PROVINCE OF MANITOBA

DEPARTMENT OF MINES AND NATURAL RESOURCES

HON. C. H. WITNEY
Minister

STUART ANDERSON
Deputy Minister

MINES BRANCH

J. S. RICHARDS
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PUBLICATION 60-4

GEOLOGY

of the

THOMPSON-MOAK LAKE AREA

11, 12, 13, 14 of 63P

CROSS LAKE MINING DIVISION

by

J. M. PATTERSON

Winnipeg, 1963

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CHAPTER I

INTRODUCTION

GENERAL STATEMENT

As a result of the discovery of the Thompson orebody by The International Nickel Company of Canada Limited in 1956, the Thompson-Moak Lake area has emerged as one of the outstanding mineral districts of Canada. Thompson, which produced about 100 million pounds of nickel in its first year of operation, 1962, is the second largest nickel operation in the world, exceeded only by Sudbury. It holds the further distinction of being the only operation where all stages of production, from mining of the ore to refining of the nickel, are carried out at a single plant site.

The discovery of the Thompson deposit climaxed ten years of exploration by International Nickel and the expenditure of some ten million dollars on geological mapping, geophysical surveys, and diamond drilling, as a result of which nickel deposits at Moak Lake and Mystery Lake were also outlined.

Bringing the Thompson mine into production required construction of a railway from Sipiwesk to Thompson, a hydro-electric plant at Kelsey, laying out of a complete new townsite along the Burntwood River and, of course, construction of a mining plant, mill and refinery, involving a total expenditure of about $185,000,000. Output of refined nickel commenced in June, 1961.

The International Nickel Company of Canada Limited commenced exploration around Setting Lake in 1946 and by 1947 had discovered a sulphide-bearing peridotite at the northeast end of the lake. In 1950, the company optioned claims at Mystery Lake which had been staked by Mr Harry Howell and the late Walter Johnson. By 1953 a large body of nickel-bearing serpentinite had been outlined by drilling. In 1955 an exploration shaft was sunk on a large low-grade nickel deposit in serpentinite at Moak Lake. This deposit carries disseminated nickel-bearing sulphides. Following the discovery of the Thompson deposit, the company announced plans to bring both the Thompson and Moak Lake orebodies into production. Further exploration and development of the Thompson deposit soon revealed that the production objective could be achieved by mining only the Thompson orebody and further work on the Moak deposit was suspended.

The International Nickel Company of Canada Limited has continued exploration along the nickel belt and has outlined several other occurrences which may be brought into production in the future.

LOCATION AND ACCESS

The Thompson-Moak map-area comprises some 1,200 square miles, the centre of which lies approximately 450 air miles due north of Winnipeg. The map-area is bounded by longitudes 97° 00′ and 98° 00′ west and latitudes 55° 30′ and 56° 00′ north.

Numerous lakes and rivers provide ready access for canoe and float-equipped aircraft. Two main water systems, the Burntwood River and the Grass River, drain the area.

Thicket Portage, at mile 185 on the Hudson Bay line of the Canadian National Railways, is situated about 16 miles south of the map-area. It was formerly the centre from which much of the exploration of the area was carried out and has served as a base for float- and ski-equipped aircraft and as a loading point for tractor trains which, in the winter of 1956-57, carried 30,000 tons of material to Thompson. Since the construction of the modern town of Thompson, Thicket Portage has become less active.

The Hudson Bay line of the Canadian National Railways cuts across the south-east corner of the map-area and the spur line from Sipiwesk to Thompson traverses the southwest quarter of the map-area. The railroad right-of-way between Thompson and the shaft at Moak Lake is currently being used as a motor road.

Thompson, Manitoba's newest modern northern community, lies on the south bank of the Burntwood River about two miles north of the minesite. The power for both the mine and town comes from Kelsey, fifty-three miles to the northeast.

TOPOGRAPHY, DRAINAGE, AND GROWTH

The Thompson-Moak map-area is generally flat and relief rarely exceeds two hundred feet. Swamps are numerous and, though bedrock locally controls the topography, most of the prominent topographic features are due to surface deposits. Surficial deposits are composed largely of clay and rarely of sand or boulders. The maximum relief occurs along a string of gravel ridges which extend in a northeasterly direction from just north of the Burntwood River near Thompson to the Odei River. These hills furnish the gravel for construction at Thompson.

Except for the area south and southwest of Thompson and in the vicinity of Pikwitonei Lake, outcrops inland from the lakes and streams are not abundant. Most outcrops occur on the slopes of small hills or at the edges of swamps. Rock exposures are generally abundant on the shores of rivers and lakes.

Most of the area has been burnt over at different times and the growth now consists mainly of poplar, spruce, and fir of a size suitable only for pulpwood. Jackpine is abundant locally.

Ducks, partridge, and fish, particularly northern pike, are generally plentiful. Moose, wolf, and fur-bearing animals are present. Trapping is the chief occupation of a few of the inhabitants.

The northwest part of the area is drained by the Burntwood River which in the Thompson-Moak area is broad, smooth, and broken by only a few rapids and falls. Rapids around which portages must be made occur due north of Thompson and at the northeast corner of the map-area. Mystery Lake drains into the Burntwood River and a 3000-foot portage connects the former to Moak Lake. An 8000-foot portage connects the Odei and Burntwood rivers.

The south and southwest parts of the map-area are drained by the Grass River, which flows from Paint Lake in the southwest corner of the map-area north and east through Partridge Crop and Natawahunan lakes. Both of these lakes are composed of several large bays which actually may be considered as separate lakes or as expansions of the Grass River. Several short portages are present between Paint Lake and Partridge Crop Lake and one short portage occurs between Natawahunan Lake and Pikwitonei Lake. An old overgrown trail is present between Buckingham Lake and Bunn Lake.

PREVIOUS WORK

Henry Kelsey is believed to have been the first explorer to enter this region; however, the route he followed in 1691 has never been clearly outlined.

R. Bell (1880) carried out a geological reconnaissance of the area in 1878; he entered the map-area where Natawahunan Lake narrows to form the Grass River, and proceeded south through Natawahunan Lake, Partridge Crop Lake, and Wintering Lake to Thicket Portage.

Tyrrell (1901), continuing the work of Bell, entered Wintering Lake at Thicket

Portage and travelled west, portaging into Paint Lake, then into Ospwagan Lake, and proceeded north on the Manasan River to the Burntwood River where he turned southwest towards Nelson House.

Alcock (1921) mapped the Ospwagan Lake area and outlined a large greenstone belt which lies along strike with the belt of sedimentary rocks in the Thompson-Moak area.

McInnes (1930) in his memoir on the basins of the Nelson and Churchill rivers refers to the greenstones of Ospwagan Lake and the rocks exposed on the banks of the Burntwood River near Split Lake.

Wright (1931) in a summary report of the Geological Survey of Canada, gives general information on the rocks and mineral deposits which occur in the southern part of the Thompson-Moak map-area. He describes sulphide deposits, containing nickel or copper and nickel, which occur on the shores of Wintering and Partridge Crop lakes and an argentiferous galena deposit on the west shore of Mystery Lake.

In 1941 Dawson (1952) mapped the Partridge Crop area at a scale of two miles to the inch. His map-area included all of the Thompson-Moak area of the present report.

Gill (1951) spent several weeks in 1950 geologically mapping Mystery Lake. His work was confined almost entirely to the shoreline.

Harrison (1951) compiled the geology shown on the Sipiwesk sheet published by the Geological Survey of Canada. The Thompson-Moak map-area forms the northwest quarter of the Sipiwesk map-area.

McDonald (1960) who had assisted the writer in 1958, made a petrological study of the ultramafic and mafic rocks of the Thompson-Moak map-area and presented the results of this study as a M.Sc. thesis at the University of Manitoba.

Innes (1960) suggested that the Nelson River gravity high lies along the two major divisions of the Precambrian of Manitoba, and that it marks the axis of an ancient mountain belt.

Wilson and Brisbin (1961) described and interpreted the regional structure of the entire Thompson-Moak Lake belt, with particular reference to the geological and geophysical setting of the nickel deposits.

The greater part of the Thompson-Moak map-area has been covered by aeromagnetic surveys. Copies of the aeromagnetic maps may be obtained at the Mines Branch.

PRESENT WORK AND ACKNOWLEDGMENTS

Three field seasons, from approximately June 1 to September 7 were spent in mapping the area. In 1958 the writer led one five-man party. Three parties under the direction of G. C. Milligan, J. A. McDonald and the writer were engaged in in 1959, and two parties under J. A. McDonald and the writer in 1960.

Because of the scarcity of outcrops and the presence of many large swamps, the traverse interval varied from approximately 1,000 to 7,000 feet. Generally traverse intervals were less than one mile and in most parts of the area, less then one-half mile. The standard pace and compass method of mapping was used with the aid of vertical aerial photographs. On the accompanying map large outcrop areas are designated by dotted outlines and smaller ones or groups of smaller ones by crosses.

The nickel deposit at Mystery Lake was examined in 1958. Brief trips underground at Thompson, through the courtesy of The International Nickel Company of Canada Limited, were made in 1958 and 1959. The underground workings at Moak Lake had been closed previous to the summer of 1958 and were not available for examination during the course of this work.

The writer was ably assisted by J. A. McDonald, G. Loveridge, G. Richardson and J. Kuryluk in 1958; by D. Cranstone, N. Neustaedter, G. Richardson, and R. Rector in 1959; and by G. Babits, D. MacDonell, W. Gibbins, and B. McCallum in 1960. Special recognition is due to John A. McDonald who led parties in 1959 and 1960. He was ably assisted in 1959 by F. Wicks, E. Schaeffler, G. Pearse, and A. Hodgson and in 1960 by S. Ghose, L. Kornik, W. Wawrykow and T. Pachowski. The writer is also obligated to G. C. Milligan who mapped most of the southwest quarter of the map-area with the assistance of E. Tagseth, I. Haugh, L. Stanlake, H. Koven, L. Grapentine, and J. Roberts.

The co-operation and hospitality of the residents of Thicket Portage and Pikwitonei as well as those at Thompson and Moak Lake are greatly appreciated.

Thanks are also due to Dr. H. D. B. Wilson and W. C. Brisbin, both professors at the University of Manitoba, for helpful suggestions and criticisms.

Information obtained from The International Nickel Company of Canada Limited is gratefully acknowledged. However, the company can in no way be held responsible or necessarily in agreement with the conclusions or suggestions presented by the writer.

CHAPTER II

GENERAL GEOLOGY

INTRODUCTION

The Thompson-Moak map-area lies in the area of highly deformed rocks which forms the boundary between the Superior and Churchill provinces as defined by Gill (1952). Both provinces are composed largely of granitic rocks and gneisses; however, the Superior province also contains east-trending bands of volcanic rocks with lesser intercalated sedimentary formations, whereas in the Churchill province the non-granitic rocks are largely sedimentary. Folding in the Churchill block is much more open than in the Superior block (Wilson and Brisbin, 1961).

J. T. Wilson (1957), showed that the granitic rocks of the Superior and Churchill provinces are of different ages. Minimum ages of 2400-2700 million years for the granitic portions of the Superior block and of 1650-1850 million years for the granitic rocks of the Churchill province have been confirmed by recent work of the Geological Survey of Canada (Lowdon; 1960, 1961).

The junction of the Churchill and Superior provinces is marked by a strong northeast-striking gravity anomaly[1] which extends from the Hudson Bay Lowlands southwest to Wabowden and then west into Saskatchewan and south as far as the Canada-United States border. Of interest here is the mainly northeast-striking area between Wabowden and Gillam on the Hudson Bay railway.

The gravity anomaly is made up of one negative and two positive strips whose locations are described by H. D. B. Wilson and W. C. Brisbin (1961, p. 817): "Within the area of Precambrian outcrop the gravity low trends northeast-southwest and can be traced as a single axis with only minor branches from Wabowden to just north of Gillam, a distance of approximately 200 miles. The axis of the Nelson River high is parallel to the low and lies approximately thirty-five miles to the southeast. A moderately high gravity ridge lies to the northwest of the low, but the anomaly lacks the continuity evident in the high to the southeast."

In the same paper (p. 815) they conclude that: "the gravity anomalies . . . . are best explained by major warps of a crust consisting of a granitic and basaltic layer."

As the boundary between the Churchill and Superior blocks is characterized by the gravity low, intense deformation, greywacke-type lithology, and serpentinite intrusions (all features of "Alpine-type" mountain structures) it is suggested that this belt of rock represents the roots of an ancient mountain chain.

Both the easterly striking Archaean rocks of the Superior province and the northeast-striking Proterozoic rocks of the Churchill province occur within the map-area (Figure 2). The contact between the two provinces appears to be one of dislocation and divides the map-area into two parts.

The bulk of the Archaean rocks are pyroxene-bearing granitic rocks or charnockites (4) in which a few remnants of sedimentary rocks (1) and larger masses of sedimentary gneiss (2) occur. Meta-gabbro (3) is prominent commonly as small bands, bodies, or inclusions, but also occurs as the larger masses shown on the accompanying map. Intruding the Archaean rocks, or those believed to be metamorphosed Archaean rocks east of the fault separating the two provinces, is the

[1]See the Gravity Anomaly Map of Manitoba, published by The Dominion Observatories, Department of Mines and Technical Surveys, Ottawa.

TABLE OF FORMATIONS

RECENT AND PLEISTOCENE				River alluvium, glacial lake clay, boulder clay, sand, gravel
				Unconformity
PRECAMBRIAN	LOWER PROTEROZOIC	INTRUSIVE ROCKS		Diabase
			(13)	Peridotite, olivine gabbro, gabbro
			(12)	Red biotite granite, pegmatite — may be younger than peridotite and olivine gabbro (13)
			(11)	Foliated grey granodiorite
			(10)	Granodiorite gneiss, gneissic granodiorite and pegmatite, with inclusions of sedimentary gneiss
			(9)	Serpentinized peridotite, serpentinite, amphibolite
				Intrusive Contact
		GNEISSES POSSIBLY DERIVED FROM (5)	(8)	Plagioclase-amphibolite
			(7)	Plagioclase-quartz-biotite gneiss
			(6)	Garnetiferous plagioclase-quartz-biotite-sillimanite gneiss
		ASSEAN LAKE GROUP	(5)	Micaceous quartzite, phyllite, quartz-mica schist Skarn, iron-formation
				Unconformity (and Fault Contact?)
	ARCHAEAN		(4)	Charnockite, pegmatite
			(3)	Meta-gabbro
			(2)	Quartz-plagioclase-garnet gneiss
			(1)	Micaceous quartzite, quartz-mica schist, skarn, iron-formation

Cuthbert Lake dyke swarm (13) which appears to be Proterozoic in age. Pegmatite is common in the charnockite.

Most of the exposed Proterozoic rocks are non-pyroxene "granites" and include granodiorite (11), granodiorite gneiss (10), and red biotite granite (12). Also prominent are various types of sedimentary gneisses (6), (7), with which amphibolite (8) commonly is associated. The latter generally occurs as small bands or inclusions, rarely large enough to be represented by a separate map-unit. Sedimentary rocks (5) outcrop in what appear to be two narrow, perhaps discontinuous, belts separated by granitic rocks. Dawson (1941) originally named the sedimentary rocks the Assean Lake series, but later the Geological Survey of Canada renamed them the Assean Lake group (5). Intruding the Proterozoic rocks are pegmatite, diabase, gabbro, and serpentinized ultramafic rocks (9). The northwest-striking diabase dykes also appear to intrude the Archaean rocks.

Both the Archaean and Proterozoic rocks are isoclinally folded with steeply dipping limbs and steep plunges. The zone of dislocation separating the Archaean and Proterozoic rocks is associated with south-plunging drag-folds (Figure 3). The forces responsible for the faulting between the two provinces was also probably responsible for the tensional direction now occupied by the Cuthbert Lake dyke swarm (Figure 1).

The time classification adopted in this report and shown in the table of formations is that outlined by Stockwell (Lowdon, 1961, pp. 108-118) and is based on the three major orogenies distinguished in the Canadian Shield. Radioactive age determinations place the oldest of these orogenies at 2300 to 2750 million years, an age found typically throughout the Superior geologic province and termed Archaean. The Hudsonian orogeny, ranging from 1550 to 1850 million years ago, marked the last period of folding, intrusion, and metamorphism throughout most of the Churchill geologic province. Rocks which are post-Archaean and which were involved in the orogeny are referred to as Lower Proterozoic. The final important orogeny, the Grenville, is not represented in the present map-area.

ARCHAEAN ROCKS

General Statement

The eastern half of the Thompson-Moak map-area is underlain by easterly trending rocks which are probably Archaean in age (Figure 2). The bulk of these rocks are, or were originally, pyroxene-bearing granitic rocks (4) or charnockites. Hypersthene is the most common pyroxene but clinopyroxene may also be present. These pyroxene-bearing granitic rocks are on strike with a pyroxene granite of known Archaean age approximately thirty miles east of the map-area.

That the pyroxenes were formed before the Proterozoic orogeny is indicated by the gradual increase in the intensity of their alteration in the Archaean rocks from east to west towards the Proterozoic-Archaean contact. Adjacent to this contact a granodiorite gneiss (4b) predominates and, though it is very similar to the typical Proterozoic granodiorite gneiss (10), structurally it appears to be re-metamorphosed Archaean charnockite. East of the Archaean granodiorite gneiss (4b) is the pseudo-charnockite in which only minerals secondary after pyroxene occur. Still further east, fresh to slightly altered hypersthene-bearing granitic rocks or charnockites (4) are present. It appears that the Proterozoic orogeny had a slight to intense retrograde metamorphic effect on the previously highly metamorphosed Archaean rocks (pyroxene granulite facies).

Highly metamorphosed sedimentary rocks (1), generally quartz-magnetite-clinopyroxene iron-formation and olivine-pyroxene-carbonate rocks, occur as small scattered remnants within the charnockite. Larger masses of sedimentary gneiss (2) commonly high in quartz and garnet also occur. Pyroxene-bearing meta-gabbro

(3) containing both clinopyroxene and orthopyroxene is common within the charnockite. Locally the meta-gabbro is highly granitized and/or amphibolitized (3a).

The Archaean rocks are folded into a near vertical, generally isoclinal sequence plunging steeply northeast to east. The southern area of the Archaean rocks has a remarkably consistent north dip suggesting that the entire sequence is tilted northward (Figure 2).

Sedimentary Rocks (1)

Only a few, generally small, isolated outcrops of highly metamorphosed, but recognizable, sedimentary rocks (1) were observed within the Archaean charnockite. Skarn is by far the most abundant type of altered sedimentary rock found. Magnetite-bearing iron-formation is also present; outcrops of quartz-plagioclase-mica schists or micaceous quartzites are rare.

Skarn occurs as small, rather massive and coarse-grained, light to dark brown rough weathering outcrops and, in places, strongly resembles some varieties of the meta-gabbro (3). Typical mineral assemblages are:

Calcite-olivine (spinel)
Calcite-olivine-diopside
Diopside-hypersthene (spinel)

Less typical and generally sheared carbonate assemblages are:

Calcite-talc
Calcite-quartz-muscovite
Chlorite-calcite-quartz
Calcite-plagioclase-quartz

The first three of the mineral assemblages occur along or near the Archaean-Proterozoic boundary zone. Dawson (1952) reports the following chemical analyses of skarn rocks composed of calcite, forsterite, serpentine, and spinel from Natawahunan Lake (I) and from the southwest arm of Partridge Crop Lake (II):

TABLE 1

Chemical analyses of Skarn

	I	II
CaO	33.36	30.91
MgO	18.41	19.75
SiO_2	14.46	14.20
Al_2O_3 – Fe_2O_3	3.00	5.63
CO_2 — H_2O	29.80	29.30
Total	99.03	99.79

Analyst – J. S. Richards, Manitoba Mines Branch.

The above chemical analyses suggest that the original rock was a dolomitic limestone with minor quartzose and argillaceous impurities.

Small outcrops of magnetite-bearing iron-formation occur sporadically throughout the pyroxene-bearing granitic rocks. These are made up of thin bands of magnetite, clinopyroxene (and secondary amphibole), and quartz alternating with generally thicker bands composed almost entirely of quartz. In most specimens the magnetite content is less than 25 per cent. A few small lenses high in magnetite also occur within a few of the meta-gabbro outcrops. The typical mineral assemblages are:

Quartz-clinopyroxene-magnetite
Quartz-amphibole-magnetite

Biotite may occur as an accessory mineral. One small outcrop of quartz-plagioclase-mica schist interbanded with micaceous quartzite and minor skarn was observed.

The outcrop was highly contorted and, to a lesser extent, sheared. A few outcrops of rather massive micaceous quartzite were also seen.

All of the sedimentary rocks are probably xenoliths within the pyroxene-bearing granitic rocks and exhibit most of the characteristics of their host: that is, the high grade of metamorphism, isoclinal folds, and the effects of retrograde metamorphism.

Quartz-plagioclase-garnet-biotite gneiss (2)

The quartz-plagioclase-garnet-biotite gneiss (2) has an extremely varied composition. Quartz varies from 10 to 70 per cent, garnet from 10 to 50 per cent, and plagioclase from 5 to 40 per cent. Outcrops of the quartz-plagioclase-garnet-biotite gneiss (2), hereafter referred to as the garnet gneiss, are generally medium grained, foliated, and rarely banded. The garnet gneiss (2) is commonly interbanded with the pyroxene-bearing granitic rocks (4) and to a lesser extent with meta-gabbro (3). Under the microscope the reddish garnet is colourless to light pink, anhedral to subhedral, cracked, and contains numerous inclusions of plagioclase, quartz, and magnetite. Partial alteration of the garnet to biotite may be present but primary biotite also occurs. Quartz occurs as anhedral strained grains and generally contains the needle-like inclusions (rutile?) that are so widespread in the quartz of the charnockite (4). The plagioclase is poorly to well twinned, has minor antiperthite, and rarely contains the needle-like inclusions common to the quartz. Accessory minerals are magnetite, sulphides, hypersthene, anthophyllite, zircon, and in one specimen, sillimanite.

Field occurrence and mineralogy indicate a close relationship between the garnet gneiss (2) and the charnockite (4) into which the garnet gneiss grades. Some of the garnet gneiss, composed almost entirely of garnet and quartz, is probably a highly metamorphosed sedimentary rock. A similar origin is probable for the other varieties of the garnet gneiss (2).

The garnet gneiss outcrops only in the southeastern quarter of the map-area. Outcrops extremely rich in quartz are common in the Partridge Crop Lake area, whereas those relatively rich in plagioclase occur elsewhere.

A few small areas of sedimentary gneiss similar to the plagioclase-quartz-biotite gneiss occur in the Archaean rocks. They have the same mineralogical characteristics as the charnockites (rutile (?) needles in the quartz, antiperthite, and perthite), but the same mineral composition as the plagioclase-quartz-biotite gneiss. In general, these metamorphosed rocks are quartz-plagioclase-biotite gneisses.

Meta-gabbro (3)

The term meta-gabbro (3) is used loosely here to define a group of generally pyroxene-bearing rocks whose composition approximates that of a gabbro, rarely more mafic, and whose origin appears to be largely intrusive. It seems likely that two ages of Archaean rocks are included within this rock-unit.

The older mafic rocks are represented by the numerous mafic inclusions in the charnockite and by the pyroxene-rich (25 per cent) charnockite which appears to be an incompletely granitized mafic rock. The younger mafic rocks, probably intruded during and or at the closing stages of Archaean metamorphism, are represented by the numerous foliated sill- and dyke-like bodies of meta-gabbro in the charnockite. Also included within this rock-unit are meta-gabbros (3a) which were amphibolized or granitized possibly during the Hudsonian orogeny and which are largely confined to the Bryce Bay and Partridge Crop Lake area where the granodiorite gneiss (4b) possibly represents metamorphosed Archaean charnockite (4).

Meta-gabbro is abundantly distributed throughout the Archaean charnockite but only in a few areas does it form bodies large enough to be outlined on the accompanying map.

Typically, the meta-gabbro (3) occurs as a well-foliated to poorly banded medium-grained rock with a sugary or granular texture. Ferromagnesian minerals, the bulk of which is clinopyroxene with lesser amounts of hypersthene, make up about 40 per cent of most specimens, the remainder consisting mainly of plagioclase. Quartz, biotite, and garnet are common accessory minerals and, in a few outcrops, are major constituents. Amphibole may be present both as a secondary or primary mineral. A few outcrops are composed entirely of ferromagnesian minerals. Amphibole and pyroxene crystals up to two inches across were observed in or adjacent to pegmatitic stringers cutting the meta-gabbro. The banding or foliation is always concordant with the strike of the local rocks. Locally the typical meta-gabbro (3) grades into a pyroxene-rich charnockite which has all the microscopic and megascopic characteristics of the typical charnockite. In the pyroxene-rich charnockite, clinopyroxene is the dominant and commonly the only pyroxene present.

The amphibolitized meta-gabbro (3a) is generally a medium-grained, slightly foliated to banded rock which commonly is sheared and contorted. Outcrops are composed of varying proportions of granitic material or pegmatite, and mafic material. At several localities in the Bryce Bay area, the meta-gabbro occurs as highly drawn-out indistinct patches or as distinct bands, blocks, or lenses in the granitic rock. The granodiorite gneiss (4b) appears to have intruded the amphibolitized meta-gabbro (3a) in some outcrops, but elsewhere the amphibolitized meta-gabbro (3a) appears to intrude the gneiss. Large drag-folds are common, particularly in the amphibolitized meta-gabbro (3a) to the east of Bryce Bay where the small drag-folds on the limb of the larger fold commonly have developed into small thrust faults. Mineralogically, the amphibolitized meta-gabbros (3a) are composed of about equal amounts of secondary pleochroic green amphibole and anhedral well-twinned plagioclase. Magnetite, biotite, epidote, and sphene are common accessory minerals and a few clinopyroxene cores may be present in the amphibole. Locally, epidote may be a major constituent. A few small bodies of red syenite gneiss occur; the largest of these lies about one mile south of Bryce Bay. These syenite gneisses are believed to have been formed by the intrusion of red microcline-rich pegmatitic material into meta-gabbro, producing a microcline or microcline-plagioclase amphibolite.

Small mafic inclusions are common in the charnockite (4) and vary in size, shape, degree of foliation or banding, and mineral composition. Mineralogically, they vary from dioritic to ultramafic, but generally have a ratio of light to dark minerals of about 1:1. In shape, the inclusions vary from relatively long lensoid to circular bodies, and in size from a few inches to several feet. Typically, they are well-foliated oval shaped bodies less than a foot long which are composed largely of plagioclase, pyroxene, and amphibole. If amphibole is present, it generally is a secondary mineral. Generally, the foliation is parallel to the long dimension of the inclusion, both being parallel to the foliation of the host rock. A few examples of discordant inclusions were observed. These are usually circular in outline. The inclusions are commonly medium grained and rarely contain coarse-grained metacrysts of amphibole or pyroxene. Locally, inclusions are highly garnetiferous, whereas their host contains no garnets, and strongly resemble the feldspathic variety of the quartz-plagioclase garnet-biotite gneiss (2).

In several outcrops containing various types of mafic inclusions on the shore of Pikwitonei Lake there is a general relationship between the composition of the inclusion and the alteration rim around it. Little or no alteration is present around inclusions composed almost entirely of ferromagnesian minerals, probably largely amphibole; a narrow granitized rim occurs around those inclusions containing about 30 to 40 per cent light minerals and a slightly wider zone occurs around inclusions with a higher percentage of light minerals. In most cases, the alteration zone rarely exceeds one inch. Elsewhere, gabbroic inclusions with sharp contacts have been observed in the charnockite.

In the same vicinity, several outcrops were observed which contain numerous mafic inclusions averaging about one foot in length. The charnockite is slightly finer grained adjacent to the long dimension of the inclusions, and has a faint pegmatitic character around the ends of some of the inclusions where it was probably protected from the stresses which produced the foliation.

Charnockite (4)

All of the pyroxene-bearing granitic rocks, generally containing hypersthene, are confined to the eastern and southeastern part of the map-area. Two main types of pyroxene-bearing granitic rocks can be recognized in the field: a brownish grey variety and a salmon pink variety containing abundant potash feldspar.

By far the most common pyroxene-bearing granitic rock, or charnockite, is a fine-grained to medium-grained well-foliated or rarely massive brownish grey rock which varies in texture from sugary to granoblastic. Deeply weathered specimens, which have a sugary texture, commonly crumble like a poorly consolidated sandstone. The surface of outcrops is generally smooth except for small pits, rarely more than six inches long, caused by the weathering out of mafic inclusions. Weathering out of highly altered pyroxenes also gives outcrops a pitted appearance. The fresh surface is light brown and slightly mottled due to the dark mafic minerals and smokey grey quartz grains. The most consistent feature is the brown or honey-coloured plagioclase which generally makes up almost 50 per cent of the rock. Metacrysts (phenocrysts?) are rare. Near shear zones the charnockite has been converted to rock which is identical, in hand specimen, to the granodiorite gneiss (10). The quartz in the charnockite occurs generally as small thin drawn-out lenticles which commonly give the rock its strong foliation. Pyroxenes can be identified in most specimens, and occur as more or less equidimensional grains or, when higher percentages are present, as elongated grains which, with the quartz, are largely responsible for the strong foliation.

Disregarding the varying proportions of mafic clots, outcrops of the above-described charnockite are extremely variable, with rapid changes in mineral composition, texture, and degree of foliation. The single exception is the charnockite in the vicinity of Pikwitonei Lake. There the changes are for the most part more subtle and the outcrops as a whole are smoothly weathered, moderately well foliated, and rarely contain more than five per cent pyroxene or its alteration products.

Locally abundant, but as a whole much less abundant than the previously described variety of charnockite, is a fine- to medium-grained, rarely coarse-grained, mottled salmon-pink charnockite. In hand specimen the salmon-pink charnockite commonly appears almost identical to the granodiorite gneiss (4b). Generally, a granoblastic, rarely igneous, texture is present and the weathered surface is pitted. The mineral composition of this variety is more consistent than the previously described variety of charnockite and the differences in colour are largely due to the presence of substantial amounts of potash feldspar. Feldspar varies in colour from light grey or buff to salmon-pink. The quartz is generally present as "eyes," but in more massive varieties it is interstitial. In colour the quartz varies from clear and colourless to a peculiar blue. The ferromagnesian minerals are generally secondary after pyroxene. In some outcrops, small brownish pyroxene cores are rimmed by a greenish alteration product, generally amphibole or biotite. In most hand specimens, pyroxene could not be identified.

Both varieties of charnockite show the same mineralogical peculiarities in thin sections. However, the main division of the charnockites into those rich in potash feldspar, and those relatively deficient in potash feldspar was supported by the study of thin sections. The two varieties appear to be randomly distributed. A visual estimate of the mineral content made from thin section is as follows:

	Typical			Potash-rich		
	low	high	average	low	high	average
Plagioclase	35	80	45	10	50	30
Quartz	10	55	35	15	50	30
K-Feldspar	tr	15	5	20	50	30
Hypersthene	tr	25	10	tr	10	5

Typical accessory minerals are primary and secondary magnetite and biotite, as well as secondary amphibole and primary sulphide, apatite, zircon, and clinopyroxene.

Plagioclase (An_{30-40}) generally occurs as anhedral or, rarely, subhedral poorly twinned grains which locally have a slight undulatory extinction. Near shear zones, and to a lesser degree elsewhere, the plagioclase may be highly altered to epidote; however, generally the plagioclase is unaltered. Antiperthite, generally of the string variety, but also of the rod and patch types, is more common in the potash-rich specimens. In a few specimens the feldspars contain the needle and hair-like inclusions which are common in the quartz (see below).

The quartz occurs as anhedral grains containing a few bubbles and varying amounts of a thin needle-like mineral believed to be rutile. Less common and abundant are small flakes of an unidentified micaceous mineral. The quartz in most specimens has undulatory extinction.

Most of the potash feldspar is microcline which occurs as clear anhedral unaltered and well-twinned grains. Locally, the twins are shadowy and appear to show the effects of stress. A few specimens have inclusions of rutile (?). Perthite is not common.

Hypersthene generally occurs as small anhedral grains which are commonly faintly pleochroic in light pink, rarely brownish, and light green. It is rarely fresh and the alteration varies from a few serpentine veinlets to grains rimmed by greenish biotite or amphibole, and to ones entirely altered to magnetite, biotite, and/or amphibole. Biotite and magnetite are by far the most common, and apparently ultimate, alteration products. Common within the hypersthene are a few small purplish to brownish-violet coloured plates of an unidentified mineral.

Unlike hypersthene, the clinopyroxene rarely occurs alone but usually is associated with subordinate amounts of hypersthene. The clinopyroxene occurs as small anhedral grains which commonly are slightly pleochroic in light greens and, though fresh in some specimens, it is generally altered to a greater or lesser degree. Calcite is a common alteration product. Like hypersthene, the clinopyroxene locally contains small plate-like inclusions of a purplish-coloured mineral.

Most of the biotite is secondary, but primary biotite was observed in specimens which are only slightly altered. The secondary biotite, pseudomorphic after pyroxene, is commonly colourless to light green or light brown in colour, except when adjacent to magnetite, where it is pleochroic in light to dark brown, like the primary biotite. In a few specimens the biotite has magnetite and sphene inclusions or small rods of ilmenite.

Both pink (potash rich) and brownish (potash poor) charnockites (1) have been observed in a single outcrop. Contacts between the two are sharp and parallel to the foliation. No intrusive relationships were recognized. Generally, the mottled pink variety occurs as narrow septa in the brownish variety. The reverse was never seen.

The charnockite, as indicated by the age of 2400 million years at Dafoe Lake (Lowdon, 1961), which is about 30 miles east of the map-area, is probably Archaean and, except for the sedimentary rocks and their gneissic equivalents found within the charnockite, appears to be the oldest rock in the area.

The eastern half of the map-area, that is all of the area east and southeast of the presumed fault zone which separates the Archaean and Proterozoic rocks, can be roughly divided into three zones which from the fault eastward and southeast are as follows:

1. Granodiorite gneiss zone (4b). This zone contains no pyroxene-bearing granites, but a few specimens have secondary biotite similar to that in highly altered charnockites. Most of the amphibolized meta-gabbro as well as amphibolized mafic dykes occur in this zone.

2. Pseudo-charnockite zone (4a). Many of the outcrops have the appearance of granodiorite gneiss but contain secondary minerals, generally biotite and magnetite, obviously pseudomorphic after pyroxene.

3. Charnockite zone (4). Most outcrops are typical pyroxene-bearing granitic rocks. In this zone the pyroxene commonly is only partly altered but fresh and completely altered pyroxenes also occur. Any outcrops which strongly resemble the granodiorite gneiss are near shear zones. The inclusions of meta-gabbro may contain amphibole, which is generally primary, as well as pyroxene.

It would appear from this that the destruction of the pyroxene in the charnockite is related to the presumed fault zone and that the granodiorite gneiss (4b) east of this assumed major fault between the Archaean and Proterozoic rocks is retrogressively metamorphosed charnockite. However, it must be pointed out that the granodiorite gneiss (4b) is practically identical lithologically with that of map-unit 10 and that the two differ only in their structural environment.

White pegmatite is common throughout the Archaean rocks and red pegmatite, apparently related to the red biotite granite, is abundant only in the vicinity of Bryce Bay and Partridge Crop Lake area. Where white pegmatite or pegmatite stringers intrude the meta-gabbro (3), amphibole, magnetite, and biotite are commonly developed. Large metacrysts of brownish to bronze-coloured pyroxene have also been observed. Though good crosscutting relationships are rare, the white pegmatite commonly has a slightly irregular and undulating border and is locally foliated whereas all the red pegmatites observed have straight regular parallel sides. One red pegmatite cutting meta-gabbro gave an age of 1770 million years (Hurley et al., 1959). The fact that ferromagnesian minerals are relatively abundant only in pegmatite cutting mafic rocks indicates that only by the extraction of such elements as iron and magnesium from the host rock could amphibole, pyroxene, and magnetite be formed in the pegmatite.

LOWER PROTEROZOIC ROCKS

General Statement

As previously stated, the time classification used here is the one set up by Stockwell (Lowdon, 1961, p. 115) who defines the Lower Proterozoic as follows:

"The Lower Proterozoic includes all sedimentary, volcanic, and igneous rocks deposited or intruded during the interval between the Kenoran and Hudsonian orogenies, as well as those igneous rocks that were intruded during the Hudsonian. The last named igneous rocks may be classified as late Lower Proterozoic."

Age determinations northeast and southwest of the Thompson-Moak map-area indicate that the metamorphism of the Assean Lake group (5) and the metamorphic formation of the sedimentary gneisses (6), (8), took place during the Hudsonian orogeny. Therefore, the Assean Lake group (5) and the sedimentary rocks from which the sedimentary gneisses (6), (8), were formed must have been deposited before or during the Hudsonian and as such are either Archaean or early Lower Proterozoic in age. If the Assean Lake group had been deposited during Archaean times, it would have been affected by the Kenoran orogeny (folding about on east-west axis and an upper metamorphic limit of the pyroxene granulite facies) as well as the Hudsonian orogeny (folding about a northeast axis and an upper metamorphic limit of the upper amphibolite facies). No geological evidence was observed that would indicate that the Assean Lake group had been subjected to two such orogenies and it seems unlikely that the thin, slightly curved belt of sedimentary rocks which make up the Assean Lake group (5) in the Thompson-Moak map-area, survived two such orogenies. Consequently, the Assean Lake group is probably Lower Proterozoic in age, and as it appears to be older than the granitic intrusive rocks which are late Lower Proterozoic, the Assean Lake group has been classified as early Lower Proterozoic.

If the sedimentary gneisses (6, 7), are the metamorphosed equivalents of the Assean Lake group, they are also early Lower Proterozoic. It is possible that part of, or all of, the sedimentary gneisses are older than the Assean Lake group. However, the sedimentary gneisses (6, 7), are here considered to be early Lower Proterozoic, although their relationship to the Assean Lake group (5) is not clear. Similarly, the amphibolite (8), which in part at least appears to be intrusive, is considered early Lower Proterozoic, although the mafic rocks from which they were derived may have been pre-Hudsonian.

Assean Lake Group (5)

(Quartzose Sedimentary Rocks, Limestone, Skarn, Iron-formation)

The Assean Lake group is confined to a discontinuously outcropping, probably double, belt of largely micaceous and quartzose sedimentary rocks which extend from Ospwagan Lake northeast, in an arcuate structure, through Thompson and Mystery Lake passing just northwest of Moak Lake, a total length of twenty miles. Minor iron-formation and skarn are present.

The best exposures of the Assean Lake group (5) occur at Ospwagan Lake and at Mystery Lake, where an average width of approximately one-half mile is apparent. Exposures within the belt, other than those at Mystery and Ospwagan lakes, are small and few in number. These occur northeast of Mystery Lake, on the north bank of the Burntwood River near Thompson, and one small outcrop of sedimentary rock occurs about two miles southwest of the Thompson mine site. However, diamond drilling encountered sedimentary rocks in many other places along the nickel belt.

A few outcrops of sedimentary rocks lie outside of the above described Assean Lake belt, and are generally either iron formation or skarn rock with a higher metamorphic grade than most of the Assean Lake group.

Associated with the Assean Lake group at and northeast of Mystery Lake are numerous well-foliated mafic sills. Of economic importance are the serpentinized ultramafic rocks which appear to be spatially associated with the sedimentary rocks.

The relationship of the Assean Lake group to the other rock units is not well known. At Ospwagan Lake and in the vicinity of the Thompson mine-site they are intruded by a white, commonly muscovite-bearing pegmatite. A similar well-foliated muscovite-bearing, somewhat pegmatitic granodiorite intrudes the sedimentary rocks (5) at Ospwagan Lake. At Mystery Lake the sedimentary rocks (5) appear to have a fault contact with the gneisses which lie to the east. The serpentinized ultramafic rocks are probably intruded along this fault as they lie beneath Mystery Lake, between the Assean Lake group and the gneisses. If the granodiorite gneiss to the west of Mystery Lake is younger than the Assean Lake group, it appears to have had only a minor metamorphic effect on the sedimentary rocks.

The Assean Lake group is highly folded. Exposures on the shores of Mystery Lake generally have long narrow folds which are up to ten or fifteen feet wide.

Drag-folds plunge steeply northeast and southwest. Most of the southwest-plunging drag-folds occur at Mystery Lake.

The metamorphic grade of the Assean Lake rocks ranges from the upper greenschist facies to the upper amphibolite facies. Locally, the lower metamorphic grade may be due to shearing.

In summary, the Assean Lake group is probably older than the granitic, mafic, and ultramafic intrusive rocks and may be the non-granitized equivalent of the sedimentary gneiss (6, 7).

Most of the sedimentary rocks which make up the Assean Lake group are fine-grained micaceous quartzite, phyllite, and quartz-mica schists. Locally, relatively pure but still slightly micaceous quartzite occurs, particularly at Ospwagan Lake, where some analysed specimens contain 88 to 92 per cent silica. Graphitic rocks are rare.

With the exception of some of the thicker beds of quartzite, outcrops of the Assean Lake group are generally thinly bedded and have a poorly to moderately well-developed cleavage or schistosity. Mica can be recognized in most specimens. Beds are commonly one to two inches thick, with the quartz-rich beds generally being slightly thicker than the mica-rich beds. Varve-like bedding is present at Mystery Lake.

The quartz content varies from 20 to 70 per cent with 45 per cent quartz being typical. Biotite and or muscovite generally makes up the rest of the rock. Garnet is a relatively common accessory mineral and locally, is a major constituent. Plagioclase is common in some of the sedimentary rocks. Locally, quartz and mica-rich sediments of the Assean Lake group are also relatively rich in amphibole, sillimanite, epidote, sulphides, or magnetite. Typical mineral assemblages of the quartz- and mica-rich part of the Assean Lake group appear below:

Ospwagan Lake (outcrop)
- Quartz-biotite-sillimanite (muscovite-garnet)

Thompson (underground)
- Biotite-quartz-plagioclase-microcline
- Plagioclase-biotite-quartz (sillimanite)
- Quartz-microcline-biotite

Burntwood River (outcrop)
- Quartz-biotite-muscovite
- Quartz-muscovite

Mystery Lake (outcrop)
- Quartz-muscovite-biotite (plagioclase-garnet)
- Quartz-muscovite
- Muscovite-quartz-epidote
- Quartz-muscovite-plagioclase

Northwest of Mystery Lake (outcrop)
- Quartz-garnet-biotite-amphibole
- Quartz-biotite-garnet

Northwest of Moak Lake (diamond drill core)
- Quartz-biotite-muscovite-sillimanite
- Quartz-biotite-plagioclase-muscovite

The least metamorphosed sedimentary rocks occur at Mystery Lake where quartz, muscovite, biotite, and locally, chlorite are common. The metamorphic grade of the belt of Assean Lake sedimentary rocks (5) appears to increase to the northeast and southwest of Mystery Lake. Also the western and northwestern outcrops within the belt appear to be more highly metamorphosed than those which are to the east and southeast.

The Assean Lake group is cut by small veinlets of quartz or quartz-feldspar, but only the outcrops southwest of Mystery Lake are known to be intruded by muscovite-bearing quartz-feldspar pegmatites.

Small shears, generally a few inches wide and parallel to the bedding, are common. Cross faults with displacements of a few inches occur particularly at Mystery Lake. They commonly are right-handed faults that strike either northeast or northwest. The sedimentary rocks at Mystery Lake are intruded by numerous well-foliated mafic sills which generally are less than twenty feet wide. A few similar sill-like bodies occur at Ospwagan Lake where the higher grade of metamorphism may have destroyed all igneous characteristics, producing a plagioclase amphibolite.

The calcareous members of the Assean Lake group which outcrop, are almost entirely confined to the shores of Ospwagan Lake. A few thin beds of calcareous rock are locally present at Mystery Lake, and skarn rock also occurs underground at Thompson. Calcareous intersections were encountered during diamond drilling northwest of Moak Lake. The following description is taken entirely from the calcareous outcrops at Ospwagan Lake.

At Ospwagan Lake, the skarn rocks generally are interbedded with quartz-mica schists and micaceous quartzites. They are thinly and well-bedded, rarely massive rocks. In colour they range from light green to pink, commonly light green with irregular pink patches. The dominant minerals are light green clinopyroxene and poorly twinned plagioclase. Biotite is common in the more impure varieties. In the less metamorphosed and purer calcareous members, calcite is prominent and elsewhere, native garnets are present. A few vugs may be present. Typical mineral assemblages at Ospwagan Lake are:

Clinopyroxene-biotite-plagioclase
Plagioclase-clinopyroxene

A calcite-tremolite mineral assemblage is present in diamond drill core found northwest of Moak Lake. One specimen of skarn rock taken underground at the Thompson mine is composed largely of clinopyroxene, biotite, and potash feldspar.

The skarn rocks are highly folded and contorted. At Ospwagan Lake, though a northeast strike is shown on the accompanying map, the sedimentary rocks (5) northwest of the lake have highly variable attitudes. It is in this area that the bulk of the calcareous rocks occur.

Plagioclase amphibolite occurs within the sedimentary rocks at Ospwagan Lake. Though they may be the metamorphic equivalents of impure calcareous rocks, they possibly may represent a more highly metamorphosed phase of the well-foliated mafic sills which occur at Mystery Lake.

Outcrops of iron-formation are rare except northeast of Mystery Lake. However, strong magnetic anomalies indicate that iron-formation is probably more plentiful than outcrops indicate. All of the exposed Assean Lake iron-formation is magnetite-bearing and sulphides occur only as accessory minerals.

No outcrops of iron-formation were encountered southwest of Mystery Lake. However, a garnetiferous sulphide-bearing rock, locally referred to as "iron-formation," is reported to occur underground at Thompson. Diamond drill core found on the north shore of Owl Lake has thin bands of magnetite alternating with much thicker bands of feldspar, quartz, and biotite.

The best exposures of iron-formation occur as inclusion-like masses in well-foliated dioritic outcrops along the railroad right-of-way northeast of Mystery Lake. The largest exposure of iron-formation is about 30 feet by 60 feet. Bands rich in quartz and magnetite alternate with thicker quartz-biotite bands. A few small bands ½ to 1 inch wide composed almost entirely of radiating crystals of actinolite are present. A few small gossan zones occur.

Well-banded iron-formation is present in diamond drill core found northwest of Moak Lake. An unusual cherty graphitic outcrop of iron-formation occurs at the northeast end of Mystery Lake. A few small exposures of iron-formation occur on the west shore of Mystery Lake.

Some typical mineral assemblages in iron-formation northeast of and at Mystery Lake are as follows:

Biotite-magnetite-quartz
Quartz-grunerite-magnetite
Quartz-amphibole-magnetite
Amphibole-garnet-quartz-magnetite

A few outcrops of iron-formation occur as inclusions within the sedimentary gneiss (7) and granodiorite gneiss (10). The iron-formation at Owl Lake probably is of this type. Three small outcrops of iron-formation occur just north of Nichols Lake. They are massive to lensoid quartz-magnetite or quartz-magnetite-amphibole rock which is commonly garnetiferous. Elsewhere, a few similar exposures of iron-formation occur. The typical mineral assemblages of the iron-formation found as inclusions within the gneiss east of Thompson and Owl Lake, and south of the Burntwood River are as follows:

Quartz-clinopyroxene-magnetite-amphibole
Quartz-magnetite-clinopyroxene
Quartz-magnetite-garnet

The metamorphic grade of the iron-formation found as inclusions within the gneisses is higher than known Assean Lake iron-formation.

SEDIMENTARY GNEISSES (6, 7), PLAGIOCLASE AMPHIBOLITE (8)

The term sedimentary gneiss is used broadly to differentiate all the well-banded rocks and those rocks whose composition suggest that they were originally sedimentary. Outcrops which were mapped as sedimentary gneiss invariably contain some injected material, generally in the form of feldspar-quartz-mica pegmatites. These are commonly of the red variety, but also include grey pegmatites. Well-foliated grey granodiorite (10) and rarely red granite (12) also occur. The amount of injected material varies widely from outcrop to outcrop.

A brief examination of the accompanying map (69-1) reveals that comparatively more sedimentary gneiss was recognized on the shores of lakes and rivers than inland, and that many bodies of sedimentary gneiss extend only a short distance inland. This is due, in part at least, to the fact that it is easier to recognize faint banding on smooth water-worn outcrops than on lichen-covered ones. Also, the sedimentary gneiss, like the sedimentary rocks, is in general more easily weathered. Consequently, there is probably more sedimentary gneiss, as well as more sedimentary rock, in the map-area than represented on the map-sheet. This fact is substantiated by the fact that diamond drilling has intersected significant footages of sedimentary gneiss in areas shown as granodiorite gneiss.

Commonly the highly sheared granodiorite gneiss (10) is well banded and closely resembles sedimentary gneiss. It is thought that much of the well-banded sedimentary gneiss (7) along the southeast bank of the Odei River may be sheared granodiorite gneiss (10).

Two main types of sedimentary gneiss (6 and 7) occur. Plagioclase amphibolite (8) occurs generally in the plagioclase-quartz-biotite gneiss (7) and to a lesser degree in the garnetiferous-plagioclase-quartz-biotite-microcline-sillimanite gneiss (6).

Garnetiferous Plagioclase-Quartz-Biotite-Microcline-Sillimanite Gneiss (6)

The garnetiferous plagioclase-quartz-biotite-microcline-sillimanite gneiss (6), hereafter referred to as the sillimanite gneiss, is confined to the northwest corner of the map-area. It is a medium-grained, light to dark grey well-banded rock. The dark bands, generally less than one inch in width but ranging from ½ inch to five inches, are composed largely of plagioclase, quartz, biotite, and garnet. In some outcrops, small knobs of sillimanite or bluish cleavable grains of cordierite can be recognized. The garnets are of a distinctive mauve colour, and are about 1/8 inch in diameter. Larger garnets occur in small clots or bands. The light-coloured bands, about the same width as the dark-coloured bands, are composed of pegmatitic material, actually small pegmatite stringers. These small pegmatite stringers are composed largely of plagioclase and quartz with minor biotite, garnet, and locally, magnetite. Larger pegmatites, up to ten feet in width, are rare. The larger pegmatites are generally present as sills, which may have some crosscutting stringers. Clots of garnet, and to a lesser extent magnetite, occur in the pegmatites. Up to 60 per cent of the sillimanite gneiss (6) may be pegmatitic material.

An interesting variety of the sillimanite gneiss is the magnetite-bearing sillimanite gneiss (6a) which outcrops in the extreme northwest corner of the map-area, and extends west and north out of the map-area. This variety is almost identical to the typical sillimanite gneiss (6) except that it contains much less garnet and a substantial amount of small steel-blue grains of magnetite elongated parallel to the foliation. Some outcrops contain no garnets. In addition, the magnetite-rich sillimanite gneiss (6a) commonly contains a little amphibole and is not as well banded as the typical sillimanite gneiss (6).

The following are visual estimates of the mineral content from thin sections of the sillimanite gneiss (6).

	Low	High	Average
Plagioclase	30	55	40
Quartz	10	35	25
Biotite	5	25	15
Microcline	tr	30	10
Garnet	tr	10	5
Sillimanite	tr	5	tr

Accessory minerals are magnetite, spinel, cordierite, apatite, zircon, and sulphides.

Plagioclase generally occurs as anhedral, clear, and moderately well-twinned grains which commonly have small rod- or hair-like inclusions of sillimanite. A few plagioclase grains contain aligned blocks, lenses, or rod-shaped inclusions of potash feldspar. Quartz is clear, anhedral, and rarely contains sillimanite.

The strongly pleochroic, almost colourless to medium-brown or dark reddish-brown biotite, commonly has pleochroic haloes and is rarely altered.

Clear anhedral unaltered microcline occurs in the plagioclase and also as individual grains. The microcline generally has an undulatory or blurred type of twinning, or it may be entirely untwinned.

The garnet commonly occurs as colourless to faintly coloured round anhedral, rarely subhedral, grains. Inclusions of quartz, plagioclase, and magnetite are present in the garnet.

Many shapes of sillimanite are present in the sillimanite gneiss. Small "seeds," rods, needles, and felted masses are commonly confined to a number of grains of plagioclase or cordierite and rarely quartz. In a knot composed almost entirely of sillimanite, abundant inclusions of magnetite contain a wormy dark green spinel. The magnetite-spinel association is common in the sillimanite gneiss.

Amphibolite is rather rare in the area underlain by sillimanite gneiss (6). The amphibolites studied are the pyroxene-bearing types. One specimen contains small anhedral grains of hypersthene.

One of the striking characteristics of the sillimanite gneiss (6) is its uniformity. With the exception of the magnetite-rich sillimanite gneiss (6a), all outcrops of the sillimanite gneiss are almost identical although the ratio of pegmatite to gneiss varies.

The sillimanite gneiss is highly folded and contorted. Folding is generally very tight and complex. Drag-folds may be up to six feet in length and only four inches wide. The limbs of the larger folds are commonly strongly crenulated, resembling, on a small scale, synclinoria.

The contact between the sillimanite gneiss (6) and the plagioclase-quartz-biotite gneiss (7) to the southeast is probably due to a change in the lithology of the original sedimentary rocks. The sillimanite gneiss (6) was probably produced from a more argillaceous rock. Lit-par-lit intrusions of pegmatitic material into the sillimanite gneiss have resulted in the same proportions of feldspar, quartz and biotite as in the plagioclase-quartz-biotite gneiss (7). Some of the core from diamond drill holes southwest of Thompson contains short sections of a rock similar to the sillimanite gneiss. The sheared pegmatitic muscovite granodiorite on the west shore of Ospwagan Lake strongly resembles the pegmatite in the sillimanite gneiss. Several outcrops west of Southwest Bay in Mystery Lake strongly resemble the sillimanite gneiss; however, sillimanite was not observed in thin sections from these rocks and they have been included with the plagioclase-quartz-biotite gneiss (7). There is a strong possibility that these outcrops represent the slightly less metamorphosed southeast border of the sillimanite gneiss and may actually be metamorphosed Assean Lake rocks.

Outcrops do not occur in the Hunter Lake area, but the airborne magnetic information indicates that an east- to northeast-striking band of magnetite-rich sillimanite gneiss (6a) is present north of the lake.

Plagioclase-Quartz-Biotite Gneiss (7)

The plagioclase-quartz-biotite gneiss generally is a medium-grained light to dark grey rock which commonly has a ribbed appearance due to differential erosion. Two types of banding common to most outcrops are a coarse banding, a foot or more wide, due to bands of plagioclase, amphibolite, and sills of pegmatite alternating with plagioclase-quartz-biotite gneiss, and a much finer banding, from 1/10th inch to a few inches thick, due mainly to differences in the ratio of light to dark minerals. Locally, differences in the ratio of feldspar to quartz gives a much less distinctly banded appearance. Pegmatites vary from thin stringers less than an inch wide to large dykes, twenty feet wide, containing perthite crystals as much as ten inches long.

Thin sections of the plagioclase-quartz-biotite gneiss (7) generally show a poorly oriented mosaic of plagioclase and quartz with sub-parallel to parallel flakes of biotite. In sheared varieties, the quartz or quartz and plagioclase commonly occurs in lenses. Potash-feldspar locally may make up about 15 per cent of the rock but generally occurs only as an accessory mineral. Visual estimates of major constituents from thin sections are as follows:

	Low	High	Average
Plagioclase	30	65	45
Quartz	15	50	30
Biotite	5	20	15

Accessory minerals are apatite, magnetite, and sphene. Several per cent of epidote or clinozoisite and amphibole are commonly present. The latter is locally a major constituent.

Plagioclase generally occurs as anhedral poorly twinned unaltered grains which, however, locally may be highly altered. In many thin sections, the plagioclase appears to have a slightly undulatory extinction. Typically, the quartz is anhedral, clear, and highly strained. The biotite is pleochroic in light and dark brown, rarely reddish or greenish brown; pleochroic haloes are common in the biotite. Secondary biotite, after amphibole, is present in a few specimens.

The well-banded plagioclase-quartz-biotite gneiss (7) is commonly highly folded or crenulated. Drag-folds are numerous, particularly in the area northeast of Thompson. Locally, cleavage may be present and is invariably related to shear zones.

Plagioclase Amphibolite (8)

Most of the amphibolite (8) occurs as bands in the plagioclase-quartz-biotite gneiss (7). However, it also occurs in granodiorite gneiss (10), both as bands and inclusions.

Typical amphibolites (8) are dark greyish-green to greenish-black with a feldspar to amphibole ratio of about 1:1. They vary in width from a few inches to tens of feet, but commonly are less than ten feet wide. Generally they are medium-grained, well-foliated, and rarely banded rocks. Pinching and swelling is common, particularly in the area northeast of Thompson. Contacts with sedimentary gneiss or granodiorite gneiss (10) are sharp, locally chloritic, and weathered out in sheared rock.

In several outcrops, lenses are confined to a single zone and appear to represent the final stage of pinching and swelling. In one outcrop, the adjoining dismembered ends of an amphibolite lens are concave and convex. The convex portion had been largely filled with pegmatitic material rich in amphibole and low in quartz. Similarly a cross-faulted amphibolite band had large books of biotite developed in a white pegmatite which was intruded into the cross-fault, but no biotite was present in the pegmatite adjacent to the sides of the amphibolite. Apparently in these protected areas, the pegmatite incorporated some of the iron and was able to produce the coarse-grained ferromagnesian minerals that generally are rare in pegmatites.

In hand specimen, the amphibolites appear to vary only in the ratio of amphibole to plagioclase. However, some amphibolites contain clinopyroxene, rarely hypersthene, and others have quartz as a major constituent. The following estimates were made visually from thin sections:

TYPICAL AMPHIBOLITES

	Low	High	Average
Amphibole	20	80	45
Plagioclase	15	55	35
Quartz	-	25	10
Biotite	-	20	5

PYROXENE AMPHIBOLITES

	Low	High	Average
Amphibole	5	70	75
Plagioclase	10	50	30
Clinopyroxene	tr	55	20

Accessory minerals are magnetite, sulphides, zircon, apatite, sphene, microcline, and garnet. Quartz and biotite may be present in the pyroxene-bearing amphibolite.

The amphibole occurs as anhedral, rarely subhedral, unaltered grains with a strong to moderate pleochroism in greens, greenish browns, and browns. No evidence was seen which would indicate that the amphibole is secondary after pyroxene.

Generally, the anhedral, well-twinned grains of plagioclase are fresh and unaltered, but some specimens of the non-pyroxene variety contain highly altered plagioclase. The plagioclase in the pyroxene-bearing amphibolite commonly appears to be either slightly zoned or has a slight undulose extinction.

Most of the biotite appears to be secondary after amphibole; however, in some specimens of the non-pyroxene amphibolite, the biotite appears to be primary. Quartz occurs as clear, anhedral grains with undulatory extinction. The clinopyroxene is colourless to very pale green, and commonly is slightly altered to amphibole and calcite. Microcline is generally poorly and finely twinned and slightly perthitic. Garnet commonly occurs as faint pink, fractured grains with inclusions of plagioclase, quartz, amphibole, and magnetite.

Pyroxene-bearing amphibolites are present in most parts of the map-area underlain by Proterozoic rocks. However, the majority of them occur either in the garnetiferous plagioclase-quartz-biotite-microcline-sillimanite gneiss (6) or in the area east of Nichols Lake, south of the grey granodiorite (11) mass and west of the red biotite granite (12). Most of the amphibolite bands appear to be metamorphosed mafic sills, but some or all of them could be highly metamorphosed impure calcareous beds. Some of the larger masses may be metamorphosed mafic volcanic rocks.

PROTEROZOIC INTRUSIVE ROCKS

General Statement

A wide range of intrusive rocks, ranging in composition from granite to peridotite, occurs in the Thompson-Moak map area. Much of the granitic rock is mixed granitized sedimentary gneiss and granite. It seems likely that the intrusive portion of these granitic rocks were intruded during the Hudsonian orogeny, which was responsible for formation of the gneissic belt. The sedimentary rocks that were metamorphosed, granitized and incorporated in these mixed gneisses may be Lower Proterozoic or late Archaean. Geological evidence also indicates that much, perhaps all, of the granodiorite gneiss (1b) just east of the assumed major fault between the Proterozoic rocks and the Archaean rocks may be metamorphosed charnockite (4). The main mass of granodiorite gneiss (10) considered here as late Lower Proterozoic also includes some early Lower Proterozoic and Archaean rocks that were metamorphosed during the Hudsonian orogeny. The foliated grey granodiorite (11) body just southeast of Thompson appears to be related to the granodiorite gneiss (10), but is perhaps slightly younger.

At Mystery Lake the foliated mafic sills which occur in the Assean Lake group may have been intruded before the Hudsonian orogeny, as the Assean Lake group is considered to be early Lower Proterozoic. However, similar narrow sills occur in the gneiss northeast of Mystery Lake and appear to have intruded the gneiss during the final stage of its formation, indicating a later Lower Proterozoic age.

The distribution of the serpentinized ultramafic rocks along the axis of the gravity low which outlines the gneissic belt suggests that they were intruded during the Hudsonian orogeny. The serpentinite underground at Thompson is cut by pegmatite. Elsewhere in the gneissic belt the serpentinites intrude gneiss, are cut by pegmatite, and possibly occur as inclusions in the grey granodiorite (11).

Geological evidence, which will be discussed later, suggests that the forces which were responsible for the major faults in the map-area were also responsible for the tensional direction now occupied by the Cuthbert Lake dyke swarm (13) as well as northwest-striking diabase dykes.

The red biotite granite (12) cuts most of the other rock-units in the map-area. A red pegmatite, believed to be related to the red biotite granite (12) is reported to be 1770 million years old (Hurley et al., 1959).

The northwest-striking diabase dykes cut all of the rock-units including the red biotite granite (12) and may actually be younger than late Lower Proterozoic.

Much of the following descriptions of, and conclusions regarding, the mafic and ultramafic rocks is a condensation from the work of J. A. McDonald (1969). To this has been added new material collected during the two years since McDonald's study was completed.

Serpentinized Peridotite (9)

Only a few small exposures of serpentinized peridotite were seen in the Thompson-

Moak map-area. The best exposures are on the southwest shore of Mystery Lake. A few small exposures of serpentinized peridotite, less than 25 feet long, are present on the banks of the Burntwood River and Buckingham Lake. Serpentinized peridotite or serpentinite is also present underground in the Moak Lake and Thompson nickel deposits, but is not exposed at the surface. Diamond drilling along the northeasterly-striking belt of rocks has outlined other peridotite bodies which do not outcrop. The zone of serpentinized peridotite outlines the Manitoba nickel belt.

Unlike the peridotite of the Cuthbert Lake swarm (13), these ultramafic rocks are highly sheared and serpentinized. Locally, pseudomorphs of secondary minerals may be present, but generally the ultramafic rocks are composed wholly of serpentinite that is strongly orientate due to shearing.

The serpentinite has been intruded as long sinuous sill-like bodies, in many places adjacent to or near the contact between sedimentary rocks (5) and gneiss.

Moak Lake Serpentinite

The Moak Lake serpentinite does not outcrop, but lies about 3,000 feet north of Moak Lake along the northeast extension of the sedimentary rocks outcropping at Mystery Lake.

The serpentinite occurs as an elongated more or less concordant body within the sedimentary rocks. It pinches and swells, has a maximum width of about 500 feet, and a probable length of about one mile.

Three drill sections of samples of the serpentinite were supplied by The International Nickel Company of Canada Limited for the use of J. A. McDonald (1960). These three sections represent the serpentinite body from hanging-wall to foot-wall (McDonald, 1960).

The dominant mineral in the serpentinite is a light to medium green serpentine. Carbonate veinlets are common and hematite stains are present along shear surfaces, and as small flecks throughout the core. Small veinlets of serpentine, locally chrysotile, occur. Sulphides are present as disseminations and along small shears.

No primary minerals were seen in thin sections of the serpentinite. However, distinct pseudomorphs of antigorite and serpophite after olivine, and serpentine after pyroxene were recognized in unsheared specimens. The pyroxene and olivine pseudomorphs were recognized by differences in distribution of secondary magnetite (McDonald, 1960). The rock was probably largely composed originally of olivine crystals. The sheared portions are composed of strongly orientated antigorite, disseminated carbonate, chlorite, and rarely, actinolite.

Pyrrhotite and/or pentlandite are the only sulphide minerals seen as separate grains within and along the borders of olivine pseudomorphs. It is also associated with magnetite, and in this case, the two metallic minerals form one grain with an irregular contact between them. It is possible that the pyrrhotite has formed from the alteration of magnetite. However, most of the magnetite is a secondary product resulting from serpentinization.

A chemical analysis of the Moak Lake serpentinite was made from a composite sample of drill hole number 12993 between footages of 320 and 670 feet inclusive (See table 2). Specimens through this interval were relatively weakly sheared. Care was taken to eliminate veinlets of secondary material.

Mystery Lake Serpentinite

Sulphide-bearing ultramafic rock outcrops on the southwest shore of Mystery Lake. It is dark grey, brownish weathering, medium-grained, massive, largely serpentinized peridotite which generally has a pitted weathered surface. Marked changes in grain size were not observed but, locally, parts are slightly coarser grained or more pitted than others. The dominant joint direction is east with dips steeply to the north. Minor fractures are common as are small veinlets composed of carbonate, with minor amounts of sulphide, magnetite, and serpentine. Much of the outcrop contains sulphides. Pyrrhotite and pentlandite were the only sulphide minerals recognized and they commonly outline the ferromagnesian minerals. An old pit is present in the serpentinite; at the time of this investigation, it was filled with water.

The rock consists largely of serpentine, pseudomorphic after olivine, clinopyroxene, and orthopyroxene. Rounded grains of olivine and remnant grains of pyroxene are present. Magnetite and sulphides make up the remainder of the rock and occupy the interstices between olivine crystals. Pyrrhotite, pentlandite, pyrite, chalcopyrite, and sphalerite were recognized in polished sections by Gill (1951).

Serpentinite outcrops on an island east of the nickel showing. It is a fine-grained, dark green to black rock which weathers brown. Red hematite stains occur along fractures. The rock at the south end of the island appears to be less mafic and contains feldspar.

Drill core found on the shore of Mystery Lake commonly contains lengths of highly sheared serpentinite. Some of the serpentinite contains open fractures and is highly leached.

Foliated Amphibolitized Mafic Rocks

Numerous foliated amphibolitized mafic bands occur within the sedimentary rocks (5) at Mystery Lake, and their extension northeast of Mystery Lake. A few bands of similar rock occur in the sedimentary rocks (5) at Ospwagan Lake. None of these are shown on the accompanying map.

The mafic rocks at Mystery Lake vary from slightly foliated, medium-grained, dark green dioritic and gabbroic rocks to highly schistose rocks. They vary in width from a few feet to 100 feet. All exposed contacts are sharp and commonly slightly sheared. A light green pleochroic amphibole, probably actinolite, makes up about 65 per cent of a typical specimen. The amphibole has the typical fibrous patchy appearance of secondary amphibole. No pyroxenes were seen in thin sections by the writer, but Gill (1951) reports the presence of remnant grains of clinopyroxene in specimens taken from these mafic rocks. Plagioclase occurs as recrystallized anhedral, fine-grained, generally untwinned grains with a composition between calcic oligoclase and andesine. It generally makes up about 35 per cent of the rock. Magnetite, sphene, and sulphides are common accessory minerals. Locally, biotite and chlorite, secondary after amphibole, may be present. Quartz is not common, but it does occur, particularly in sheared sills.

A few of the mafic bands in the sedimentary gneiss (7) on the east side of Mystery Lake have textures similar to the mafic rocks in the sedimentary rocks (5) and appear to be slightly different than the typical amphibolite bands (8) which are common to the sedimentary gneiss.

Both Dawson (1952) and Gill (1951) reported the presence of mafic volcanic rocks interbanded with the sedimentary rocks (5) at Mystery Lake. However, it is possible that these mafic rocks are sheared sills. Hand specimens from known sheared mafic sills are identical with the green schistose rocks formerly mapped as volcanic rocks. Thin sections of both types are also essentially identical. Small, poorly formed structures, suggestive of pillows, are present on a small portion of the outcrop which makes up the long point west of the nickel showing at Mystery Lake but these are very similar to small weathered-out elliptical fractures that occur in the mafic sills. In addition, the highly sheared rock on the western side of the point quickly grades, in one small section, into a rather coarse-grained rock identical to known mafic sills. The writer cannot offer any suggestion for the almond-shaped amygdaloid-like structures which occur in the same outcrop.

A large part of the map-area is underlain by gneissic granitic rocks whose bulk composition is that of a granodiorite, but which locally varies from a granite to a quartz diorite. All outcrops included within this rock-unit are foliated and many are poorly and discontinuously banded. The banding is commonly accentuated by sills of pegmatite and, to a much lesser extent, by inclusions and rarely by bands of amphibolite. Outcrops are generally medium-grained and grey in colour but locally may be tinged slightly pink or orange. Included within this map-unit are many small outcrops or inclusions of sedimentary gneiss and areas underlain by an intimate mixture of granodiorite gneiss and granitized phases of sedimentary gneiss (6, 7).

Mineralogically, the granodiorite gneiss (10) can be classified as either a high- or low-potash variety. There appears to be no systematic distribution to these two varieties and the low-potash variety is by far the most abundant. The following table presents visual estimates of the minerals in thin sections:

	Low-Potash Variety			High-Potash Variety		
	Low	High	Average	Low	High	Average
Plagioclase	35	65	50	10	55	30
Quartz	20	45	35	20	40	30
Microcline	tr	10	tr	5	50	30
Biotite	2	15	12	tr	15	8

An uncommon type of the low-potash variety is high in amphibole and low in biotite, but with approximately equal amounts of plagioclase and quartz. Accessory minerals in the granodiorite gneiss (10) are magnetite, apatite, sphene, zircon, sulphides, and locally, garnet. The minerals in the amphibole-rich type appear to have the same characteristics in hand specimen and thin section as the ones rich in biotite.

The plagioclase is generally light grey, yellowish or brownish in hand specimen but is unlike the typical honey-coloured plagioclase in the charnockite (4). The plagioclase occurs as anhedral poorly twinned grains which, though they may show minor alteration to fine-grained white mica and to a lesser extent epidote or calcite, are rarely extensively altered. Typical specimens have a few bent twin lamellae and the grains appear to be slightly zoned, or have an undulatory extinction, probably the latter. Plagioclase occurs as augens in sheared gneiss. Antiperthite is rare.

Typically, the quartz has a light smoky grey colour in hand specimen. In thin section the quartz appears as clear anhedral elongate grains with an undulatory extinction. In sheared outcrops the quartz commonly occurs in small ribbons or lens-like masses. In most outcrops the quartz accentuates the foliation caused by biotite.

Generally, the microcline is slightly pink or orange coloured in hand specimens but grey microcline was also observed. In thin section the microcline appears to be poorly twinned or untwinned, unaltered, anhedral, and interstitial. Commonly the twinning is vague and gives grains an undulatory type of extinction. Augens of microcline are more common than augens of microperthite.

The biotite occurs as fine-grained finely divided flakes or in small thin lenses. It is strongly pleochroic in light and dark brown and rarely is reddish or greenish coloured. Pleochroic haloes are not uncommon and locally the biotite may be partly altered to chlorite, magnetite, and sphene.

Amphibole locally is prominent in rocks low in potash feldspar. It occurs as small anhedral to subhedral grains which are pleochroic in greens, rarely brownish greens. Locally the amphibole is a secondary mineral.

Garnet generally occurs as small distinct pinkish or reddish coloured grains which are colourless in thin section. They are relatively common in the gneisses on the banks of the Burntwood River between the outlet of Mystery Lake and the large bay in Apussigamasi Lake.

Though this rock unit (10) appears to be largely of igneous origin, substantial amounts of granitized sedimentary rocks are present. All gradations between sedimentary gneiss (7) and granodiorite gneiss (10) have been observed and commonly the classification of an outcrop is arbitrary and depends on the size and the condition of the exposed surface.

Long bands of amphibolite (8) are locally present in the granodiorite gneiss (10). The amphibolite bands appear to be identical to those in the sedimentary gneiss (7). In a few outcrops, these bands are 100 feet long and less than a foot wide. Small inclusions are common in the granodiorite gneiss (10) and vary in composition from a quartz diorite to a meta-hornblendite.

Grey Granodiorite (11)

Only one large body of rather massive to slightly foliated grey granodiorite (11) is outlined on the accompanying map. It is a north-striking mass about five miles long with a maximum width of 1½ miles, situated approximately four miles southeast of Thompson. Typical outcrops are smooth, relatively massive, and light grey in colour. It is generally composed of about 60 per cent sodic plagioclase and 30 per cent quartz, with about equal amounts of microcline and biotite making up the rest of the rock. Biotite occurs as scattered flakes, which along with the quartz, give the rock a faint foliation. Local pegmatitic phases are present, generally lie parallel to the foliation, and have gradational boundaries with the grey granodiorite. Locally, a few phenocrysts of feldspar, rarely exceeding 1½ inches in cross-section, are present. Red pegmatite dykes, sills, and stringers cut the grey granodiorite. A few small well-banded inclusions of gneiss have been seen in the grey granodiorite. Characteristically, the grey granodiorite is low in biotite, generally less than five per cent, and unlike the granodiorite gneiss (10) rarely contains inclusions.

The age of the grey granodiorite body is not certain. However, it appears to be younger than the granodiorite gneiss (10) and the plagioclase-quartz-biotite gneiss (7). It seems likely that the grey granodiorite is a pure phase of the granodiorite gneiss (10), that is, the granodiorite gneiss is probably the gneissic and impure equivalent of the grey granodiorite (11).

Outcrops of grey granodiorite occur on the east shore of Southwest Bay at Mystery Lake, beneath the bridge across the Burntwood River at Thompson, and west of the southwest end of Mystery Lake. Though these outcrops are low in biotite and free from inclusions, they have a much higher content of potash feldspar than normal. They may represent a part of a body similar to that southeast of Thompson and as such are responsible for the separation of the sedimentary rocks at Mystery Lake by intrusion.

Red Biotite Granite and Pegmatite (12)

The red biotite granite (12) forms a wedge-shaped mass, about eleven miles long with a maximum width of about four miles, which outcrops in the south-central part of the map-area. It occupies the northeast end of a granite batholith which extends for almost thirty miles to the southwest and is exposed along much of the northern and western shores of Wintering Lake. Although the accompanying map and table of formations lists the red biotite granite as older than the Cuthbert Lake dykes, it may in fact be younger.

Specimens of the red biotite granite (12) are generally medium grained, foliated, and pinkish red to red-brown in colour. Outcrops of porphyritic granite are common; the phenocrysts of microcline are generally twice as large as the matrix minerals. Locally, the red biotite granite (12) is fine- or coarse-grained. Massive outcrops are more common in the central part of the pluton, and strongly foliated phases occur along its margins.

Red to pink microcline is the dominant mineral and occurs as anhedral, clear, well-twinned, and unaltered perthitic grains. Locally, it contains a few inclusions, generally of plagioclase. Commonly the edges of the microcline grains are slightly recrystallized and one specimen contained minor microbreccia.

Plagioclase is grey to white in hand specimen, but appears dusky and brownish in thin section. It generally occurs as anhedral, poorly twinned grains which are commonly slightly altered to fine-grained white mica and calcite. Recrystallized edges, inclusions of microcline, and wormy intergrowths with quartz also occur. In a few specimens, bent twin lamellae are present. Several specimens of biotite granite located outside of the main mass have clear rims of an unidentified feldspar around cloudy, partly altered plagioclase. These rims are commonly best developed adjacent to microcline.

The quartz is clear to grey in hand specimens and appears in thin sections as clear anhedral grains with an undulatory extinction. In sheared specimens, the quartz appears to "flow" around eyes of feldspar.

Biotite occurs as finely divided flakes which are generally almost entirely altered to chlorite, magnetite, and sphene. Unaltered grains are strongly pleochroic in light to dark brown. Accessory minerals are apatite, zircon, and rarely, primary magnetite. The following is a visual estimate, made from thin sections, of the major minerals which occur in the red biotite granite (12).

	Low	High	Average
Microcline	20	55	45
Plagioclase An_{20-25}	20	50	25
Quartz	20	30	25
Biotite	tr	15	5

Inclusions are common along the margins of the red biotite granite (12) and rare in the central parts. The most common and largest inclusions are of granodiorite gneiss (10) whose foliation is generally parallel to the foliation of the red granite. Sharp contacts are present but there is generally a narrow reaction zone between the inclusion and the red biotite granite (12). Reaction zones up to eighteen inches wide have been observed but much narrower ones are more common. Locally, inclusions make up more than one-half of an outcrop. Mafic inclusions are generally small and in many cases are distributed in a manner which suggests that they represent the remnants of broken and invaded dykes. Some inclusions, both granitic and mafic, located near the margins of the red biotite granite are sheared and folded. Some of the granite dykes are also folded indicating that movement along the fault into which this red biotite granite was probably intruded did not cease until after the intrusion of the granite. This is also suggested by the northeast-striking shears common to both sides of the granite. The red biotite granite is thought to have been intruded into the southern extension of a major fault which is discussed in Chapter III. Joints in the red biotite granite generally have a steep dip and strike northeast or northwest.

Small stocks, dykes, sills, and stringers of red biotite granite (12) intrude most rock types except the northeast-striking diabase dykes.

Pegmatite is widely distributed throughout the map-area. It is of two main types, red and white, which locally appear to grade into one another. This suggests that the white and red pegmatite have a common origin. However, the white pegmatite appears to be older than the red pegmatite as crosscutting relationships were observed in places.

Though the red pegmatite cuts the red granite (12), it may have been derived from it. Typically, the red pegmatite occurs as sills, though small stringers and dykes are relatively common; it is composed chiefly of red potash feldspar, commonly a perthite, with lesser amounts of quartz and plagioclase. The latter, along with biotite, is commonly present only as an accessory mineral. Books of biotite, up to three inches across are present locally, as are small amounts of graphically intergrown feldspar and quartz. Zoned pegmatites, consisting of a quartz core and a feldspar border are rare. In the larger dykes, up to ten feet wide, feldspar crystals approximately six to ten inches long are relatively common.

Where dykes or sills of red pegmatite are found in mafic gneisses they commonly are richer in biotite than is normal and in some cases contain amphibole and magnetite.

Peridotite, Olivine Gabbro, Gabbro (*13*)

(*Cuthbert Lake Dykes*)

The Cuthbert Lake dyke swarm refers to the series of ultramafic dykes trending northeast through Cuthbert Lake and includes numerous northeast-striking gabbro dykes associated with the main zone of ultramafic intrusions. Both the ultramafic (peridotite) and mafic (gabbro) dykes of the Cuthbert Lake swarm differ from other ultramafic and mafic dykes in the area in that they are almost completely unaltered. Dykes similar to those at Cuthbert Lake are abundant at Pikwitonei Lake and are included in the same map-unit.

The most prominent feature of the dyke swarm is the large northeast-striking peridotite mapped by Dawson (1952) which extends from Cuthbert Lake to Begg Lake. Detailed mapping by McDonald (1960) showed that this is not a continuous dyke, but rather represents several dyke segments arranged "en echelon," each segment having a more northerly strike than the general trend of the break which the peridotite occupies. The maximum exposed width of the largest segment is less than 200 feet. Gradations from a true ultramafic rock to a mafic gabbro were seen in individual outcrops. Also, variations from the margins of outcrops to interior portions are present and although in no way regular, indicate progressive differentiation of the rock. Similar large dykes occur at Pikwitonei Lake.

Outcrops of peridotite have a dark brown to black, finely pitted, weathered surface and the rock is extremely tough and hard to break. Exposures are commonly low, smoothly rounded, and elongated parallel to their strike. Specimens generally appear to be fine grained at first sight, but actually are medium to coarse grained.

The only consistent structural feature of the peridotite dykes is the presence of joints. At least one set of joints is present in each outcrop and up to four sets may be present. The most common joints are steeply dipping and are either parallel to or perpendicular to the strike of the dyke.

Major minerals in the peridotite are olivine, hypersthene, augite, and diopside. Minor amounts of primary amphibole, plagioclase, magnetite, spinel, and sulphide are present. An increased plagioclase content and a corresponding decrease in ferromagnesian minerals characterizes the olivine gabbro. Although the peridotite is relatively fresh, alteration occurs in varying degrees: olivine to serpophite, antigorite, and magnetite; hypersthene to antigorite and magnetite, or amphibole and magnetite; and augite and diopside to amphibole. The mineral content of the ultramafic rocks varies as follows:

Olivine	15%		60%
Hypersthene	8	-	20
Clinopyroxene	15	-	57
Plagioclase	5		15
Hornblende	5	-	

McDonald distinguished two ages of olivine and hypersthene. He also reports that though the composition of the plagioclase ranges from An_{44} to An_{72}, it is generally very constant, ranging from An_{65} to An_{70}. Sulphides are rare in outcrops and thin sections.

The mafic dykes vary from less than one foot to 200 feet wide, but generally are less than 20 feet wide. Typically, specimens are medium grained and the minerals equiangular; diabasic and porphyritic textures are common. Outcrops are dark green to greenish black in colour, and generally only plagioclase and a green pyroxene can be recognized in hand specimens. Chilled margins are relatively common; the margins of porphyritic dykes generally contain smaller phenocrysts of pyroxene than those in the centre of the dykes.

The dykes are intruded "en echelon." In several outcrops, dykes were seen which terminated abruptly against gneiss, with a small unsheared feeder, parallel to the gneissosity, linking it to another abruptly terminated dyke of similar size. Feeders up to 20 feet long were seen. This "en echelon" pattern of the dykes makes the tracing of individual dykes extremely difficult because, though several outcrops may be of the same dyke, the straight line between them does not necessarily mark the trace of it.

The minerals in the mafic dykes are essentially the same as those in the ultramafic dykes. The most characteristic difference between the mafic and ultramafic dykes is in the proportions of the constituent minerals and the resulting change in texture. Mafic dykes contain an average of 45 per cent plagioclase, but 50 per cent plagioclase is not rare. Plagioclase generally occurs as individual, commonly lath-shaped, zoned, dusty grains with a composition between sodic bytownite and calcic labradorite. The minor plagioclase in the peridotite is unzoned and less dusty than that in the mafic dykes.

Olivine and hypersthene are generally rare in the mafic dykes, but in some specimens form as much as 15 per cent of the rock. When present, they are euhedral and always show partial to complete alteration to amphibole or serpentine.

Clinopyroxene is present in all of the mafic dykes. Some outcrops are characterized by numerous clinopyroxene phenocrysts up to half an inch long. These euhedral to subhedral phenocrysts are in some cases partly to completely altered to uralitic amphibole. Clinopyroxene was either the first or second mineral to crystallize, alternating with plagioclase in this respect.

Primary minerals found only in the mafic dykes are quartz, which may form up to 10 per cent of the rock, and accessory amounts of biotite, apatite, and either ilmenite or titaniferous magnetite.

Amphibole is present both as a primary and secondary mineral. The primary amphibole has a definite brownish tinge. Secondary amphibole is present generally as uralite associated with clinopyroxene, but also as thin, fine-grained rims around pseudomorphs of uralite.

McDonald (1960) states that titanium is more common in the mafic dykes than in the ultramafic dykes. This is indicated by the purplish tinge common to the clinopyroxene in some specimens, secondary sphene associated with the alteration of primary to secondary amphibole, and the ilmenite or titaniferous magnetite, commonly with leucoxene; these features are not present in the peridotite.

Sulphides were seen in outcrops and in thin sections. Pyrite, pyrrhotite, and chalcopyrite were identified. At several locations, sulphide bearing dykes have been trenched. None of these showings appear to be of economic significance.

Distinctions between the Moak Lake (9) and Cuthbert Lake (15) Ultramafic Rock

Although both the Moak Lake (9) and Cuthbert Lake (15) rocks are ultramafic, there is a marked difference in the original composition of these two rocks. In unsheared specimens of the Moak Lake serpentinite, McDonald (1960) was able to distinguish the original mineral content by the outlines of the pseudomorphs, and showed that the original rock was composed largely of olivine with minor pyroxene and oxides. The Cuthbert Lake peridotite has a much more varied mineral content; commonly pyroxene is the dominant mineral. The peridotite grades locally into mafic gabbro. A strong orientation is visible in the olivine pseudomorphs in the Moak Lake serpentinite and though an orientation is present in the Cuthbert Lake peridotite, it is much less prominent. The minerals in the Cuthbert Lake peridotite are fresh or only slightly altered, whereas the Moak Lake serpentinite is composed wholly of secondary minerals.

The CaO and Al_2O_3 contents (Table 2) of the Moak Lake serpentinite are much lower than the corresponding values for the Cuthbert Lake peridotite. In addition, the Mg:Fe ratio for the Moak Lake serpentinite is much higher than that of the most ultramafic rock available from the Cuthbert Lake dyke swarm.

The Moak Lake serpentinite occurs along a major structural break and is highly sheared, especially along the borders. However, the Cuthbert Lake peridotite and its associated dyke swarm have a general distribution over a large area, and shows no evidence of major shearing. In addition, the Moak Lake serpentinite has no large volume of associated mafic rocks even if the foliated and amphibolitized mafic sills at Mystery Lake are considered to be related to it.

All of the above facts, compared with the criteria established by Hess (1955) for distinguishing between "Alpine-type" and "Bushveld-type" ultramafic rocks, led McDonald (1960) to the conclusion that the Moak Lake serpentinite is of the "Alpine-type" and the Cuthbert Lake peridotite is of the "Bushveld-type."

TABLE 2

Chemical Analyses of Ultramafic and Mafic Rocks[1]

	1)	2)	3)
SiO_2	36.46	42.21	48.76
Al_2O_3	3.00	5.92	14.01
Fe_2O_3	6.48	2.96	3.94
FeO	3.65	7.25	7.46
CaO	0.76	4.68	13.55
MgO	35.65	29.07	6.90
Na_2O	0.03	0.70	1.68
K_2O	0.02	0.21	0.13
H_2O +	10.92	5.06	0.52
H_2O	0.28	0.20	0.41
TiO_2	0.15	0.30	0.57
P_2O_5	0.05	0.03	0.06
MnO_2	0.09	0.16	0.15
CO_2	0.80	0.15	0.15
S	0.50	0.07	0.08
NiO	0.91	0.48	trace
Cr_2O_3	0.44	0.36	0.16
Total	100.23	99.81	N.D.
Less	0.19	0.03	
Total	100.04	99.78	98.53

1) Moak Lake serpentinite.

2) Cuthbert Lake Peridotite, by S. Courville, Analytical Chemical Division, Geological Survey of Canada.

3) Mafic dyke of Cuthbert Lake Swarm, by D. Brown, Assay Laboratory, Manitoba Mines Branch.

[1] After I. A. McDonald, 1960.

Diabase Dykes

About twenty northwest-striking diabase dykes, which are not represented on the accompanying map (60-4), were found in the area west of the red biotite granite (12), at Bryce Bay, McKillop Lake and northwest and north of the Burntwood River. Locally on the banks of Natawahunan, Pikwitonei and Cuthbert lakes thin fine-grained, slightly porphyritic trap dykes were found crosscutting typical dykes of the Cuthbert Lake dyke swarm. These trap dykes are similar to the northwest-striking diabase dykes found in the western half of the map-area, and though mineralogically they are almost identical to the Cuthbert Lake dykes they generally have a slightly higher magnetite content.

Most of the diabase dykes were seen at Mystery Lake; however single dykes were found at Moak Lake and on the bank of the Grass River near the red biotite granite (Figure 1). Generally these rocks are fine-grained dark green and dense with a texture that varies from that of a diabasic gabbro to one typical of very fine-grained trap rocks in which a few small phenocrysts occur. Although the dykes range in width from six inches to 100 feet, few exceed five feet. The strike of the dykes varies from N80°W to N30°W and all measured dips are steeply to the southwest. Fine-grained margins are present in some of the dykes. Though the fine-grained margin on the largest dyke was only six inches wide the grain size increased for six feet towards the centre of the dyke before it became constant. Many of these dykes are magnetic.

The strike of the dykes is approximately parallel to the northwest trend of two marked airborne magnetic anomalies situated northwest of Mystery and Moak lakes. At Mystery and Moak lakes the diabase dykes occur within the area outlined by these magnetic anomalies. The anomalies extend for at least twelve miles northwest from the shores of Mystery and Moak lakes but their extension southeast to the charnockite is much less marked. The northwest-trending anomalies probably outline weak zones of tensional origin into which many small mafic dykes have been intruded and may be related to the major faulting believed to have occurred in the area. A similar but less pronounced anomaly strikes northwest from the shores of Birchtree Lake, just west of the Thompson-Moak map-area.

CHAPTER III

STRUCTURAL GEOLOGY

INTRODUCTION

The structural complexity of Thompson-Moak map-area may be attributed to the fact that it lies in the strongly deformed belt of rocks which occurs along the junction of the Superior and Churchill provinces. It is believed by Wilson and Brisbin (1961) that this strongly deformed zone represents the roots of an ancient mountain chain.

Reliable marker horizons are absent and bedrock exposures are sparse throughout the area. Consequently a complete solution of the structure is not possible. However, a broad but incomplete structural analysis of the map-area is possible.

Structurally the Thompson-Moak map-area can be divided into three main zones, an east block (Archaean) and a west block (Proterozoic) separated by a central zone which appears to be common to both. The marked structural differences between the Archaean and Proterozoic blocks is well illustrated by: Figure 1, showing distribution of mafic dykes; Figure 2, showing structural trends compiled from observations on rock outcrops; Figure 3, showing drag-fold structures; and Figure 4, showing magnetic trends compiled from aeromagnetic maps of the area.

The central zone is a belt of highly deformed north- to northeast-striking rocks about 45 miles long with a maximum width of two miles. It extends from the northeast corner of the map-area, southwest parallel to the Burntwood River for about twenty miles to the large southeast-trending bay in Apussigamasi Lake, then southeast passing southwest of McKillop Lake and finally almost due south passing just west of and including most of Bryce Bay to the red biotite granite (12). Field evidence, such as the reversal in the direction of the plunge of drag-folds, and abrupt changes in regional trends suggests that a major structural break is responsible for this central zone.

The west or Proterozoic block includes all of the area north and west of the central zone and is characterized by steeply dipping and plunging isoclinally folded rocks with a north to northeast strike; a metamorphic grade of middle to upper amphibolite facies; and a lack of both the pyroxene-bearing granitic rocks and the dykes of the Cuthbert Lake dyke swarm. These rocks are on strike with known Lower Proterozoic igneous and metamorphic rocks both to the northeast and southwest. These igneous rocks were intruded, and the metamorphic rocks formed, during the Hudsonian orogeny as defined by Stockwell (Lowdon, 1961) and as such are considered to belong to the Churchill province.

The east or Archaean block includes all of the area southeast and east of the central zone. It is characterized by: steeply dipping and steeply plunging isoclinally folded rocks with an easterly trend which appears to pass unbroken into the Superior province; a metamorphic grade of the pyroxene granulite facies; pyroxene-bearing granitic rocks and the Cuthbert Lake dyke swarm. Secondary minerals pseudomorphic after pyroxene occur generally in the western part of the east block suggesting that the destruction of the pyroxene is related to the major structural boundary which apparently forms the central zone. Lowdon (1961) published an age of 2400 million years (G.S.C. 60-83) for a pyroxene granite from the north shore of Dafoe Lake, approximately thirty miles east of the eastern boundary of the Thompson-Moak map-area, which indicates the granite lies within the Superior province. None of the known granitic rocks believed to have been formed or intruded during the Hudsonian orogeny contain hypersthene. The dated Archaean rock contains hypersthene and is similar to the pyroxene-bearing granites of the east block; these pyroxene-bearing granites therefore, are believed to be Archaean and belong in the Superior province.

ARCHAEAN BLOCK

FOLDING

The east or Archaean block is mainly composed of well-foliated to poorly banded westerly-striking rocks which belong to the charnockite suite (4). These westerly-striking rocks terminate abruptly to the west (McKillop Lake, Bryce Bay, and Partridge Crop Lake), across a width of less than one-half mile, against the north- to northeast-striking rocks of the central zone (Figure 2).

South of Bryce Bay the rocks of the east block appear to have been dragged to the south; north of Isbister Lake they appear to have been dragged to the north (Figure 2). At Gostling Lake, which lies in the bulge caused by the right-angled turn in the central zone, there is no indication of dragging.

One of the dominant features of the east block is the consistent north dip of all of the rocks south of Natawahunan Lake and southeast of Bryce Bay (Figure 2). However, a consistent south dip, or locally a mixture of north and south dips, is present on strike with the north-dipping rocks adjacent to the red biotite granite (12). The maximum width of this reversal zone is approximately one and one-half miles. If this reversal is due to a fault which may separate the east and west blocks, and not to the intrusion of the red biotite granite (12), then a rotary movement is indicated.

Between Buckingham Lake and the north shore of Begg Lake a consistent dip to the south is present, indicating that a nearly vertical east-trending synclinal axis is present south of Buckingham Lake and north of Natawahunan Lake. Local reversals in this area indicate that the trough of this fold has minor flexures.

In the east block 83 per cent of the 124 drag-folds on which the relative movement was recorded have a right-handed movement (Table 3). The bulk of these drag-folds were recorded from rocks along or south of the synclinal axis and have the relative movement expected on the southeast limb of a northeast-plunging syncline. North of Bunn Lake and Buckingham Lake there are very few outcrops, but dips suggest the rocks form broad steep folds.

Of 128 plunges of drag-folds measured in the east block 72 per cent are to the east or northeast (Table 3). All drag-folds have moderate to vertical plunges. Commonly the west- or southwest-plunging drag-folds are localized. The plunges indicate that the east block is probably a tightly but broadly folded sequence of rocks which plunges steeply east to northeast with local westerly-plunging flexures.

FAULTING

The east block is cut by numerous small faults and shears. Small faults with a displacement of a few inches to a few feet generally strike approximately northeast or northwest and have steep dips. A few more right-handed than left-handed faults were observed.

Small shear zones are numerous and generally strike parallel to or slightly more northerly than the country rocks. These shears have steep to vertical dips. Though shear zones are common only a few breccia zones were seen; two of these were cemented by fine-grained trap rock.

Strong shearing is present in the rocks at the northeastern outlet of Natawahunan Lake. Mylonitized rocks and sheared granodiorite gneiss, both probably derived from pyroxene "gneiss" (1), are present. Similar, but less sheared, outcrops occur westward along the shore of Natawahunan Lake along with pseudo-charnockite (4a) and pyroxene-bearing granitic rocks (1). The rocks on the shores of the narrow east-trending stretch of water south of Bryce Bay are also highly sheared.

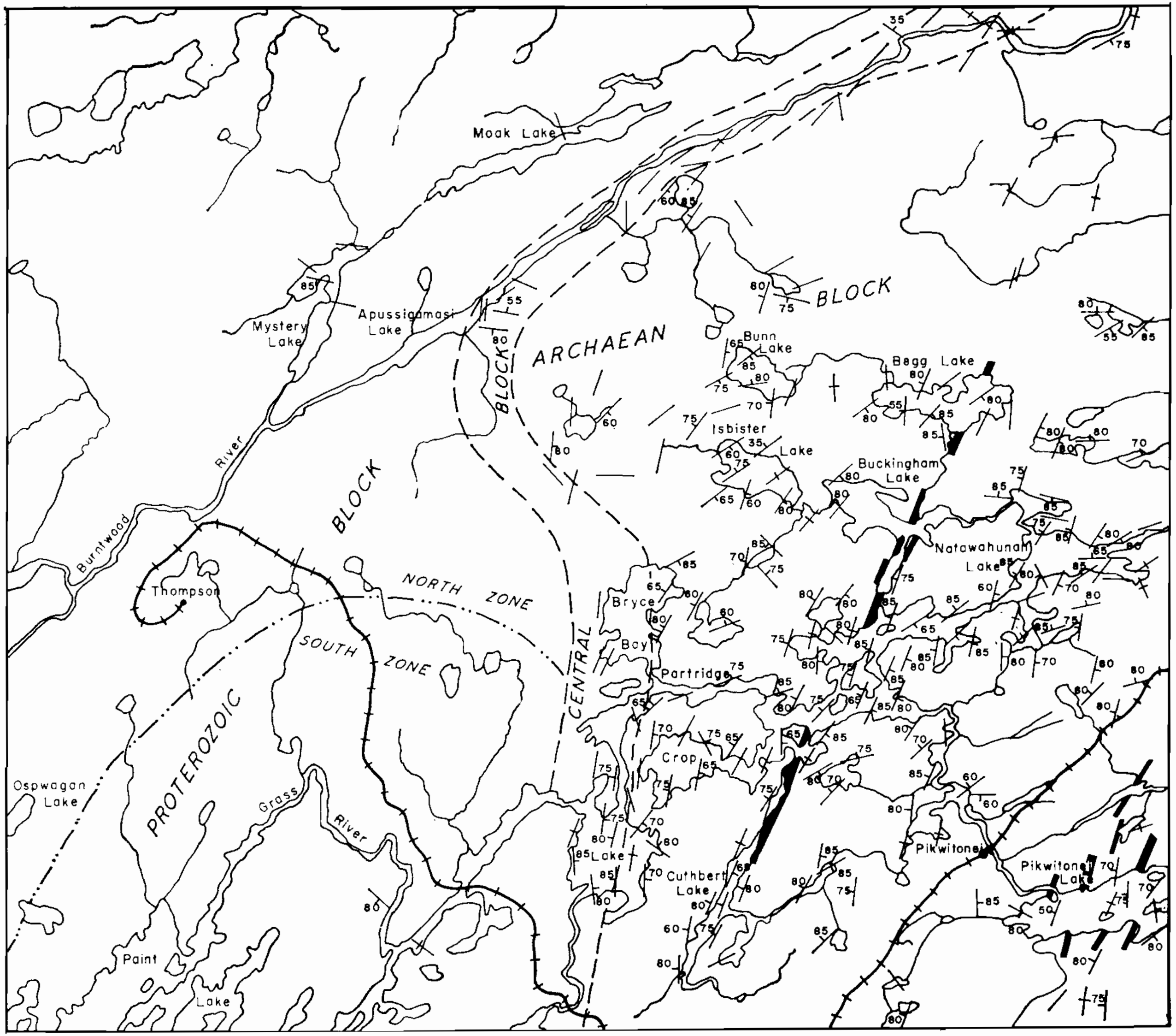

Figure 1. Distribution of mafic and ultramafic dykes.

At that locality a small body of sheared and pegmatized meta-gabbro (3a) occurs. It appears that an easterly-striking shear zone extends from the nose of the red biotite granite (12) northeast along or underlying the bodies of water mentioned above.

The presence of sheared outcrops on the banks of Moffat Creek suggests that the creek may be underlain by a fault or shear zone. This is supported by the narrowness, straightness, and depth of the creek valley.

Sheared charnockite (4), granodiorite (4b), and mafic sills (13) in Pikwitonei Creek south of Pikwitonei Lake suggests the presence of a northeast-striking shear zone, similar to that thought to underlie Moffat Creek.

The three shear zones described above are essentially parallel and the presence of sheared rocks of the Cuthbert Lake dyke swarm (13) indicates that the shearing (i.e., feather faults) is late and is probably related to the main zone of dislocation between the east and west blocks.

TABLE 3

Distribution of Drag-folds

Area	Plunge					Relative Movement		
	No.	N-NE	S-SW	E-NE	W-SW	No.	Right-handed	Left-handed
Archaean	138			72%	28%	124	83%	17%
Central	67	42%	58%			67	69%	31%
Proterozoic								
North	125	86%	14%			105	57%	43%
South	33	79%	21%			12	17%	83%

CENTRAL ZONE

The central zone occupies a strip of ground, between the east and west blocks, approximately 45 miles long and less than two miles wide (Figure 3). It is characterized by steeply dipping granitic and sedimentary gneiss with minor amphibolite and amphibolitized mafic dykes and sills. No pyroxene-bearing granitic rocks were found in this zone but locally the distribution of the ferromagnesian minerals is similar to that found in the pseudo-charnockite (4a). The bulk of the rocks in this zone are considered to be remetamorphosed Archaean rocks; however there exists the possibility that the granodiorite (4b) does not represent altered charnockite (4) but rather is a border phase of the granodiorite gneiss of map-unit 10.

Locally the rocks within this zone are schistose, but generally they are similar to although more contorted and chloritic than the rocks in the west block. One small highly garnetiferous island outcrop in the large southeast-trending bay in Apussigamasi Lake is highly sheared and contorted and probably lies very close to the proposed fault which appears to be responsible for the central zone.

Like the Proterozoic and Archaean blocks the central zone is folded into vertical to near vertical folds. However, unlike the Proterozoic and Archaean blocks the predominant plunge direction of the drag-folds is to the south or southwest (Table

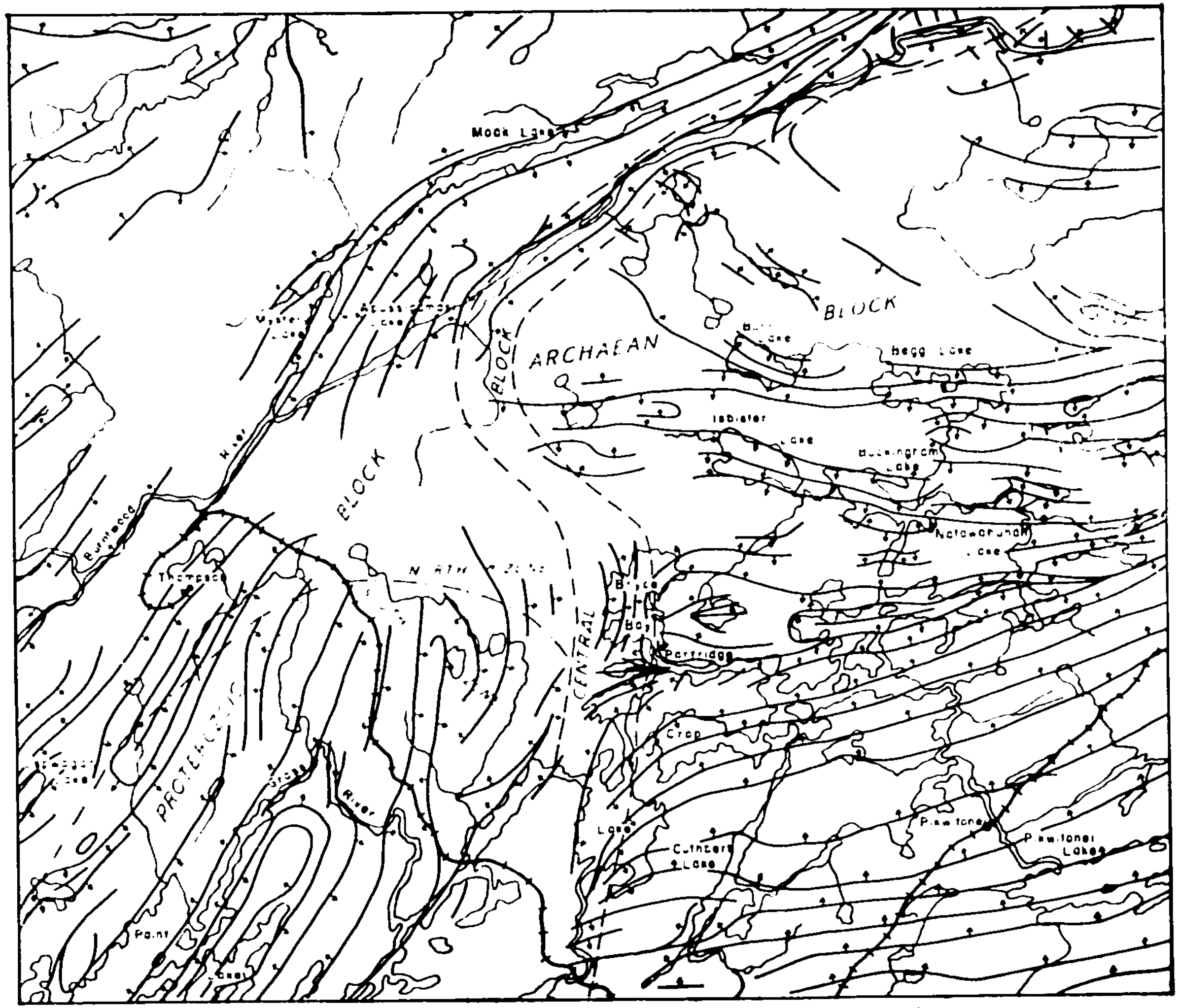

Figure 2. Structural trend map from field observations and aerial photographs.

3). Of the 67 measured plunges of drag-folds within this zone 58 per cent plunge to the south or southwest. All of the 27 measured plunges of drag-folds from the exposures in the Proterozoic block on the banks of the Burntwood River between the outlet of Mystery Lake and the large southeast-trending bay in Apussigamasi Lake are to the north. Of the 33 measured plunges measured on drag-folds or outcrops within the central zone along the banks of the Burntwood River, 25 are to the southwest. Similarly 12 of 15 drag-folds on the east contact of the red biotite granite (12) plunge south. Most of the drag-folds immediately east of the south-plunging drag-folds on the eastern contact of the red biotite granite (12) plunge north as do all the drag-folds on the western shore of Bryce Bay. This suggests that the red biotite granite (12) may be intruded into the southern extension of the proposed fault. The lack of south-plunging drag-folds in Bryce Bay suggests that the fault lies just west of it.

The ratio of the directions of the relative movement of drag-folds in the central zone lies between those of the east and west blocks. Of the 67 drag-folds on which the relative movement was recorded, 69 per cent (Table 3) indicate a right-handed movement. If only the south-plunging drag-folds are considered, almost the same ratio of relative movement is found.

Small faults and shears are common in the central zones. The most easily recognized are the small cross-faults whose displacement rarely exceeds a few feet. About equal numbers of left-handed and right-handed cross-faults were recorded. Dips are generally steep. Small shears and faults parallel to the foliation or banding also occur. Most small shears are parallel to the strike of the contact zone but locally cross-shears are present. Shearing is most pronounced at Bryce Bay and along the Burntwood River northeast of McKillop Lake.

A strong northwest-striking shear zone which does not appear to cross the Burntwood River, is present about two miles southwest of McKillop Lake. Similarly the rocks in the vicinity of the double elbow in the Burntwood River about 12 miles northeast of McKillop Lake are commonly sheared parallel to the river. Lack of a northwest-trending topographic expression along the Odei River suggests that the northwest-striking shears along the Burntwood River do not occur north of the Odei River. In both cases cited above these northwest-striking shears do not appear to extend into the west block, suggesting that they are confined to the central zone and the east block.

In summary, the major structural break which appears to be responsible for the central zone extends from the northeast corner of the Thompson-Moak map-area just northwest of the Burntwood River southwest parallel to and in part underlying the Burntwood River for 20 miles to the large southeast-trending bay in Apussigamasi Lake where it turns southeast, passing southwest of McKillop Lake. It appears that it then turns almost due south and passes just west of Bryce Bay. This structural break has the shape of a large left-handed fold. The steepness of the plunge of the drag-folds which appear to be related to this fault indicate an essentially horizontal movement to the fault.

PROTEROZOIC BLOCK

FOLDING

The west or Proterozoic block is composed of granitic gneisses (10) lacking pyroxene, and sedimentary gneiss (6, 7) which have a northeast trend and vertical to a near-vertical dips. There appears to be a slight change in the general structure of the folds from the southwest to the southeast. Unfortunately this change occurs in the area south of the Burntwood River and north of Barkman Lake which, except for the area immediately north of Barkman Lake, is practically devoid of outcrop. Consequently although the west block can tentatively be divided into two zones little is known about the rocks in the area where these two zones meet.

The southern zone includes all the area east of Owl and Nichols lakes west to the central zone. Strikes in the southern zone suggest that it is folded into a broad tight

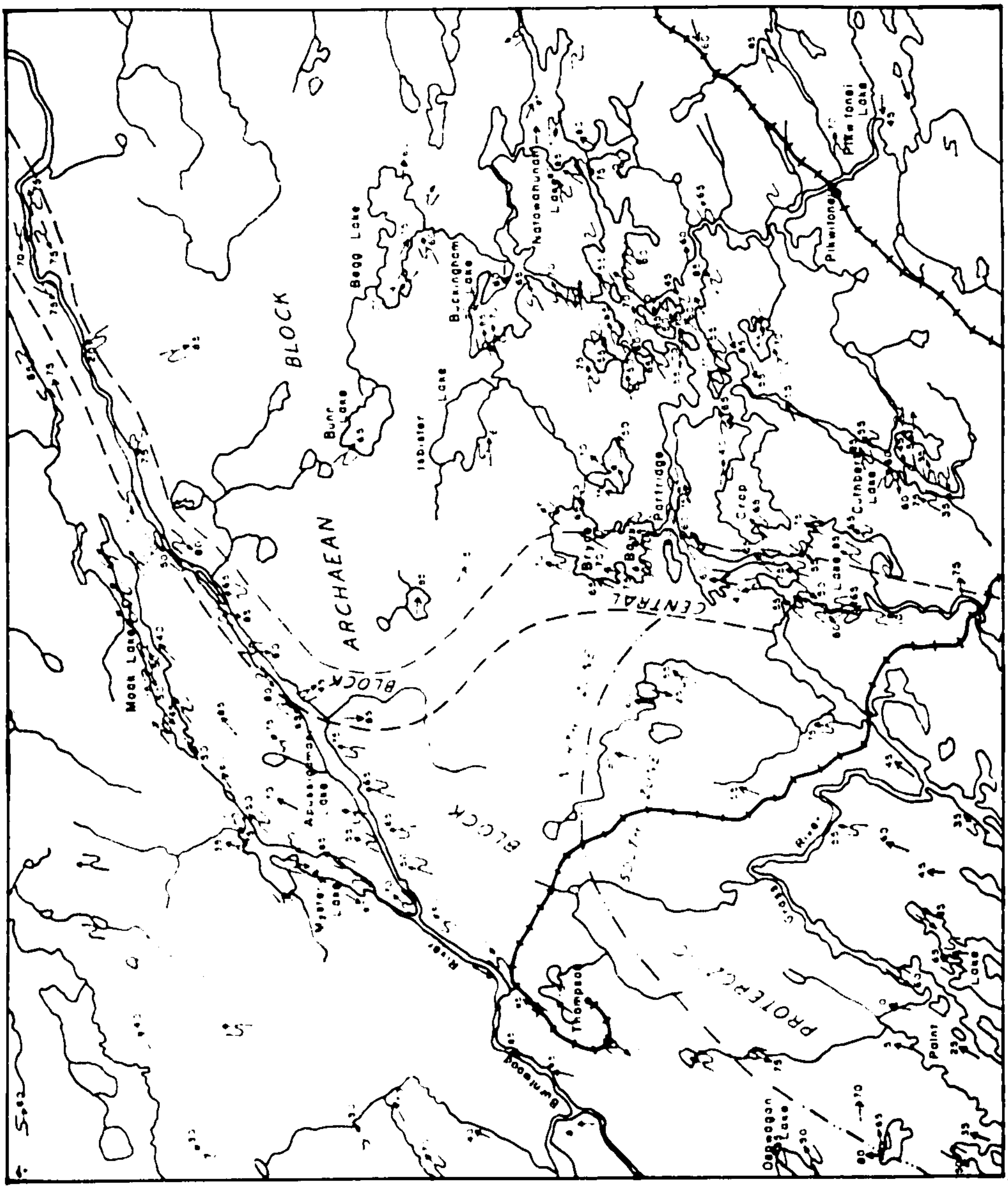

Figure 3. Distribution of drag-folds.

fold about ten miles wide whose apex would lie about six miles east of Thompson and whose axis would extend from the east shore of Paint Lake north thirty degrees east, in a slight curve for about fifteen miles. However, field evidence, such as the variation in dip direction, indicates that the area is isoclinally folded. Unlike the broad syncline outlined in the Archaean block (Figure 2), this fold has no consistent dip direction. Few drag-fold data were recorded from the rocks in the southern zone of the west block but 79 per cent of thirty-three recorded plunges are to the north (Table 3). Of the twelve drag-folds whose relative movement is known, ten are right-handed (Table 3). The south-plunging drag-folds occur in four isolated areas containing north-plunging drag-folds.

The rest of the west block appears to be a vertical to near vertical isoclinally folded area which is probably best exemplified by the section along the Burntwood River from the outlet of Mystery Creek northeast to the large southeast trending bay in Apussigamasi Lake. Except for a few small local variations in strike all of the strikes in the northern zone fit in with the smooth curve of the west block. The single exception is a small folded area immediately north of the Burntwood River, whose axis is on strike with, and may actually be part of, the broad fold outlined in the south zone.

Of the 125 plunges recorded on drag-folds in the north zone, 86 per cent plunge to the northeast (Table 3). This ratio is similar to that in the south zone. However, all of the south-plunging drag-folds in the north zone fall within a narrow belt that extends from the north shore of Moak Lake southwest and along the western shore of Mystery Lake. A few south-plunging drag-folds occur on strike with this belt just northeast and southwest of Thompson. No south-plunging drag-folds, but 27 north-plunging drag-folds, were recorded from exposures on the banks of the Burntwood River between Mystery Lake and the Central zone. Some south-plunging drag-folds would be expected if the general structure of the south zone continued unchanged into the north zone.

Of the 105 drag-folds whose relative movement was recorded fifty-seven per cent have a right-handed movement (Table 3). This is very close to the fifty per cent right-handed movement expected in any isoclinally folded rocks, as in an isoclinally folded sequence equal proportions of right-handed and left-handed drag-folds would be expected to develop.

In summary it would appear that the entire Proterozoic block is folded into near-vertical north-plunging isoclinal folds. Field evidence indicates that the south zone is also folded into one or perhaps several broad folds. The fact that there is a change in width, as measured from the belt of sedimentary rocks (5) to the central zone, from twelve miles in the south to about six in the north, suggests that rocks in the north zone were compressed much more than those in the south zone and broad folds were not developed in the northern part of the block.

FAULTING

Though many small faults and shears were recorded they are not as numerous as those recorded in the east block, probably because most of them parallel the strike of outcrops and commonly are not easily recognized.

Small faults with a displacement of a few inches or a few feet generally strike west or northwest and have vertical to near-vertical dips. About three times as many right-handed faults were recorded as left-handed ones.

Many small shears are present on the shores of Mystery Lake and are particularly numerous in the foliated mafic sills and sedimentary rocks (5). Shears are particularly well developed at the southwest end of Mystery Lake. Outcrops on the long point west of the nickel showing at Mystery Lake are highly sheared and locally brecciated. Sheared serpentinite apparently underlies part of the southwest end of Mystery Lake. These shears may be associated with the fault which is presumed to be present on the southern boundary of the sedimentary rocks at Mystery Lake and which probably extends to the south and southwest passing just

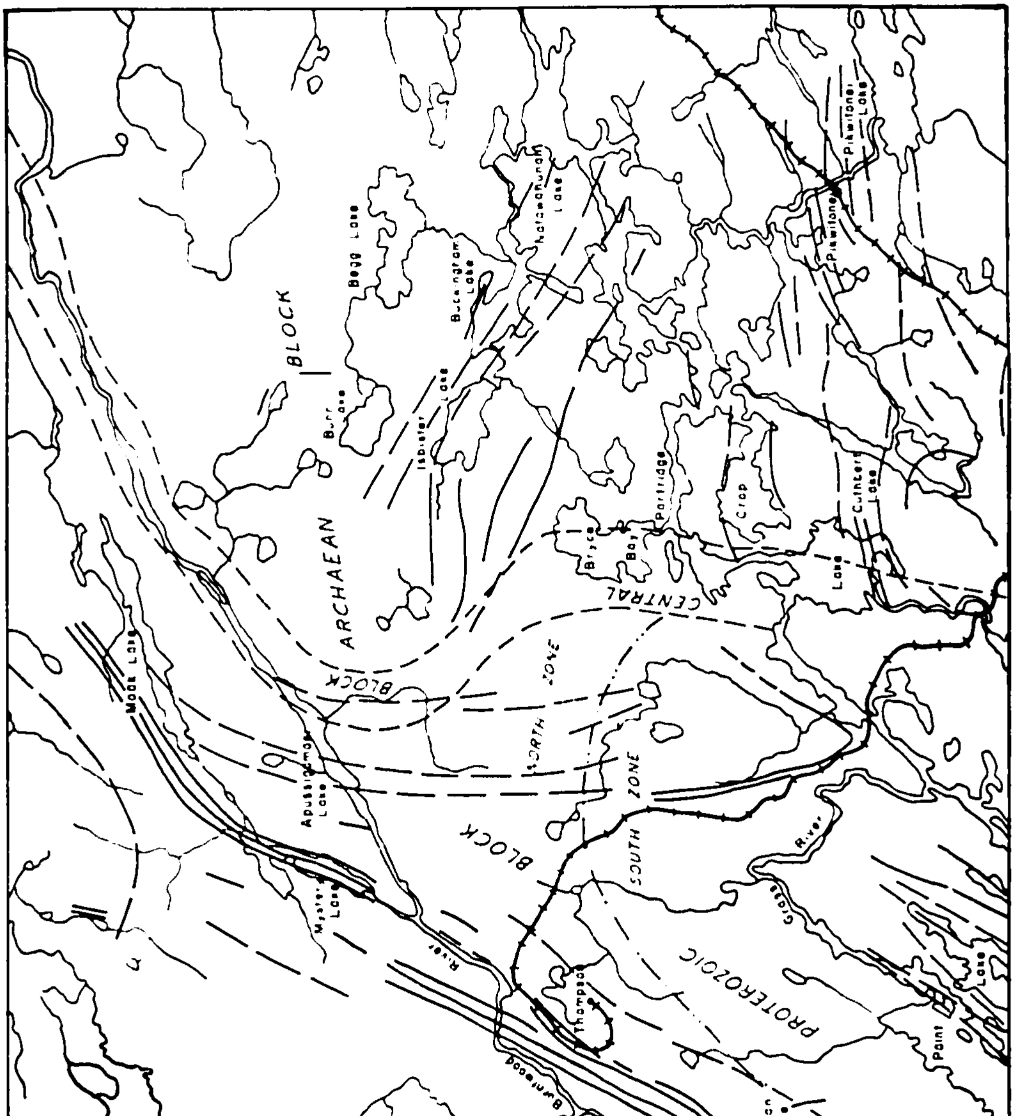

Figure 1. Magnetic trends.

west of Thompson and Ospwagan lakes. This, of course, has been referred to for some time as the Thompson-Moak "break." It is along this break that the majority of the south-plunging drag-folds occur, and if they were formed by the movement along this fault they indicate a right-handed movement, as eight of nine south-plunging drag-folds recorded along this break have a right-handed movement.

Ospwagan Lake is another locality where shearing is common. Immediately northwest of Ospwagan Lake the shearing is locally so intense that it is difficult to differentiate between granitic gneiss and quartzose sedimentary rocks. The sedimentary rocks there are highly contorted, and only detailed mapping would solve the structure. Southwest of Ospwagan Lake, outside the map-area, numerous outcrops of talc-chlorite-amphibole schist occur and are believed to be altered volcanic rocks. These are on strike with the Thompson-Moak break and their schistose nature may be due to the movement on this fault.

The rocks on the southeast bank of the Odei River are highly sheared and locally resemble the mylonite present at the northeast end of Natawahunan Lake. The straightness and steepness of the Odei River valley and the sheared condition of the rocks on its southeast bank strongly indicate that a fault underlies the Odei River and may represent a northeastern extension of a branch of the Thompson-Moak break.

SUMMARY

The Thompson-Moak map-area is divided approximately in half by a north- to northeast-trending fault or fault zone about 45 miles long shaped like a left-handed drag-fold. Abruptly terminated by this fault zone to the east and southeast are the east-trending charnockites (4) which appear to be Archaean. West and northwest of the fault zone are the north- to northeast-striking rocks intruded or metamorphosed during the Hudsonian orogeny.

The Archaean rocks are isoclinally folded into generally east to northeast steeply plunging folds with near vertical limbs. South of Natawahunan Lake the charnockites have a remarkably consistent north dip. Contrary to what would be expected in an ideally isoclinally folded series of rocks about 80 per cent of the recorded drag-folds in the Archaean block are right-handed.

The Proterozoic block, west and northwest of the fault zone is isoclinally folded into generally north to northeast steeply plunging folds with near vertical limbs. As would be expected in an ideally isoclinally folded sequence the ratio of right-handed to left-handed drag-folds is about 1:1. The area northeast of Thompson appears to be more highly folded than the area southeast of Thompson. South-plunging drag-folds are largely confined to the Assean Lake group (5) or rocks adjacent to it.

Between the Proterozoic block and the Archaean block is the central zone, up to 2 miles wide, made up of north- to northeast-striking isoclinally folded rocks. The percentage of right-handed drag-folds, 69 per cent, in the central zone is almost exactly equal to the average of the percentages of right-handed drag-folds in the Archaean (83 per cent) block and the Proterozoic (57 per cent) block. This suggests that the central zone is, in part at least, made up of Hudsonian metamorphosed and folded Archaean rocks as previously indicated. The high percentage of south-plunging drag-folds (58 per cent) in the central zone indicates that the movement in this zone was responsible for the south plunge, either by creating new south-plunging drag-folds or possibly by rotation around an essentially horizontal pole so that approximately 50 per cent of the formerly steeply north-plunging drag-folds plunge south. A 30-degree rotation of drag-folds plunging from vertical to 60 degrees north, compatible with plunges in the Thompson-Moak map-area, would produce drag-folds with plunges that varied from 75 degrees to the south to 75 degrees to the north. The location of the south-plunging drag-folds in or adjacent to the Assean Lake group (5) suggests a similar association.

CHAPTER IV

ECONOMIC GEOLOGY

INTRODUCTION

In 1946 The International Nickel Company of Canada commenced an exploration program around Setting Lake, situated southwest of the present map-area. In 1950, continuing the search for economic nickel deposits, the company optioned a group of claims that had been staked by Mr. Harry Howell and the late Walter Johnson at Mystery Lake. Drilling on these and adjacent claims outlined a large tonnage of low-grade nickel-bearing serpentinite. In 1955, following drilling of a serpentinite body at Moak Lake, an exploration shaft was sunk on a large marginal-grade nickel deposit discovered there. Late in 1956 the company announced that drilling had indicated the presence of a large high-grade deposit at Thompson, south of the Burntwood River.

Two shafts were sunk on the Thompson orebody, one a development shaft to 1057 feet, and the other a production shaft to 2100 feet. Mining is by the cut-and-fill method. Production commenced in 1961 and during 1962 is estimated at approximately 100,000,000 pounds of nickel and 7,000,000 pounds of copper. Cobalt is also recovered from the ore.

Apart from the known nickel deposits, small sulphide zones, containing mainly pyrrhotite with lesser amounts of pyrite and marcasite, are common in mafic rocks which locally are rich in garnet. Several such zones have been trenched and one on the south shore of Buckingham Lake contained recognizable grains of chalcopyrite. Analyses revealed only 0.08 per cent nickel.

Small flakes of molybdenite are commonly scattered throughout the rocks along the banks of the Grass River and Partridge Crop Lake. West of the Grass River, about 2 miles north of the outlet of Paint Lake, abundant flakes of molybdenite are disseminated throughout a sheared amphibolite.

No rare or unusual minerals were recognized in the pegmatites of the area, though it is possible that some may contain feldspar of ceramic grade.

Small outcrops of iron-formation generally of low magnetite content are common in parts of the area. However, no indication of large possibly economic bodies of iron-formation were observed.

GEOLOGICAL AND STRUCTURAL SETTING OF THE NICKEL DEPOSITS

The nickel deposits lie within a belt of gneissic rocks which trend northeasterly and extend from the Palaeozoic sedimentary formations north of Lake Winnipeg to the Palaeozoic rocks bordering Hudson Bay. The belt of gneissic rocks marks or lies close to the junction of the Superior and Churchill provinces of the Precambrian Shield. Gravity data indicate that the belt extends both to the northeast and southwest beneath the flat-lying Palaeozoic rocks (Wilson and Brisbin, 1961). Nickel deposits are known to occur for a length of 80 miles or more along this belt, from Wabowden to Moak Lake.

The nickel deposits and serpentinite intrusions with which they are associated, or in which they occur, lie along a negative gravity strip that is bordered by two positive gravity anomalies, similar to those found in present-day island arc structures (Wilson and Brisbin, 1961). Similar to island arcs, which normally are concave towards the continental masses, the arcuate structure of the Thompson-Moak Lake area is concave towards the older, Archaean, rocks. As in other island arcs, Alpine Mountain systems, and eroded roots of mountains, the zone of serpentinized peridotite bodies and the negative gravity anomaly are coincident.

McDonald (1960) demonstrated that the Moak Lake serpentinite, one of several bodies along the nickel belt, is of the Alpine type. The Cuthbert Lake peridotite dykes were regarded as of the Bushveld type. These dykes, which occur in the Archaean rocks on the concave side of the negative gravity strip, lie at an angle of about 45 degrees to the arcuate structure and probably occupy tensional fractures similar to the graben structures reported by Wilson (1957) to be related to some of the Alpine Mountain belts. The nickel deposits are associated with the serpentinites along the negative gravity strip but not with the younger, Cuthbert Lake peridotites.

Besides the negative gravity strip, series of serpentinite intrusions, and associated nickel deposits, the so-called Thompson-Moak Lake structure is characterized by bands of recognizable sedimentary rock of the Assean Lake group. These are confined largely or wholly to the narrow zone, 5 miles or less wide, forming the nickel belt. Apparently the sediments are more or less coincident with this major structure along its entire length from Setting Lake to Assean Lake.

Reference has been made to the Thompson "break." There is little direct evidence, within the map-area, of a major fault along the negative gravity strip, zone of serpentinite intrusions, and bands of Assean Lake sediments. However Dawson (1941), Gill (1951) and Mulligan (1956) all agree that a fault follows a linear topographic feature through Assean Lake and southwest along the Burntwood River. This is northeast of the present map-area. Similarly, southwest of the map-area, Quinn (1954) shows several branching faults extending southwest of Ospwagan Lake. Within the map-area itself shearing is evident at the southwest end of Mystery Lake and at Ospwagan Lake. Slickensiding is common in outcrops of gneiss along the railroad right-of-way between Mystery Lake and Thompson; intense deformation (crumpling and drag-folding) is evident along the Thompson structure. It is assumed, therefore, that the fault indicated to the southwest and northeast of the map-area passes through the Thompson area more or less as shown on the accompanying map. Major thrust faults are commonly believed to be an integral part of Alpine Mountain structure and island arcs. Normally they dip beneath the continental masses.

THE NICKEL DEPOSITS

The nickel deposits in the Thompson-Moak map-area occur in two distinct forms. The first type consists of large low-grade deposits of finely disseminated nickel-bearing sulphides in serpentinized peridotite. The Moak Lake and Mystery Lake deposits are of this type. The second type occurs at Thompson Lake where bands or stringers of massive and disseminated sulphides occur in gneiss, schist, and serpentinite. Both types of deposits contain little chalcopyrite. The Thompson orebody contains recoverable amounts of cobalt and the precious metals.

A high grade of metamorphism, upper almandine amphibolite facies, of the host rocks is indicated by the presence of sillimanite in the wall-rocks of the Thompson deposit. A similar, or perhaps slightly lower, grade of metamorphism is believed to be present at the Moak Lake deposit. However, the mineralogy of the sedimentary rocks at Mystery Lake, quartz-biotite-muscovite, indicates a much lower metamorphic grade (upper greenschist to lower almandine amphibolite facies) at the Mystery Lake deposit. This suggests that there may be a relationship between degree of metamorphism and the formation of higher-grade ore.

THOMPSON MINE

Only a small part of the Thompson orebody had been opened up by underground development at the time that field investigations for this report were in progress.

Examination of the orebody, therefore, was limited to the southwest end of the deposit. Data from diamond drilling, however, indicate that the general features described below probably apply to the entire orebody.

The deposit is situated about 2 miles south of the Burntwood River in an area where rock outcrops are exceedingly rare. At the minesite itself, however, a few outcrops of sedimentary and granitic rocks are exposed. The orebody is not exposed at surface and was discovered only as a result of geophysical surveys and diamond drilling carried out along the favourable structural belt discussed above.

As development of the orebody has only recently commenced and as rock exposures are not available in sufficient quantity to permit detailed surface studies of the orebody and its environment, the following data must be considered incomplete and any suggestions regarding ore controls and origin must be regarded as entirely tentative.

Geology

The Thompson orebody occupies a zone of biotite schist that forms part of a long narrow band of altered sedimentary rocks which are presumed to belong to the Assean Lake group and which are enclosed within granitic gneisses. Both sediments and ore horizon strike about N 30° E and dip southeast at 65 to 70 degrees. Diamond drilling has outlined the ore horizon for a length of approximately 2½ miles and along its entire length it appears to lie conformably within the biotite schist member of the sedimentary sequence. At the southwest end of the ore-bearing structure both the ore zone and the enclosing sedimentary rocks form the nose of an anticlinal structure plunging steeply southwest.

The zone of biotite schist in which the sulphides occur is bounded on the south by well-bedded quartzite and arkose and on the north by a band of quartzite and interbedded sulphide-bearing sedimentary rock locally referred to as "iron-formation." These rocks and the schist apparently are the most continuous members of the sedimentary series. Around the nose of the anticlinal fold at the southwest end of the deposit, bands of plagioclase amphibolite, garnetiferous plagioclase-amphibole gneiss, limestone, and skarn are interbanded with the quartzite. A relatively small lens of serpentinite, measuring a hundred feet or so wide and a few hundred feet long, intrudes the sedimentary rocks around the nose of the anticlinal fold.

The sedimentary series is in contact with more or less stratiform grey granitoid gneiss and this in turn is in contact with an irregularly hybrid buff to pink gneissic granitic rock that may be classified as granodiorite gneiss. The relationship between the sedimentary rocks and granitoid gneiss is uncertain; the stratiform granitoid gneiss may represent a recrystallized sedimentary band of the Assean Lake group.

The sedimentary rocks and derived schist form a well-defined stratigraphic horizon whose total thickness is unknown but which extends for at least 2½ miles in a northeasterly direction from the minesite.

In the present workings the biotite schist which encloses the ore attains widths of 200 to 300 feet. The schist consists dominantly of brown biotite but also contains quartz, plagioclase, microcline, muscovite, garnet, and sillimanite. Some of these minerals may be secondary as variable amounts of pegmatitic material in the form of small stringers, lenses, and irregular bodies occur within the biotite schist. In places the schist is intimately mixed with quartzo-feldspathic material, forming a "pegmatized" schist.

The band of sediments enclosing the ore-bearing biotite schist zone consists of light grey to brown biotitic and feldspathic quartzite and arkose. These occur in beds an inch or so wide. The feldspathic quartzite consists of about 70 per cent quartz, 20 per cent feldspar (both plagioclase and microcline) and between 5 and 10 per cent biotite. Arkosic beds contain about equal amounts of quartz and feldspar, more than half of which is plagioclase and the remainder, microcline. Accessory minerals in the quartzite and arkose include apatite, epidote, muscovite, and pyrite.

Interbedded with the quartzite that underlies the biotite schist and ore zone is a band of pyrrhotite-bearing rock that has been classified as "iron-formation." This rock consists of quartz, feldspar, amphibole, garnet, and pyrrhotite. The pyrrhotite is not nickeliferous. The iron-formation forms a fairly continuous band parallel to the biotite schist and ore horizon.

Discontinuous bands of recrystallized limestone, lime-silicite rock (skarn), and plagioclase-amphibole gneiss are interbedded with the quartzite underlying the biotite schist and ore. The limestone is light grey in colour and consists of about 95 per cent recrystallized calcite containing scattered small flakes of muscovite and minor apatite. The skarn, which is grey with a green tinge, is composed of an aggregate of diopside, tremolite, calcite, muscovite, and biotite with minor epidote, apatite, and sphene. Diopside formed more than 50 per cent of one specimen examined.

The plagioclase-amphibole gneiss, which is closely associated with the limestone and skarn, possibly represents altered impure limy and aluminous sediments. The rock consists essentially of a foliated aggregate of hornblende, plagioclase, and quartz, usually with a small amount of microcline and biotite and as much as 10 per cent garnet in the form of small pink crystals. The rock is gneissic, though not well banded, and is dominantly quartzo-feldspathic; however, it grades into a highly amphibolitic phase containing about 75 per cent hornblende, 15 per cent quartz, and 10 per cent plagioclase. The amphibole-rich phase, where observed underground, constituted the outer parts of the plagioclase-amphibole gneiss band.

A lenticular mass of serpentinite intrudes the sedimentary rocks at the southwest end of the deposit, but does not extend to the bedrock surface. The serpentinite is a dark green to greyish black fine-grained rock composed mainly of antigorite and 5 per cent or more magnetite. Its relationship to the granitoid gneiss described below is uncertain, but the serpentinite is intruded by bodies of pegmatite similar to that forming parts of the granodiorite gneiss.

Stratiform granitoid gneiss forms a relatively narrow zone overlying the sedimentary rocks. The gneiss is characterized by a somewhat irregular stratiform structure caused by alternation of bands rich in quartz and feldspar with those rich in biotite. The rock is characteristically medium- to coarse-grained and in the aggregate has a grey appearance, though individual bands or groups of bands may be white, grey, or black. Most bands are a fraction of an inch to an inch or so wide. The lighter-coloured bands are composed essentially of quartz, oligoclase, and orthoclase in about equal amounts. A few per cent biotite occurs as thin trains in the granitic material. Thin wavy biotite ribbons may separate different light-coloured bands; however, more prominent are dark grey to black bands about an inch wide. These are composed dominantly of biotite with subordinate quartz and feldspar. Small pink garnets are present in much of the dark material. A few thin bands and lenses of white granitic material may be interlayered with the dark bands. Besides the two extremes (white and dark) types of material forming the stratiform gneiss, many layers are medium grey in colour and contain 15 or 20 per cent biotite. The stratiform granitoid gneiss may represent recrystallized sedimentary rocks which originally formed part of the sedimentary sequence described above.

The country rock surrounding the band of sediments, derived schist and gneisses, is a granodiorite gneiss characterized by distorted and discontinuous banding, irregular mixtures of pink and grey granitic material, and remnants of darker grey material in various stages of granitization. The rock consists of oligoclase, microcline, quartz, biotite, and accessory apatite, muscovite, magnetite, and epidote. Some phases of the rock are pegmatitic; the pegmatite is similar to that within the biotite schist zone.

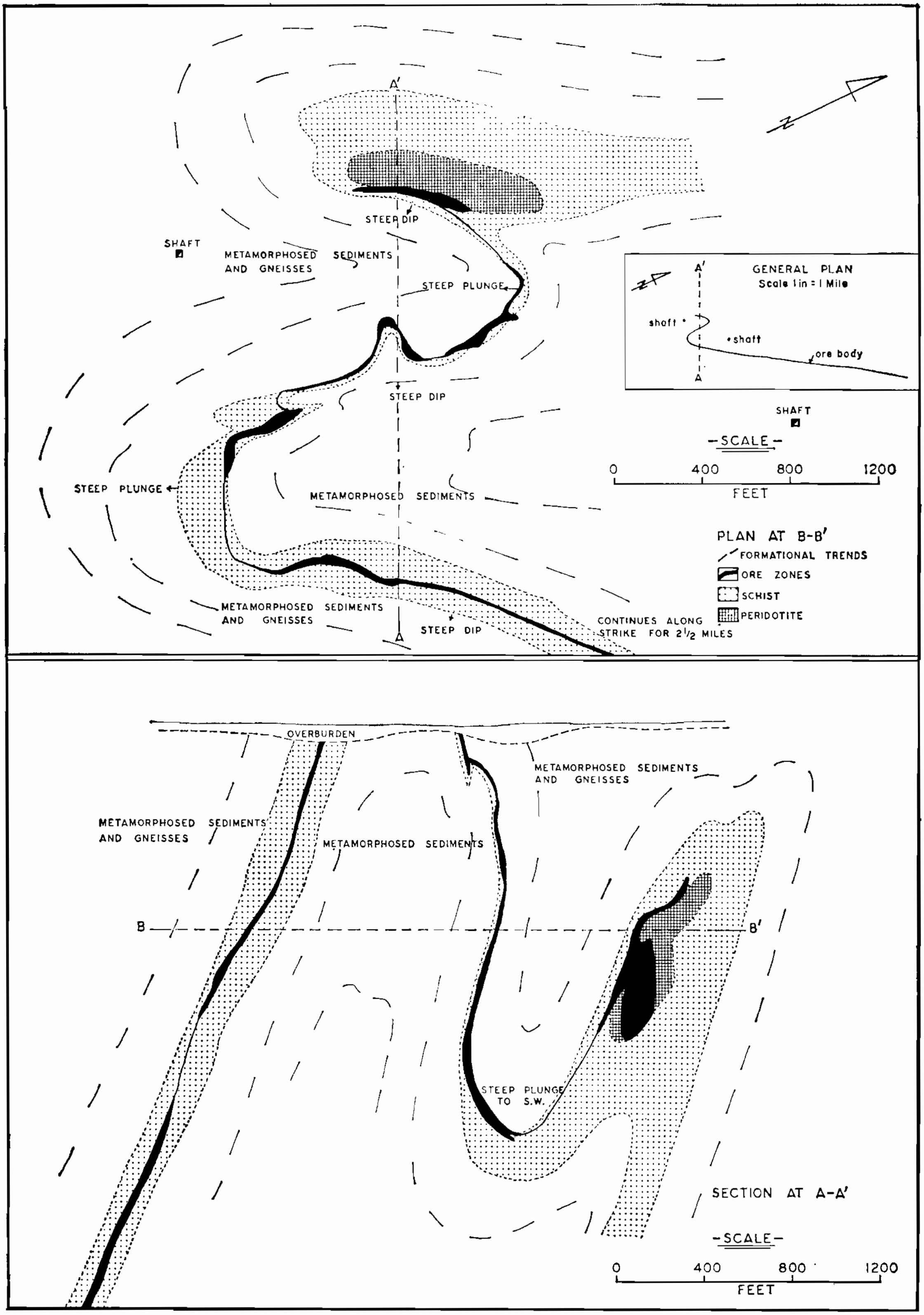

Figure 5. Plan and section — Thompson orebody.

Structure

The Thompson nickel deposit occurs along the major structural belt delineated by the coincidence of: (1) the strip of low gravity, (2) the bands of Assean Lake group sediments, (3) a zone of intense deformation, and (4) the series of small Alpine-type serpentinite intrusions (Davies, 1960; Wilson and Brisbin, 1961). At the Thompson minesite there is no clear evidence of the major thrust fault which is believed to follow this structural-stratigraphic belt. However, it is most probable that in places a wide zone of deformation rather than a single fault is present. The assumed projection of the fault zone or zone of maximum deformation passes north of and parallel to the band of Assean Lake group sediments in which the orebody occurs. It is possible that the anticlinal fold at the southwest end of the deposit represents a drag-fold formed by movement along the fault.

Apart from the anticlinal fold at the southwest end of the deposit, other important large structures appear to be lacking. However, it is apparent that stresses created during deformation were responsible for formation of the biotite schist which is interlayered between bands of more competent quartzite surrounded by granitic gneisses; it is equally evident that the schist formed the band structurally favourable for the access and deposition of the nickel-bearing sulphides. The manner in which the relatively narrow sulphide body (100 feet wide or less) is confined to the band of biotite schist for a length of $2\frac{1}{2}$ miles or more apparently reflects the structural influence of the schist on emplacement of the sulphides.

The Orebody

The sulphide orebody occurs as a long more or less continuous but irregular sheet within the biotite schist. Stringers and irregular intrusions of pegmatite which invade the schist also contain and are cut by sulphides. Some sulphides are also present in the serpentinite lens that lies within the schist.

The orebody pinches and swells from place to place in an irregular manner. In places it attains widths of 100 feet but may narrow rapidly along strike to a few feet wide. For the most part it is a few tens of feet wide. In other places the sulphide band splits into two or more branches surrounding large wedges of unmineralized or poorly mineralized schist.

The ore consists of coarse-grained sulphides, mainly pyrrhotite and pentlandite, in the form of irregular stringers and bands containing numerous sub-angular to rounded fragments and blocks of wall-rock, i.e., biotite schist, pegmatized schist, and, in places, pegmatite. Besides wall-rock fragments, considerable quartz is present in some of the sulphides. Small individual flakes and cluster of flakes of biotite are abundant throughout much of the sulphides. In some of the ore the biotite flakes exhibit excellent alignment; elsewhere the biotite is randomly oriented. Minute veinlets of sulphides cut the silicate fragments. Irregular sulphide grains are scattered throughout the silicate gangue. Much of the ore, containing fragments of wall-rock and quartz, is a typical breccia ore.

Sulphides are confined almost entirely to the zone of biotite schist and pegmatite that intrudes it in places. However, the serpentinite lens near the southwest end of the deposit contains ore, both as stringers and bands of coarse-grained sulphides and as finely disseminated material. The sulphide bands and stringers occupy fractures in the serpentinite. Some of the fractures have been invaded by pegmatite as well as sulphides.

Pyrrhotite and pentlandite are the main sulphides minerals in the ore. The pentlandite occurs as abundant small blebs throughout the pyrrhotite. Chalcopyrite is widespread but not abundant in any of the ore. It commonly occupies fractures in the gangue minerals. Gersdorffite is present locally in the sulphides. Besides nickel, copper, and cobalt, the ore contains recoverable amounts of the platinum group metals.

The International Nickel Company of Canada Limited has released an ore reserve figure of 25,000,000 tons which comprises ore outlined from underground development (company annual report, 1960). Reserves indicated by diamond drilling greatly exceed this figure. The ore averages slightly less than 2.9 per cent combined nickel and copper, of which copper forms almost 0.2 per cent. Rate of production in 1962 was 4,000 tons daily.

MOAK LAKE DEPOSIT

The Moak mine had been closed down before the field work for the present study had begun. Consequently the following description of the deposit is based largely on conversations with company geologists and examination of drill logs and specimens from underground.

No rocks are exposed in the immediate vicinity of the Moak Lake nickel deposit. The nearest outcrops lie along the north shore of Moak Lake about 3,000 feet south of the minesite. These are exposures of well-banded grey to white granitoid gneiss injected by widespread though not abundant stringers of pink pegmatitic granite. The bands are an inch or so wide, straight, and persistent as in a typical sedimentary gneiss. The gneiss strike northeast to east and dips steeply to either the north or south. Small patches and narrow bands of dark grey to black plagioclase amphibolite and biotite schist lie within the gneiss. These darker bands commonly are highly crenulated.

Rocks similar to those described above apparently underlie the area between Moak Lake and the minesite, where a body of serpentinite lies within a band of quartzite, impure quartzite, and altered limestone of the Assean Lake group, near its contact with the gneiss.

The serpentinite occurs as an elongate, lenticular, body within the sediments. The ultramafic intrusion pinches and swells, has a maximum width of about 500 feet and is roughly a mile long. The rock consists of a felted mass of serpentinite in part pseudomorphic after olivine, and in places contains prominent grains of chrysotile. Small grains of magnetite are disseminated throughout the serpentinite; magnetite also occupies short narrow fractures in the rock. Graphitic "slips" are common. Some fractures a fraction of an inch wide are occupied by cross-fibre asbestos.

Sulphides, mainly pyrrhotite and pentlandite, are disseminated throughout the serpentinite as small grains and networks of fine irregular short thread-like stringers and blebs. The networks of stringers display crude alignment along weak schistosity that lies parallel to the length of the serpentinite intrusion.

Massive sulphides occupy zones of fracturing within the serpentinite but these form only a minor portion of the total sulphides in the deposit. The massive ore occurs in bands, a few inches to a foot or so wide, that cannot be traced for any great distance. In part the massive sulphides form a breccia ore containing fragments of quartz and silicified rock.

Only parts of the serpentinite at Moak Lake are mineralized; others contain no sulphides. There appears to be no regular pattern to the areas of mineralized rock in the serpentinite intrusion. Although no estimates of reserves at Moak Lake have been released, it can be stated that the deposit is large and of low grade.

MYSTERY LAKE DEPOSIT

Several small outcrops of serpentinite are exposed at Mystery Lake. In 1949 a group of claims was staked by Harry Howell and the late Walter Johnson covering nickel-bearing serpentinite. In 1950 the claims were optioned to The International Nickel Company of Canada Limited who commenced investigation of the occurrence and who acquired further claims at Mystery Lake.

The sulphides, mainly pyrrhotite and pentlandite, are disseminated throughout serpentinite underlying the lake. Drilling of the serpentinite revealed the presence of a large low-grade nickel deposit that is of no commercial interest at this time.

ORIGIN OF THE NICKEL DEPOSITS

The regional and local structural features apparently controlling emplacement of the serpentinite and nickel sulphides have been discussed briefly above.

The association of nickel deposits with mafic and ultramafic intrusions is worldwide. Serpentinites and peridotites in island arc structures and Alpine Mountain belts, if they contain nickel, often carry only low-grade disseminated sulphides. Wilson (1953, p. 389) suggests that most peridotite magmas, in which sulphur is more soluble than in siliceous magmas, are undersaturated with respect to sulphur. Sulphides, therefore, separate out too late from the crystallizing magma to allow accumulation, leaving the sulphide minerals distributed throughout the ultramafic rock. This would apply to the deposits at Moak and Mystery lakes.

The Thompson deposit presents a particular problem. The ore is not disseminated, but rather a coarse-grained sulphide breccia, and it occurs for the most part not in serpentinite but rather biotite schist. The emplacement of the sulphides was separated from emplacement of the serpentinite by intrusion of pegmatite. This is indicated by the fact that pegmatite intrudes serpentinite and is in turn cut by sulphides. Therefore simple separation of sulphide liquid from the serpentinite will not explain the Thompson deposit. In any case, no matter what mechanism may have operated to concentrate the sulphides the source of this large orebody could not have been the small serpentinite lens at the southwest end of the deposit.

Dilation structures in the schist, penetration of inclusions by sulphides, and the occurrence of sulphides in fractures in serpentinite, and in pegmatite which has intruded the serpentinite, suggest sulphide liquid injection. On the other hand a certain amount of rounding of inclusions suggests that at least some replacement also occurred. The source of the sulphide liquid may have been deep within the mantle from which the serpentinites also originated. On the other hand metasomatism by sulphur-bearing fluids or vapours may have converted nickel silicate, originally in serpentinite, to sulphide. In order to explain the Thompson orebody by this method, it would be necessary for the sulphides to have later migrated from other serpentinite bodies in addition to the one presently associated with the orebody. Migration of sulphides, whether formed by metasomatism of silicates or whether originally present as disseminated sulphides, can occur along thermal gradients at temperatures above 400°C (Gill, 1960). Such a process, occurring under conditions of regional metamorphism might account for accumulation of the sulphides. A final possibility that may be suggested is reaction between nickel-bearing serpentinite and a granitic magma (or pegmatitic or hydrothermal solutions related to it), involving release of sulphides which, being less soluble in acid than in basic fluids, would collect to form a sulphide liquid.

The last suggestion may receive some support from the fact that pegmatite intrudes the Thompson ore zone, from the presence of pegmatite and quartz fragments in the Thompson sulphides, and from the occurrence of massive sulphides in quartz-filled fractures in the Moak Lake deposit which, for the most part, contains only disseminated sulphides.

It should be stated clearly, however, that the limited data so far available permit only the vaguest suggestions as to the origin of the Thompson orebody.

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