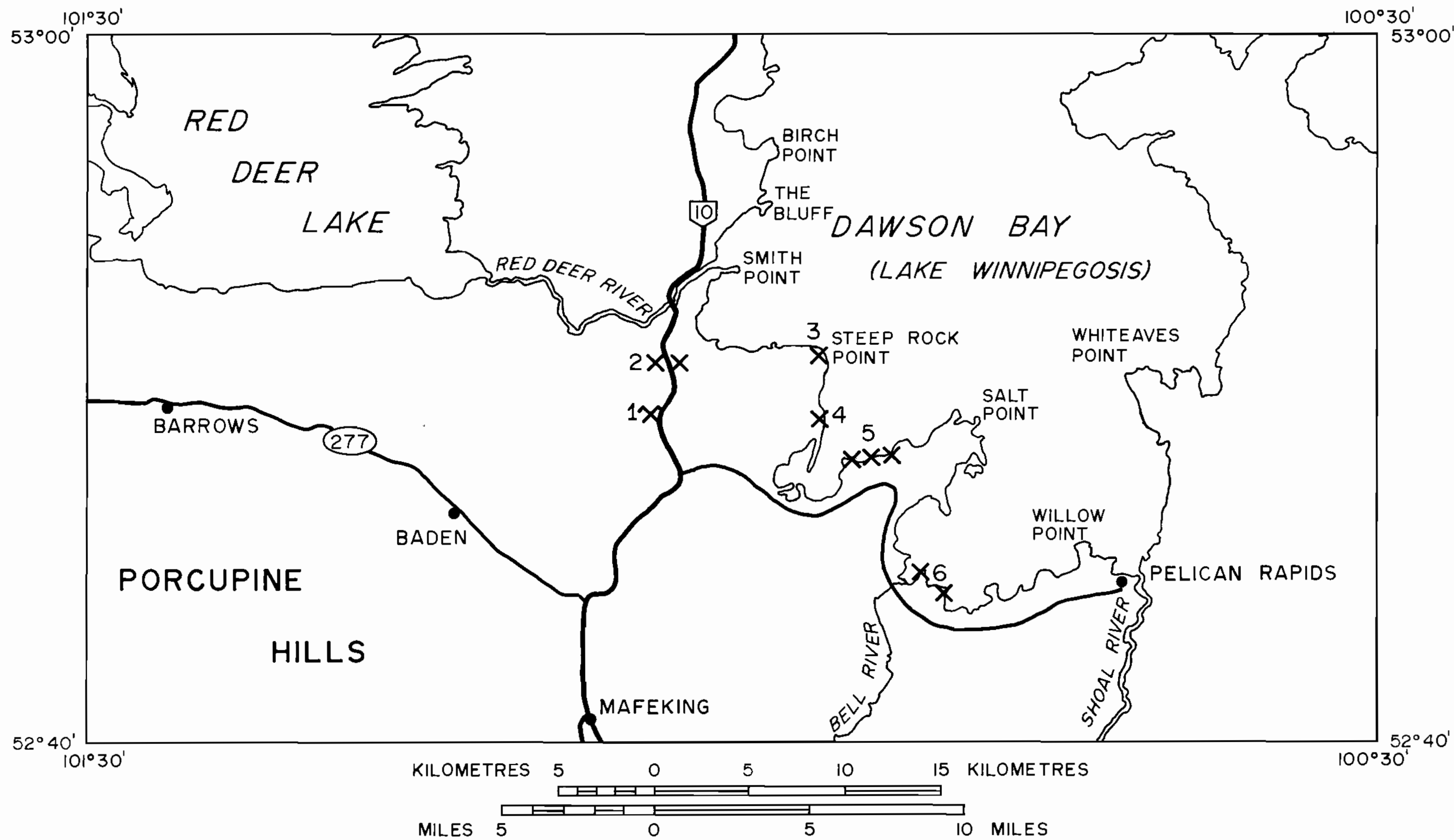




Gypsumville Area

F

Dawson Bay



MINERAL OCCURRENCES

1 LIMESTONE QUARRY (INLAND CEMENT INDUSTRIES LIMITED)

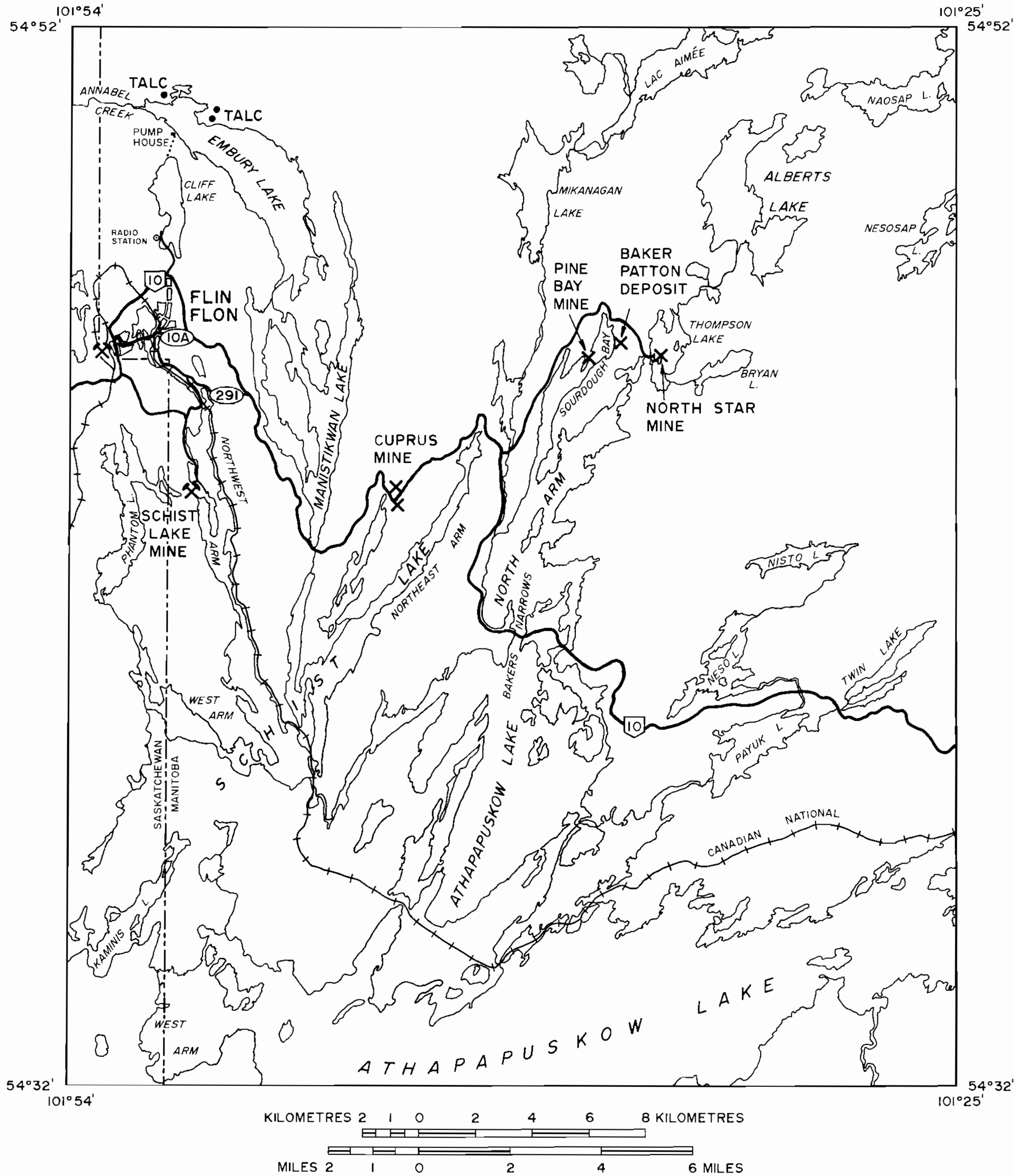
2 CALCITE IN LIMESTONE (ROAD-CUT)

3 RUGGED LIMESTONE CLIFFS

4 FOSSILIFEROUS LIMESTONE OUTCROPS

5 CALCITE IN CLIFFS OF LIMESTONE UNDERLAIN BY DOLOMITE

6 CALCITE IN LIMESTONE-SHALE CLIFFS

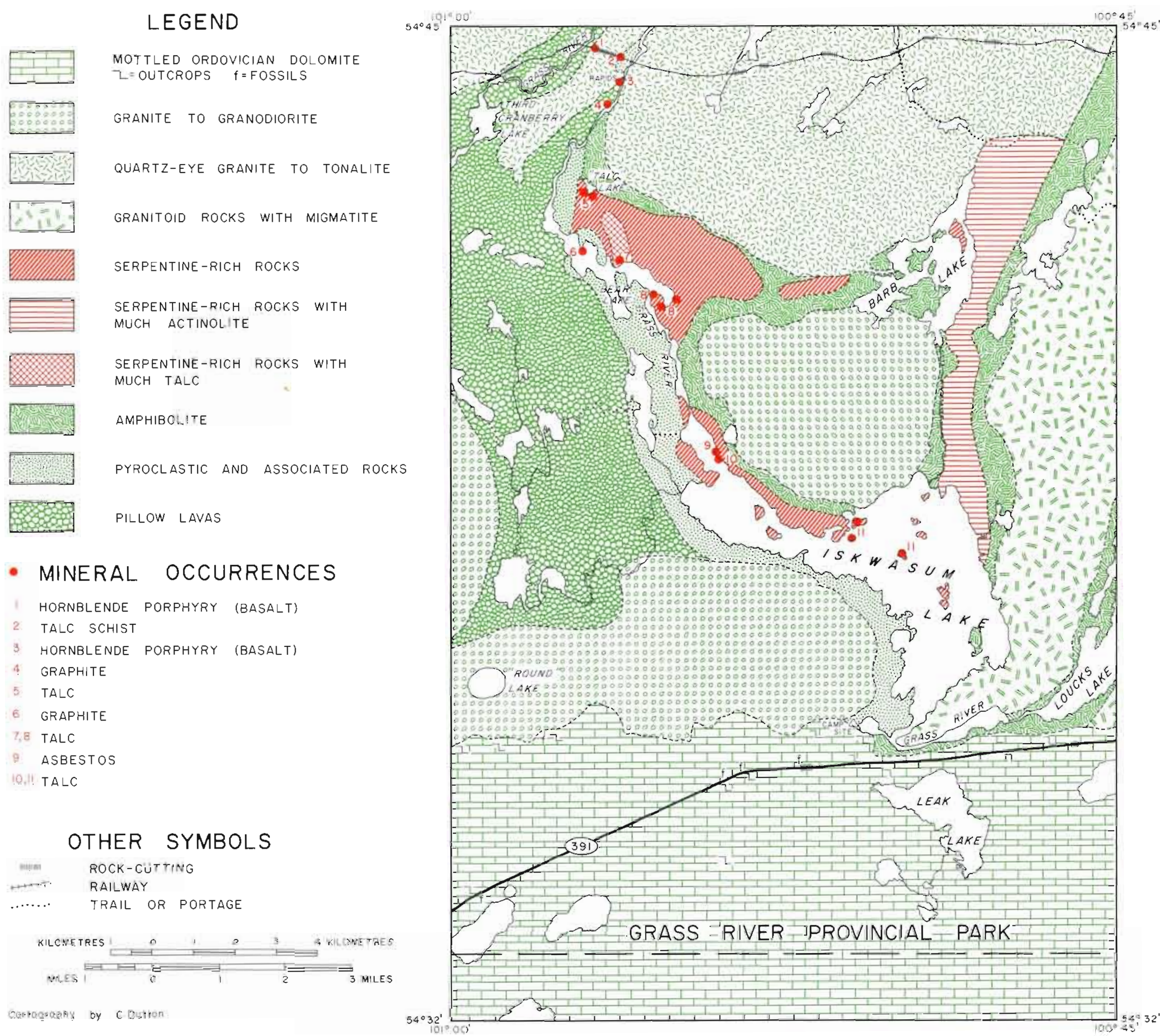


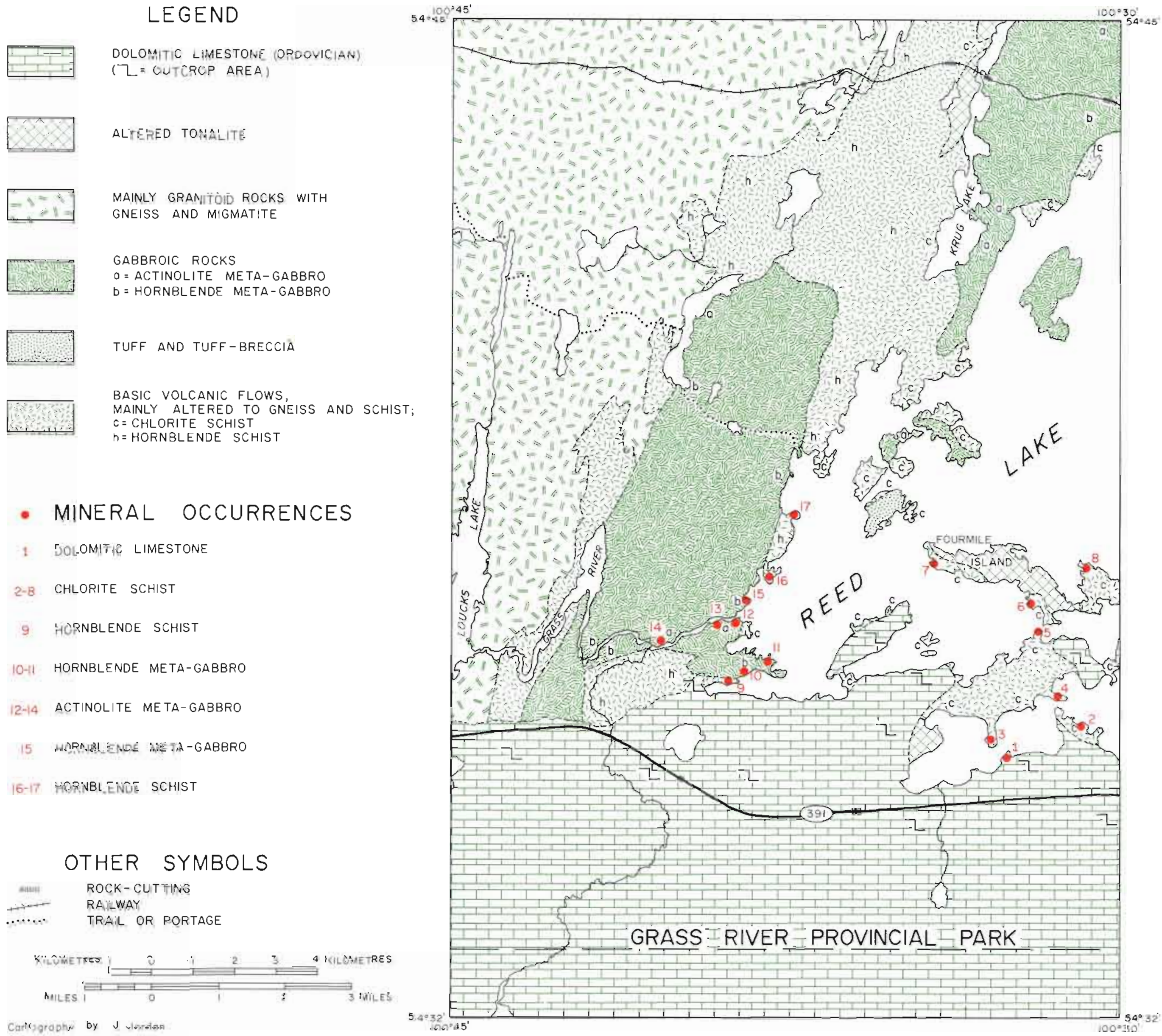
⚒ OPERATIONAL MINE (COPPER-ZINC) × OLD MINE DUMP • OUTCROP (TALC)

Flin Flon Area

H

Iskwasum Lake

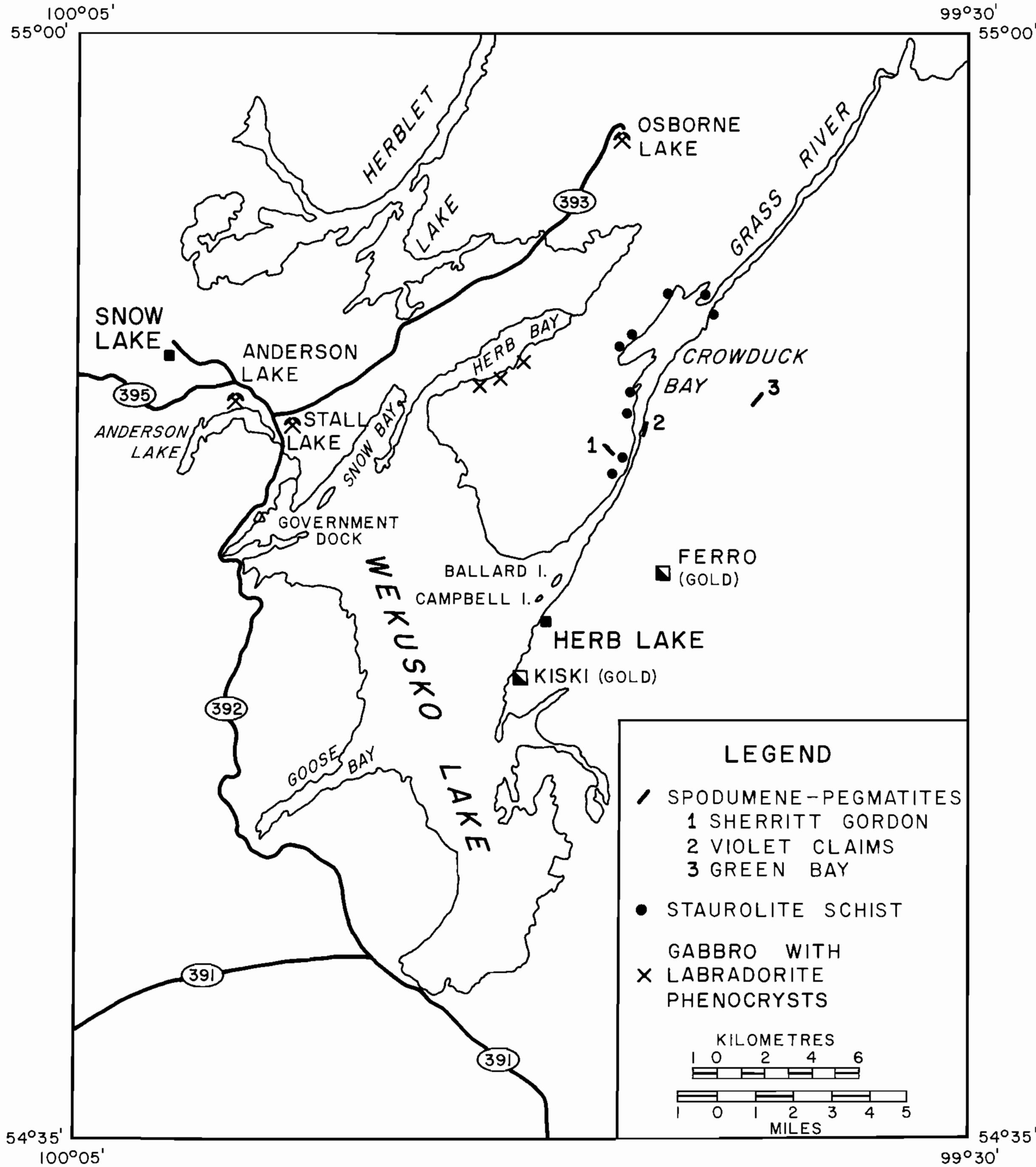


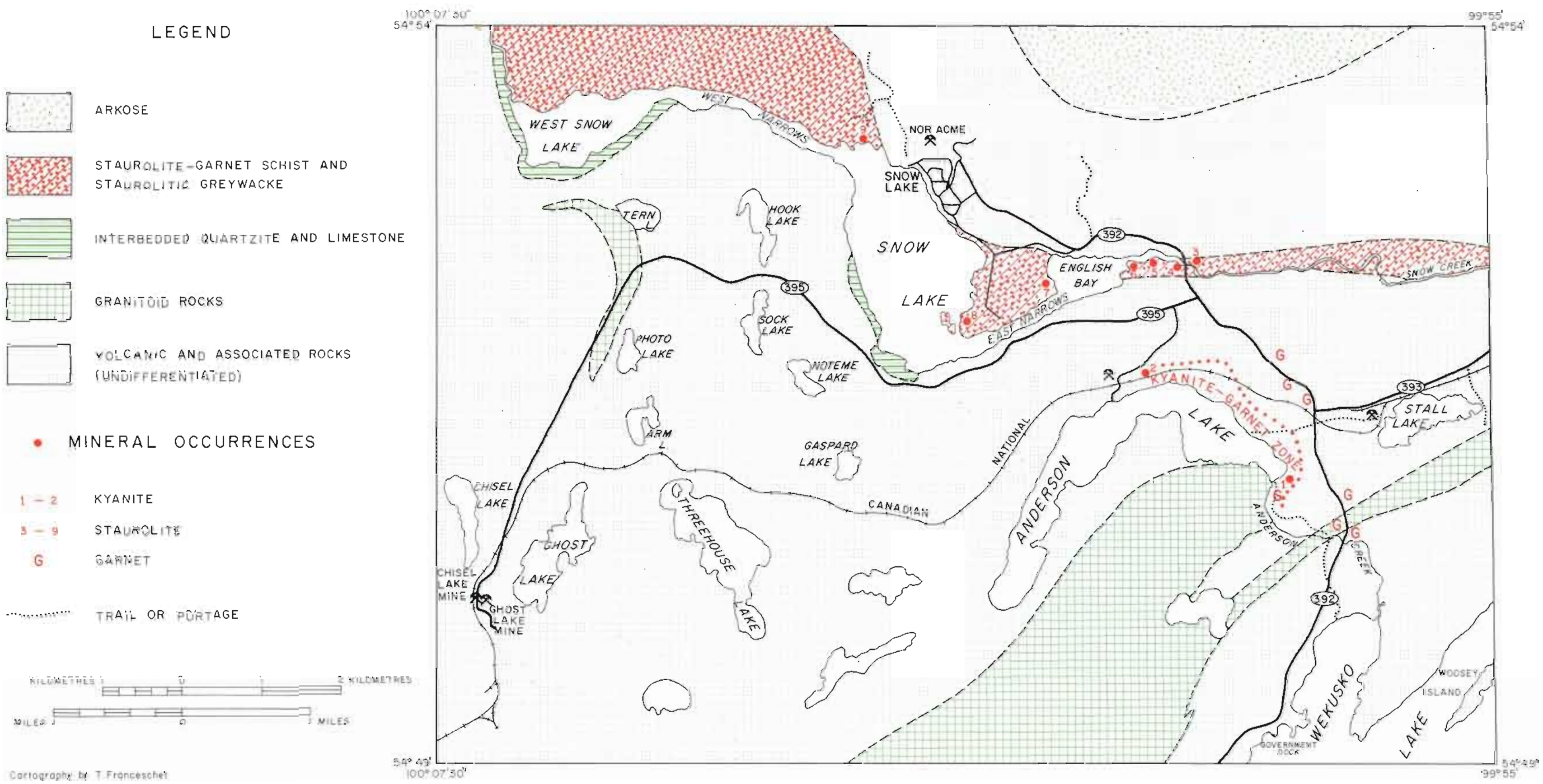


Reed Lake (West)

J

Wekusko Lake




LEGEND
ARKOSE
STAUROLITE-GARNET SCHIST AND STAUROLITIC GREYWACKE
INTERBEDDED QUARTZITE AND LIMESTONE
GRANITOID ROCKS
VOLCANIC AND ASSOCIATED ROCKS (UNDIFFERENTIATED)
MINERAL OCCURRENCES
1 — 2 KYANITE
3 — 9 STAUROLITE
G GARNET
TRAIL OR PORTAGE
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MILES 1 0 1 MILES
Cartography by T. Franceschet
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WEST SNOW LAKE
WEST NARROWS
NOR ACME
SNOW LAKE
SNOW LAKE
ENGLISH BAY
EAST NARROWS
SNOW CREEK
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HOOK LAKE
SOCK LAKE
PHOTO LAKE
NOTEME LAKE
ARM L
GASPARD LAKE
CHISEL LAKE
GHOST LAKE
THREEHOUSE LAKE
CHISEL LAKE MINE
GHOST LAKE MINE
CANADIAN NATIONAL
ANDERSON LAKE
KYANITE-GARNET ZONE
ANDERSON CREEK
STALL LAKE
WEKUSKO LAKE
WOOSEY ISLAND
GOVERNMENT DOCK
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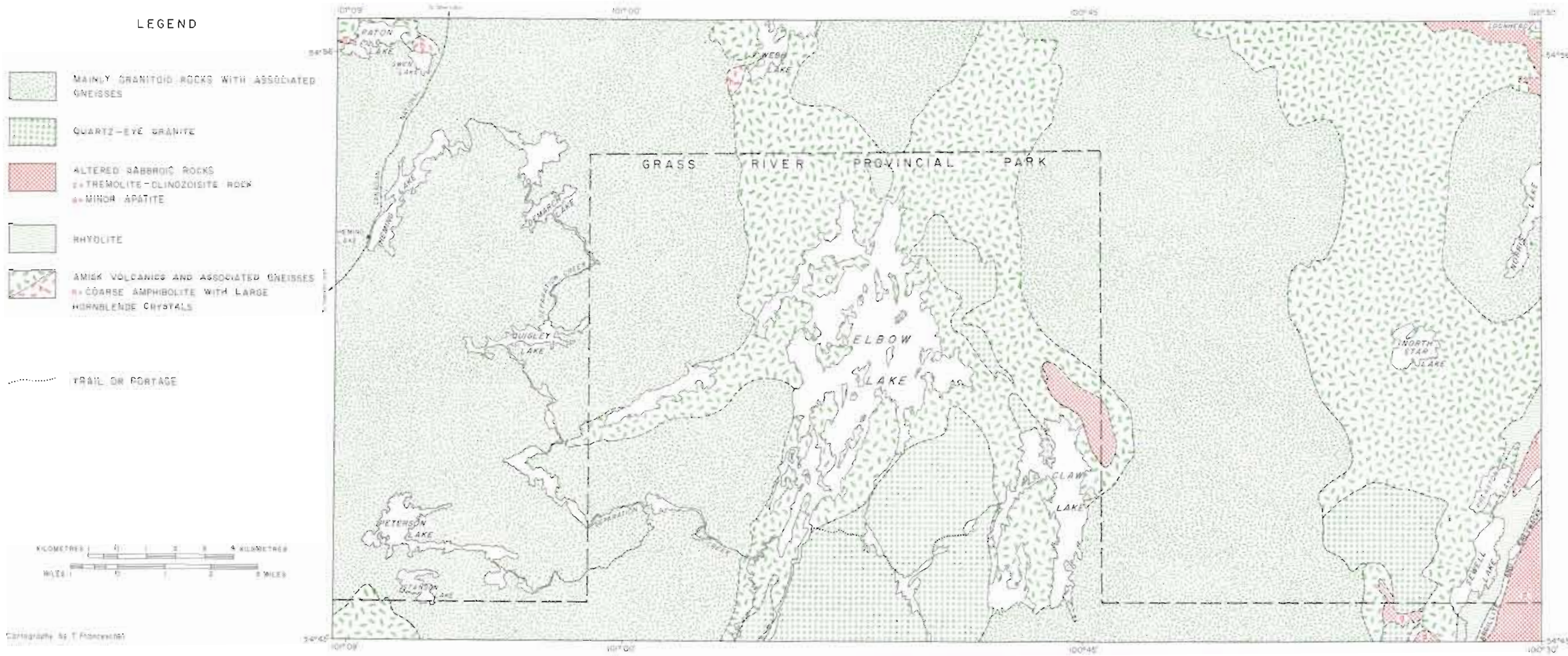
393
395

Snow Lake

L

Elbow Lake


LEGEND
MAINLY GRANITOID ROCKS WITH ASSOCIATED GNEISSES
QUARTZ-EYE GRANITE
ALTERED GABBROIC ROCKS
TREMOLITE-CLINOZOISITE ROCK
MINOR APATITE
RHYOLITE
AMISK VOLCANICS AND ASSOCIATED GNEISSES
COARSE AMPHIBOLITE WITH LARGE HORNBLENDE CRYSTALS
TRAIL OR PORTAGE
GRASS RIVER PROVINCIAL PARK
ELBOW LAKE
CLAW LAKE
NORTH STAR LAKE
PATON LAKE
QUIGLEY LAKE
PETERSON LAKE
100°45'
101°00'
54°45'
54°56'

LEGEND

- GRANITE AND ASSOCIATED ROCKS
- BASIC INTRUSIONS AND COUNTRY ROCKS
- STAUROLITE SCHIST AND GNEISS ± GARNET ± SILLIMANITE
- MAINLY GNEISSES (UNDIFFERENTIATED) AND SUBORDINATE SCHISTS
- ARGILLITE, GREYWACKE AND ASSOCIATED ROCKS
- VOLCANIC AND ASSOCIATED ROCKS

MINERAL OCCURRENCES

- 1 to 2 STAUROLITE AND GARNET
- 3 STAUROLITE
- 4 GARNET
- 5 SILLIMANITE

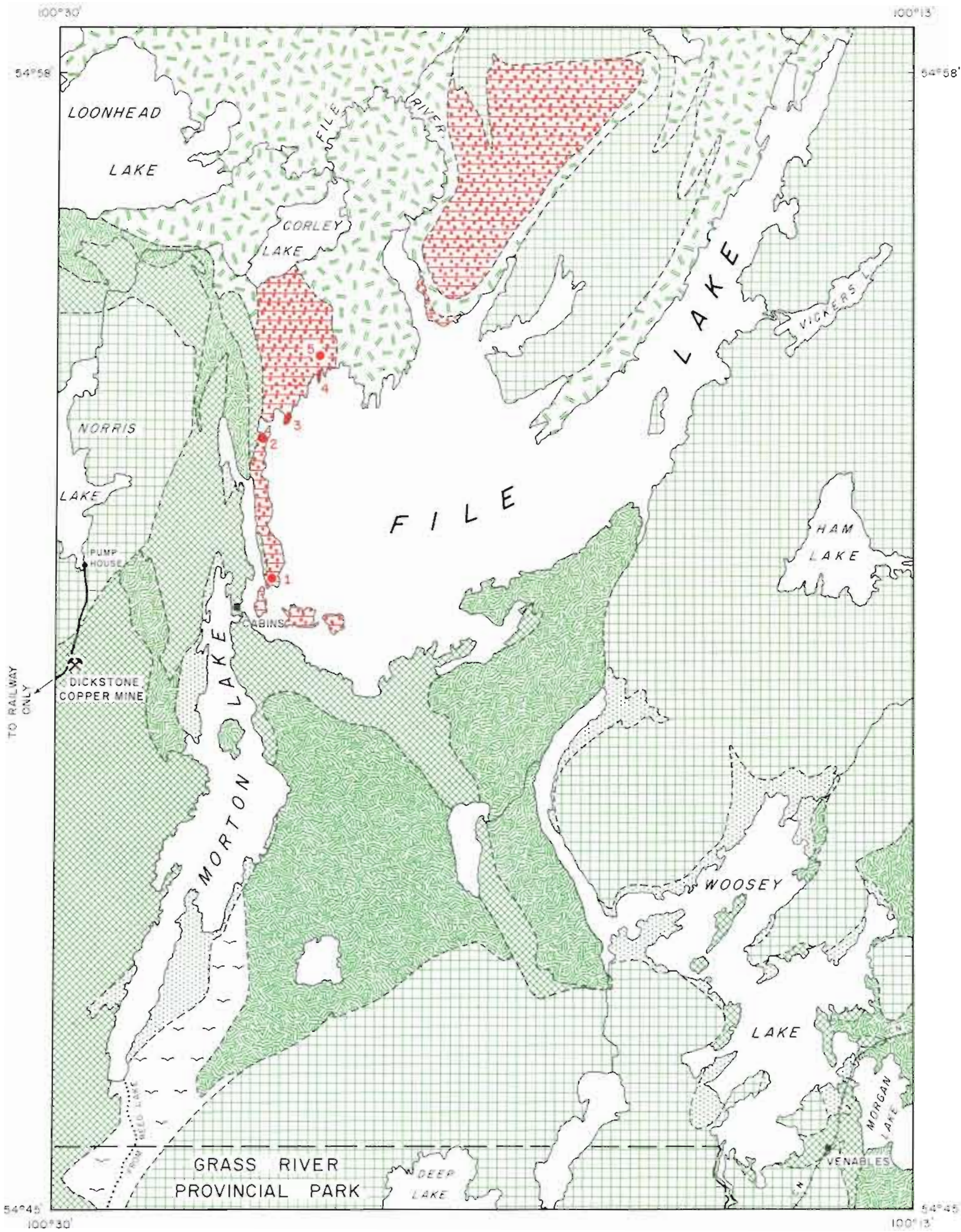
TRAIL OR PORTAGE

DRIFT

KILOMETRES 1 0 1 2 3 4 KILOMETRES

MILES 1 0 1 2 3 MILES

Cartography by P. Buonpensiere

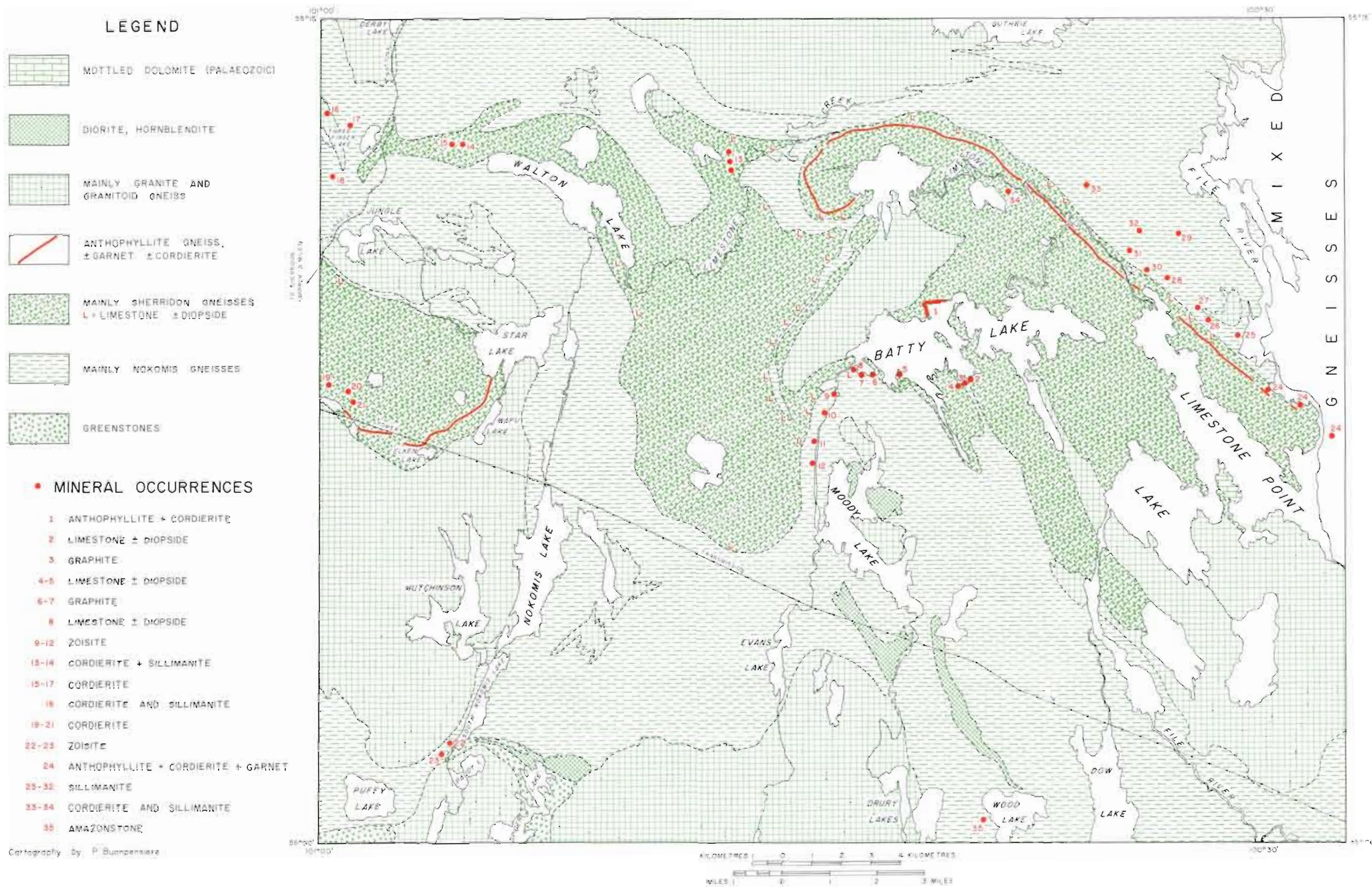


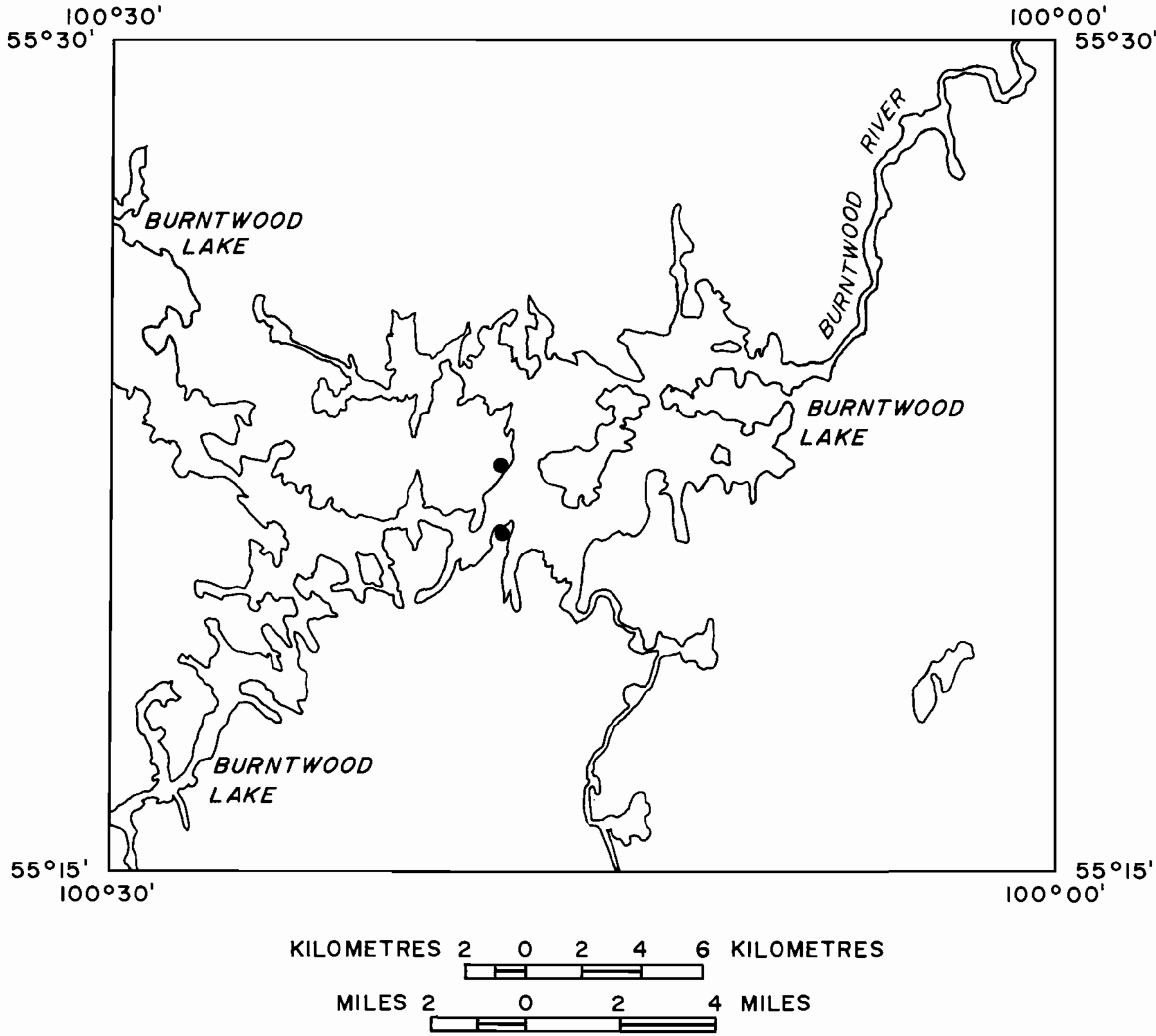
File Lake

N

Batty Lake

O


LEGEND
MOTTLED DOLOMITE (PALAEOZOIC)
DIORITE, HORNBLENDITE
MAINLY GRANITE AND GRANITOID GNEISS
ANTHOPHYLLITE GNEISS, ± GARNET ± CORDIERITE
MAINLY SHERRIDON GNEISSES L = LIMESTONE ± DIOPSIDE
MAINLY NOKOMIS GNEISSES
GREENSTONES
MINERAL OCCURRENCES
1 ANTHOPHYLLITE + CORDIERITE
2 LIMESTONE ± DIOPSIDE
3 GRAPHITE
4-5 LIMESTONE ± DIOPSIDE
6-7 GRAPHITE
8 LIMESTONE ± DIOPSIDE
9-12 ZOISITE
13-14 CORDIERITE + SILLIMANITE
15-17 CORDIERITE
18 CORDIERITE AND SILLIMANITE
19-21 CORDIERITE
22-23 ZOISITE
24 ANTHOPHYLLITE + CORDIERITE + GARNET
25-32 SILLIMANITE
33-34 CORDIERITE AND SILLIMANITE
35 AMAZONSTONE
Cartography by P. Buonpensiere
MIXED GNEISSES
BATTY LAKE
LIMESTONE POINT LAKE
WALTON LAKE
STAR LAKE
NOKOMIS LAKE
MOODY LAKE
EVANS LAKE
HUTCHINSON LAKE
PUFFY LAKE
DRURY LAKES
WOOD LAKE
DOW LAKE
FILE RIVER
JUNGLE LAKE
KILOMETRES 0 1 2 3 4 KILOMETRES
MILES 1 0 1 2 3 MILES



• COARSE CORDIERITE AND SILLIMANITE IN GARNETIFEROUS MIGMATITIC GREYWACKE-GNEISS

Burntwood Lake

P

Paint Lake - Cuthbert Lake

• MINERAL OCCURRENCES

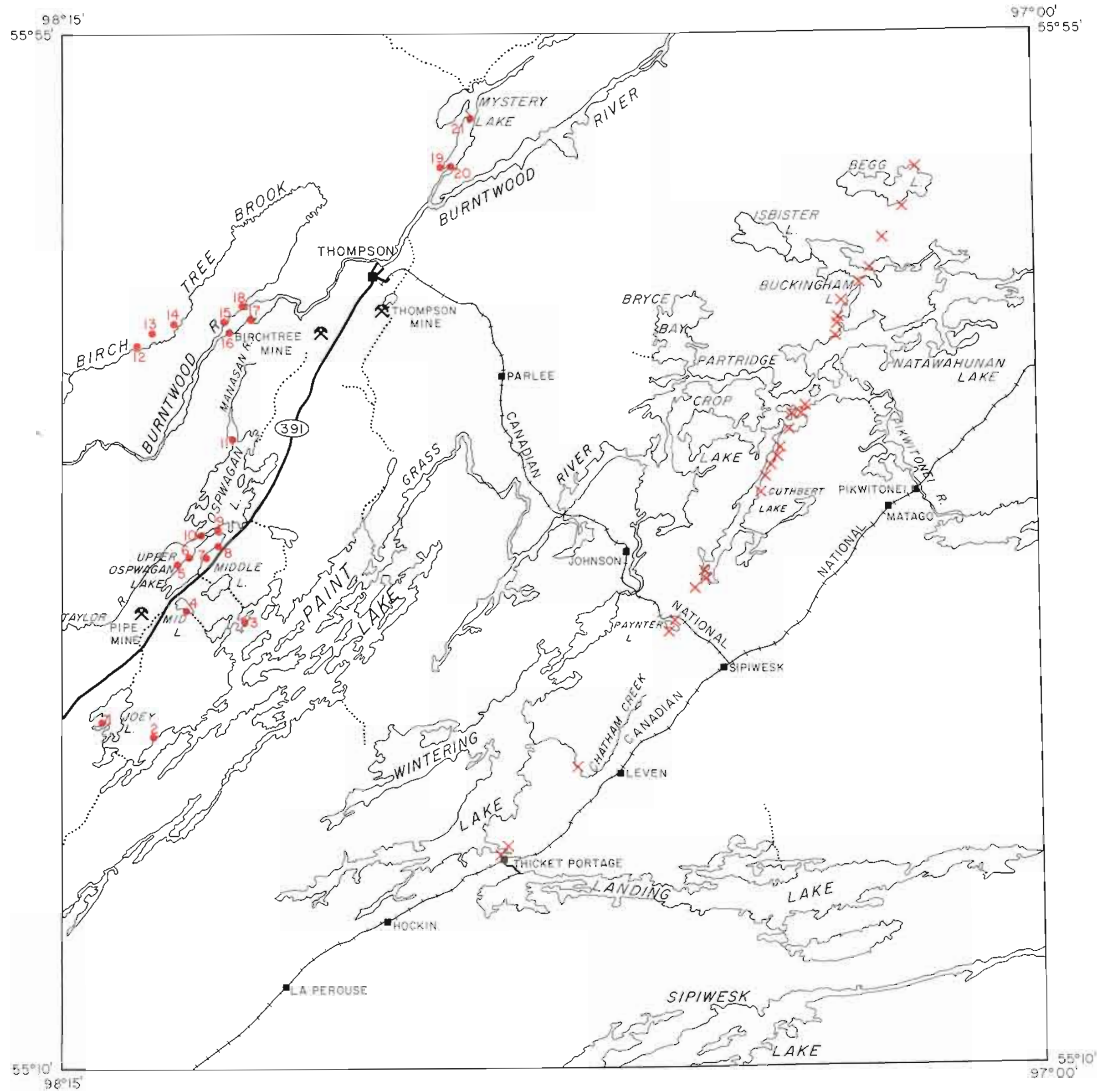
1 SKARN
2–3 CORDIERITE–GARNET–HYPERSTHENE ROCK
4 GARNET–BRONZITE GNEISS
5 OLIVINE IN PICRITE
6 TREMOLITE IN ALTERED PICRITE
7–10 OLIVINE IN PICRITE
11 AUGITE PYROXENITE
12–18 CORDIERITE–GARNET PARAGNEISS
19–20 SERPENTINITE
21 ACTINOLITE SCHIST

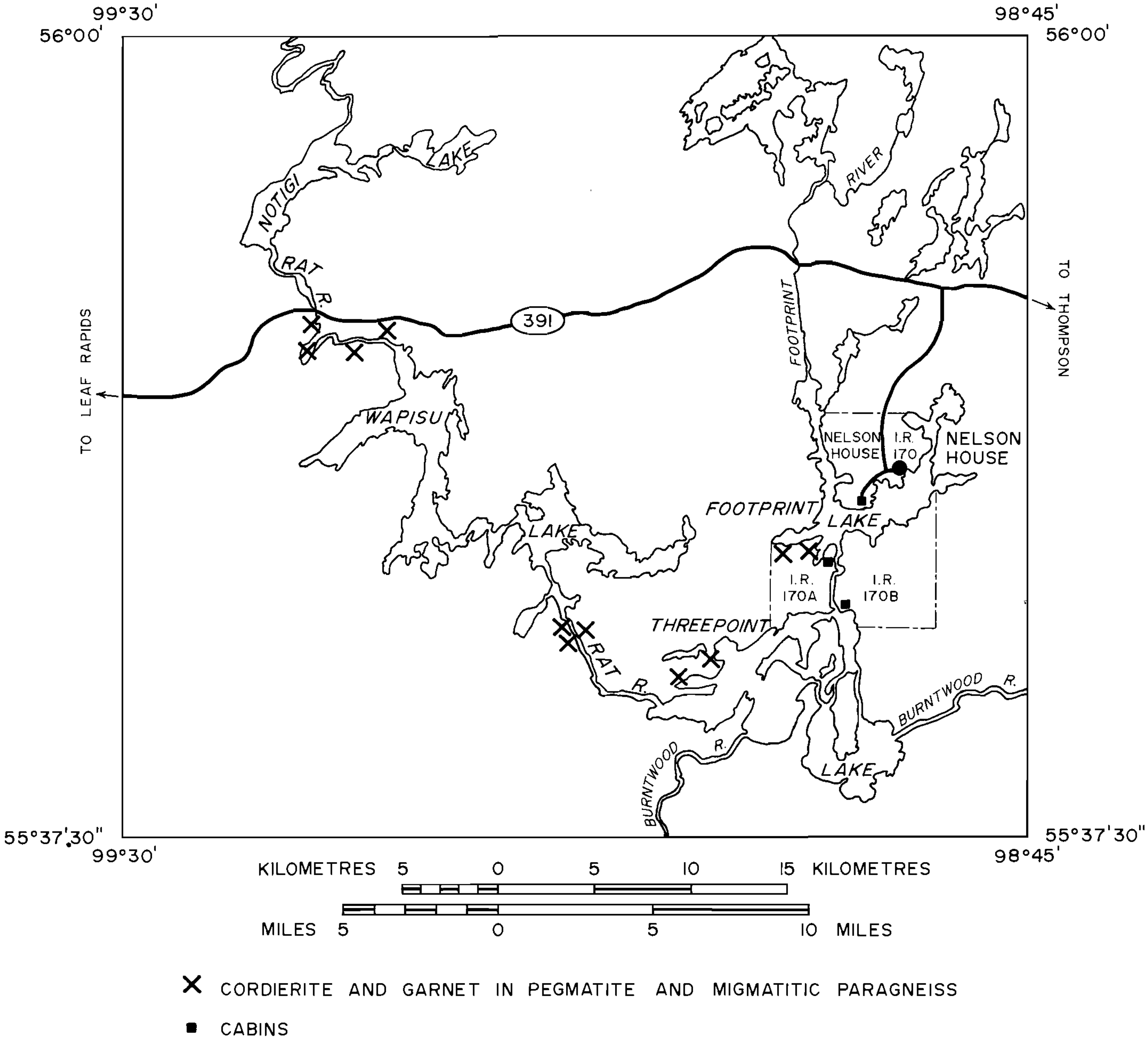
× CUTHBERT LAKE DYKE–OUTCROPS (GABBRO–PERIDOTITE)

.... TRAIL OR PORTAGE

KILOMETRES 5 0 5 10 15 KILOMETRES
MILES 5 0 5 10 MILES

Cartography by T. Franceschet

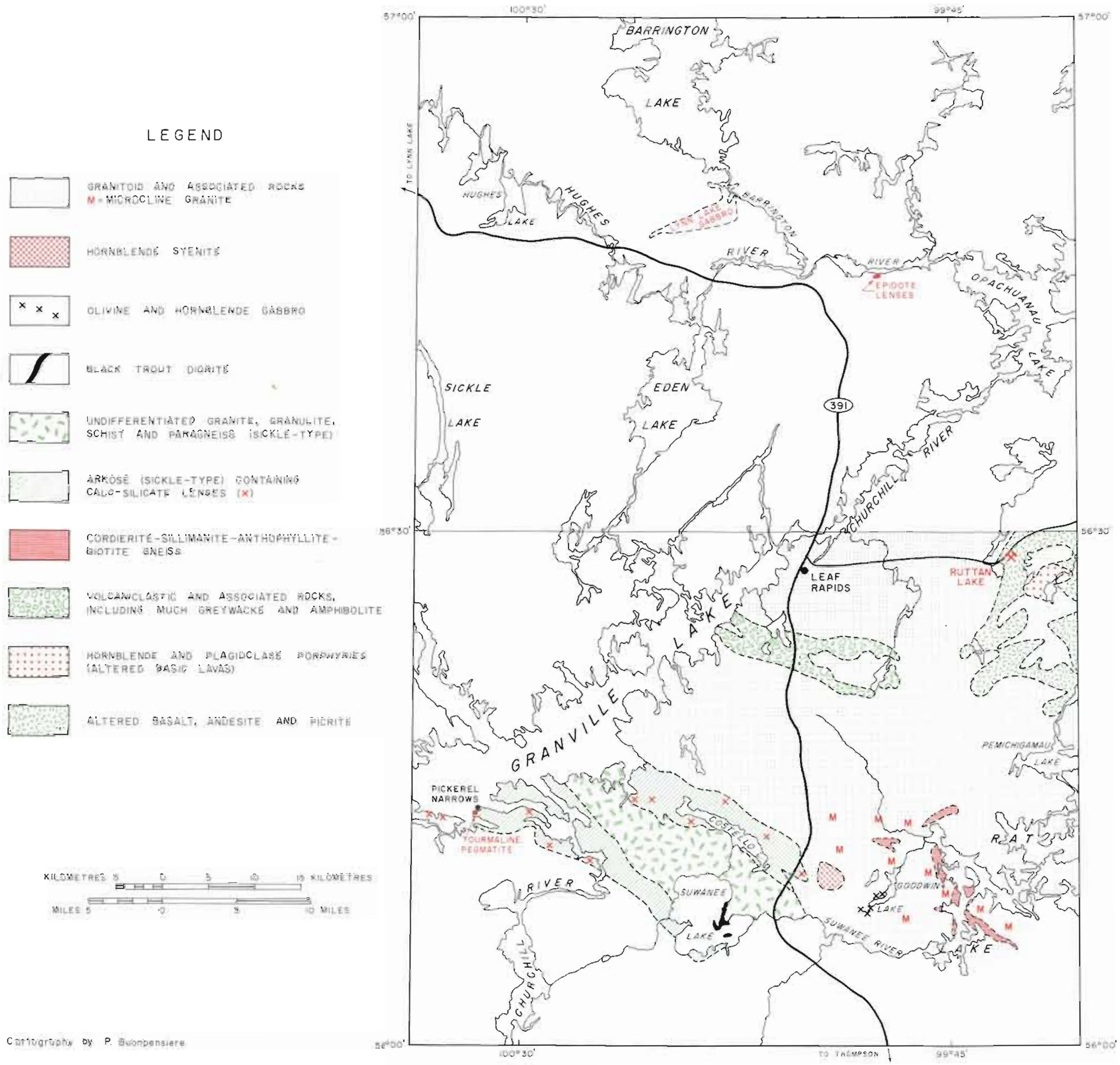


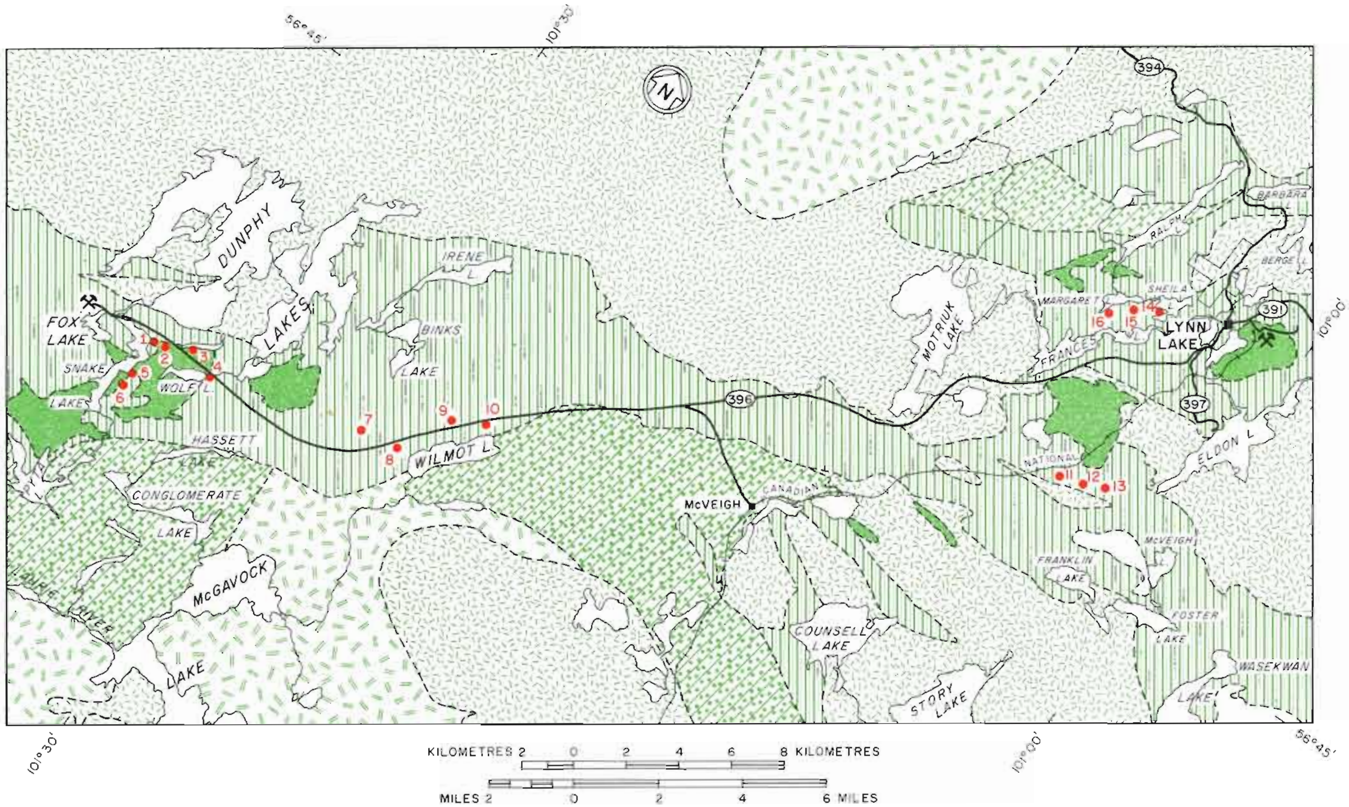


Nelson House Area

R

Rat Lake - Granville Lake - Ruttan Lake





LEGEND

GRANITIC AND ASSOCIATED ROCKS

GNEISSES (KISSEYNEW)

ARKOSE, QUARTZITE, SCHIST, CONGLOMERATE (SICKLE)

LYNN LAKE GABBRO AND RELATED ROCKS

BASALT, TUFF, GREYWACKE AND ASSOCIATED ROCKS (WASEKWAN)

• MINERAL OCCURRENCES

1-4 TREMOLITE-TALC ROCK

5-6 GARNET-STAUROLITE GNEISS

7-10 GARNET GNEISS ± STAUROLITE ± SILLIMANITE

11-13 EPIDOTE IN MAFIC TUFF

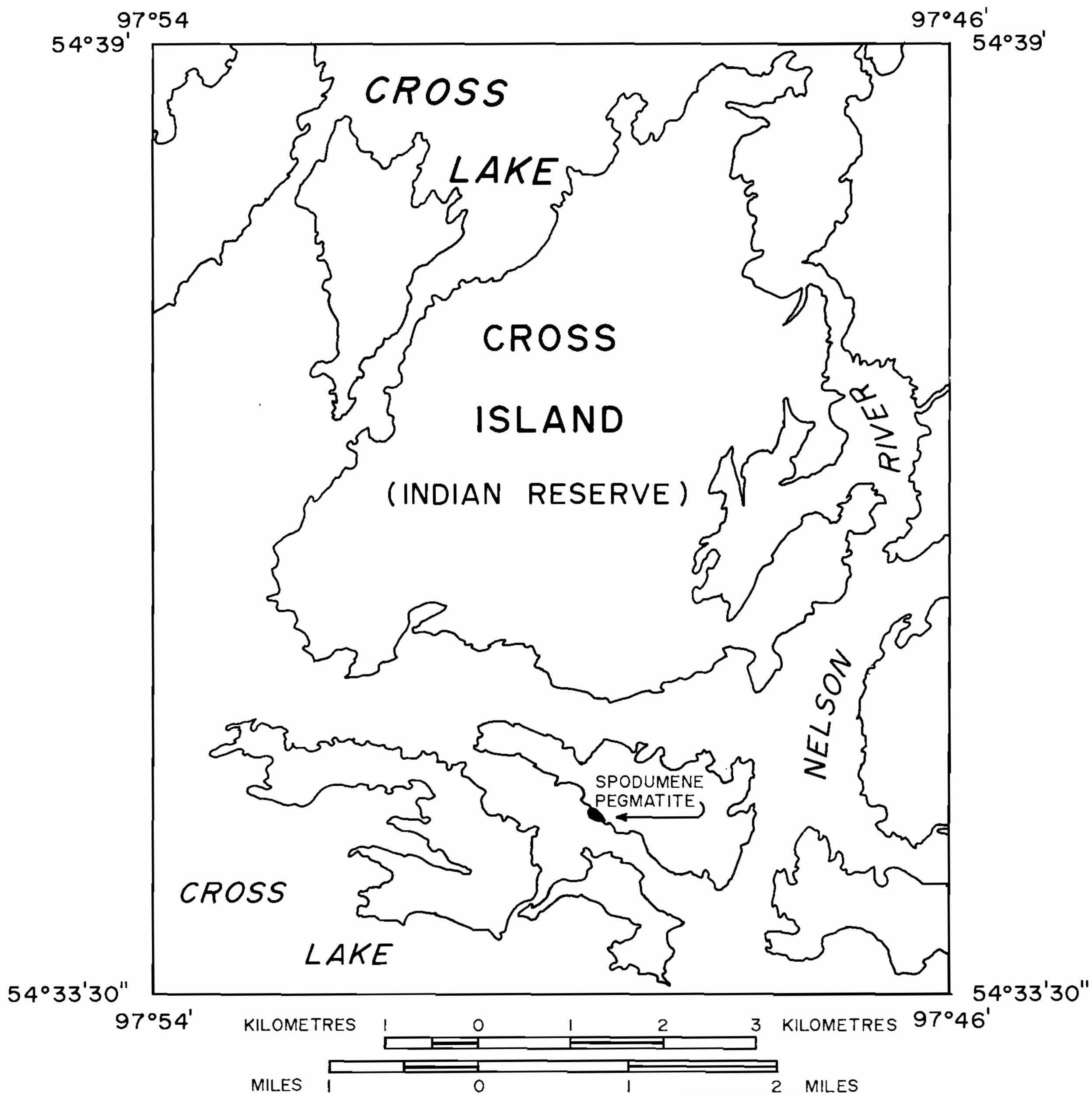
14-16 GARNET IN AMPHIBOLE-CARBONATE ROCK

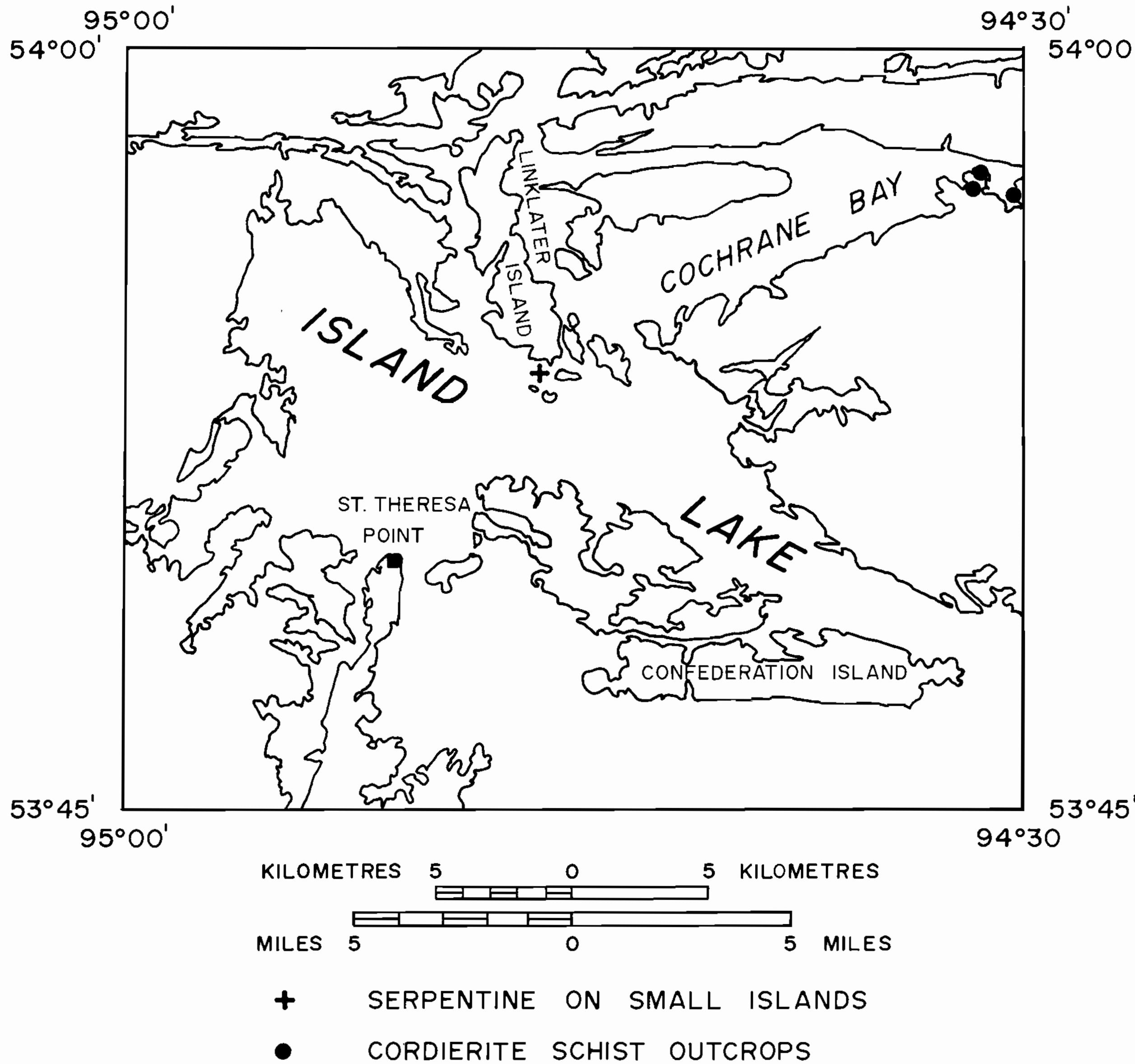
Cartography by P. Buonpensiere

Lynn Lake - Fox Lake

T

Cross Island

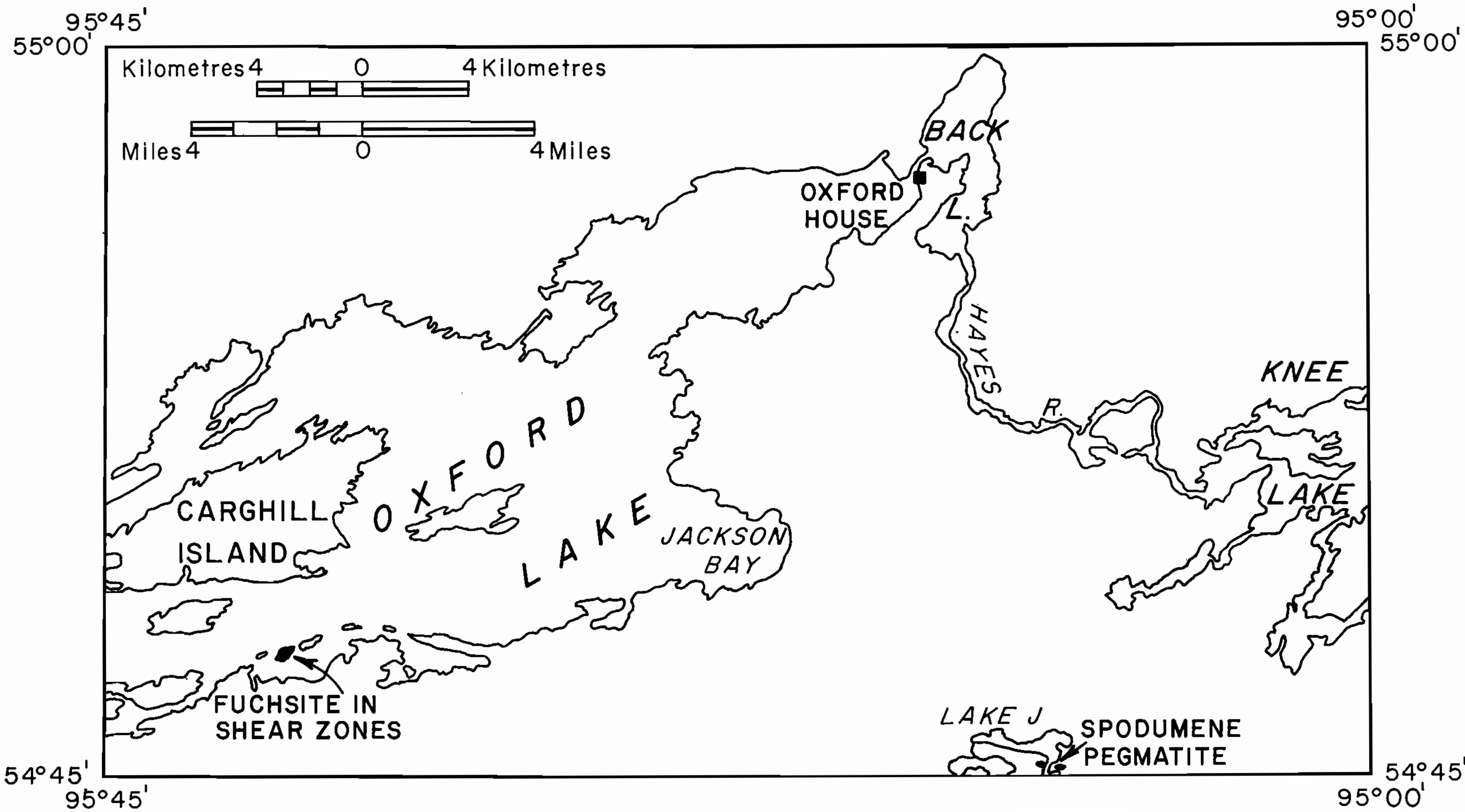


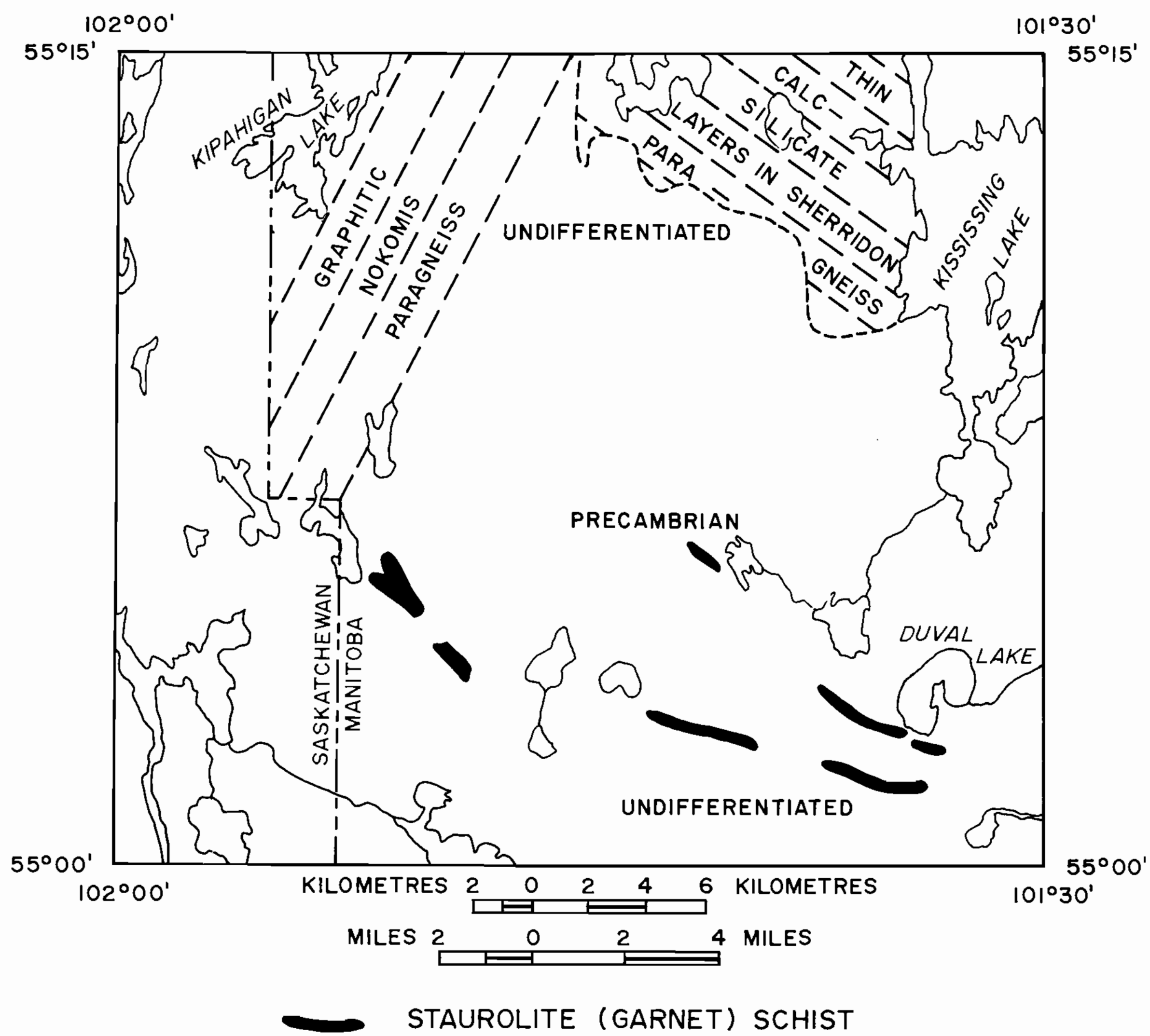


Island Lake (West)

V

Oxford Lake - Knee Lake

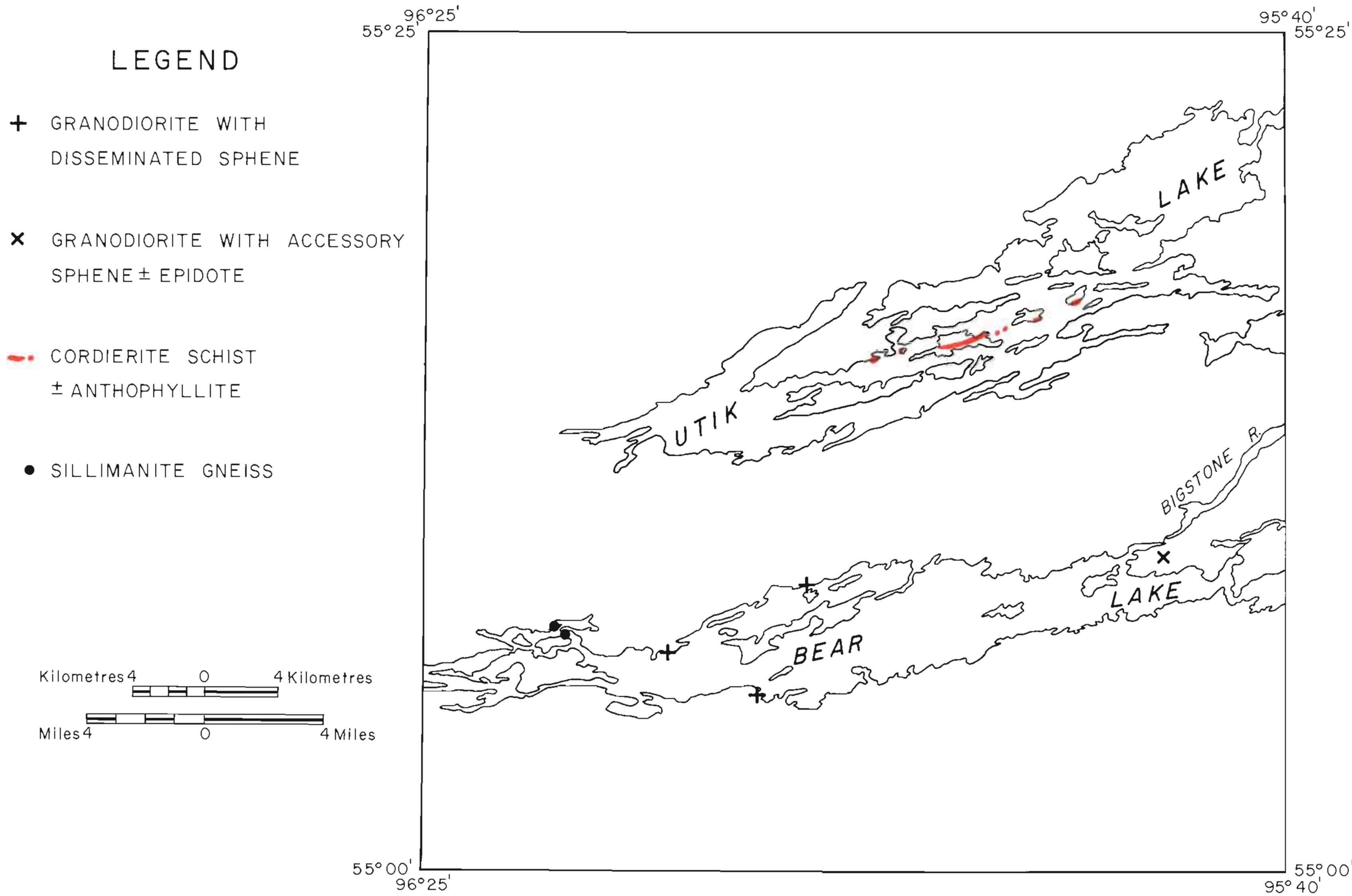


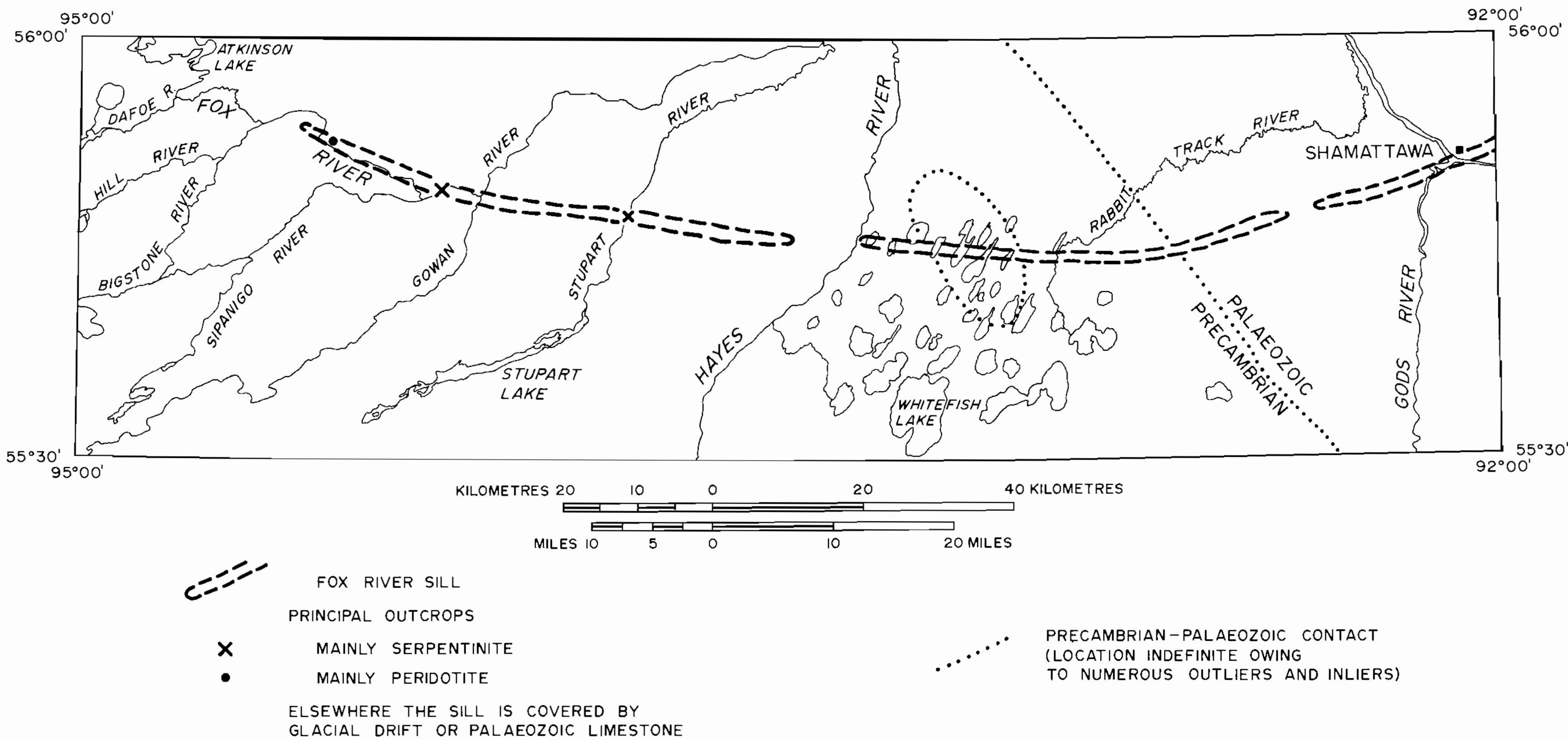


West of Kississing Lake

X

Bear Lake - Utik Lake




95°00'
56°00'
92°00'
56°00'
55°30'
95°00'
55°30'
92°00'
ATKINSON LAKE
DAFOE R.
FOX
RIVER
HILL RIVER
RIVER
BIGSTONE
SIPANIGO RIVER
GOWAN RIVER
RIVER
STUPART
STUPART LAKE
HAYES
RIVER
WHITEFISH LAKE
RABBIT
TRACK RIVER
SHAMATTAWA
PALAEOZOIC
PRECAMBRIAN
GODS RIVER
KILOMETRES 20 10 0 20 40 KILOMETRES
MILES 10 5 0 10 20 MILES
FOX RIVER SILL
PRINCIPAL OUTCROPS
MAINLY SERPENTINITE
MAINLY PERIDOTITE
ELSEWHERE THE SILL IS COVERED BY
GLACIAL DRIFT OR PALAEOZOIC LIMESTONE
PRECAMBRIAN–PALAEOZOIC CONTACT
(LOCATION INDEFINITE OWING
TO NUMEROUS OUTLIERS AND INLIERS)

Fox River

Z