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GEOLOGICAL REPORT ON NORMANVILLE AREA (COMTE DE SAGUENAY)

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EXPLORATION GEOLOGIQUE

MINISTÈRE
DES RICHESSES
NATURELLES

DIRECTION GÉNÉRALE
DES MINES

NORMANVILLE AREA
SAGUENAY COUNTY

P.J. Clarke

Final report

DEPARTMENT OF NATUREL RESOURCES
GEOLOGICAL EXPLORATION SERVICE

NORMANVILLE AREA
SAGUENAY COUNTY

by

P.J. Clarke

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GEOLOGICAL REPORT

on

NORMANVILLE AREA

SAGUENAY COUNTY

by

Peter J. Clarke

INTRODUCTION

General Statement

During the past 20 years an increased demand for iron and the approaching exhaustion of old deposits has lead to the use of beneficiating techniques for the development of large low grade deposits. Some of the most important deposits of this type are found between Wabush lake and Lac Jeannine near the southern end of the Labrador Trough. Active exploration of these deposits began in the early nineteen-fifties, and the first ore was shipped from the Lac Jeannine mine in 1961.

The Quebec Geological Survey has mapped much of the region as part of its policy of providing geological information in areas of current interest. The present report is a part of this mapping program.

The rocks of the area are all Precambrian in age. They represent in part metamorphosed sediments of the Labrador Trough, and in part the Archean basement on which the sediments were deposited. The Archean rocks are exposed in the northwestern part of the area, and the Proterozoic rocks in the southeastern part. The Grenville Front, represented here by a gradual increase in metamorphic grade, passes northeast across the area, approximately parallel to the Archean-Proterozoic contact.

Location and Access

The area is bounded by latitudes $52^{\circ}45'N$ and $53^{\circ}00'N$, longitude $67^{\circ}30'W$, and an irregular limit slightly east of the height of land dividing waters of the Moisé and Hamilton River systems. This map-area lies about 190 miles north-northwest of Sept Iles, 15 miles southwest of Wabush lake, and directly north of Mount Wright. It covers approximately 260 square miles, including most of Normanville, 2855, and 2756 townships, and part of 2854, and Raimbault townships in Saguenay county, as well as some undivided land in the New Quebec district north of $52^{\circ}55'N$, and some (land claimed by) Labrador.

The area is most easily accessible by float-plane from Wabush lake or Sept Iles. The lakes in the southern part of the area are generally large and deep enough to

allow access by Canso. In the northern part of the area the lakes are shallow and island-dotted making access by any aircraft hazardous.

The area can also be reached by canoe from Wabush lake via Long and Virot lakes. The proposed rail line from Lac Jeannine to Mount Wright, or roads from Wabush lake, will eventually provide direct access to the area.

Canoe travel within the area is generally restricted to the lakes as interconnecting streams are shallow and boulder-filled. However, the lakes are large and close enough together so that only a few portages are needed to reach most parts of the area.

Foot travel is generally easy owing to the light forest cover.

Field Work

The field work, on which this report is based, was done in the summer of 1959. Pace and compass traverses were run at $\frac{1}{2}$ mile intervals, using $\frac{1}{2}$ mile = 1 inch aerial photographs for ground control. Areas of complex geology and good exposure were mapped in more detail.

Field data were plotted on a $\frac{1}{2}$ mile = 1 inch map prepared by the Cartography branch of the Quebec Department of Mines.

Previous Work

The first description of the geology in the Grenville portion of the Labrador Trough was made by Gill, Bannerman, and Tolman (1937). More recently the work to develop the iron deposits has brought many geologists to the region. Mining companies have mapped the iron deposits in detail, and although the results of much of this work are confidential, important aspects of the regional geology and mineralogy of the iron formation have been published by Gastil and Knowles (1960), Mueller (1960, 1961), and Krank (1961).

A more general coverage, incorporating some of the detailed work, is available in government publications. Quebec Government reports covering the area between Mount Wright and Lac Jeannine, on a 1 mile = 1 inch scale, have been written by Murphy (1959, 1960), Clarke (1961, 1963), Phillips (1958, 1959), and Sinclair (1960, 1961). The Geological Survey of Canada published two 1 degree sheets on a scale of 4-mile = 1 inch; one including the present area, Duffel and Roach (1959), and one lying directly to the northeast, Fahrig (1960).

Unpublished theses by Gross (1955), and Jackson (1962) cover parts of the area.

Acknowledgments

Anders Jepsen, a graduate of McGill University acted as senior assistant; John Cassils also of McGill University, Claude René and Claude Bertrand, both of University of Montreal were junior assistants. Sylvestre and Joseph Pinet of Maliotanem served as canoe men, and Odilon Arsenault of Thivierge as cook. All these men performed their duties in a satisfactory manner.

Unpublished geological and geophysical reports on the holdings of Quebec Cartier Mining Co., Normanville Mining Co., Bellechasse Mining Corp. Ltd., Canadian Javelin Ltd., Holannah Mines Ltd., Mount Wright Iron Mines Co. Ltd., and Mallen Red Lake Gold Mines Ltd., were available to the author.

~~The above mentioned maps and reports~~ were most useful in planning field work and locating interesting exposures. Without them, much of the details of the economically important parts of the area would not have been known. Officers of the mining companies have been most helpful in approving this information for publication. The writer also expresses thanks to geologists of Bellechasse Mining Corp. and Mount Wright Iron Mines for information given during the field season, and to the Normanville Mining Co. for permission to use their cabin on Mogridge Lake at the end of the season.

DESCRIPTION OF THE AREA

Physiography

The physiography of the area is typical of much of the Canadian Shield. The land surface lies between 1900 to 2900 feet above sea level, and local relief is largely determined by the resistance to erosion of the different types of bedrock. In the southern part of the area resistant quartzite, iron formation, and gabbro, stand in ridges some 500 feet higher than the surrounding gneisses and schists (Plate I).

The rocks in the northern part of the area erode more evenly, and the topography here is flatter. Except for isolated hills, the northern sector is a level plain covered by a network of shallow, interconnected lakes.

The height of land, which marks the approximate eastern limit of the area, divides the waters flowing into Rivière aux Pékans and the St. Lawrence river, from those flowing into Wabush lake and the Atlantic ocean. Sudbury and Huguette lakes lie on the northeastern side of the watershed and drain eastward, but in the rest of the area the drainage is to the south.

East-west ridges hold back the water on their northern side to form the largest lakes of the area.



Quartzite, iron formation hills south of Daigle Lake,
as seen from near Tupper Lake.

Flora and Fauna

The area is lightly forested with black spruce and some white birch on hill sides. The best timber grows on protected slopes and valleys, where the spruce may grow to 100 feet high with a base diameter of 30 inches.

Hill tops are almost bare, with a thin pebbly soil covered by caribou moss and a few stunted spruce and balsam. Labrador tea and muskeg are common in wet areas, and alders line the stream courses.

The area supports most of the animals native to northern Canada, but none are especially abundant. Beaver dams and other trails were found but the only fur-bearing animal actually seen was mink. Moose and caribou are scarce. Lake trout, pike and speckled trout live in the lakes and streams.

Climate

Summer weather of the region is generally cool, and often rainy. Ice leaves the lakes early in June and freeze-up is in early October. Mean minimum and maximum temperatures during the summer are quite constant at about 40 and 70°F. Very warm days are unusual, but temperatures may reach the mid-80's several times during the summer. Overnight temperatures may drop below freezing anytime up to the middle of June and after the middle of August.

A station at Wabush lake now supplies complete weather information for the district.

GLACIAL GEOLOGY

The most noticeable effect of the glaciation was the deposition of a layer of boulder-till. These deposits occur throughout the area, and in places, north of Boulder and Sudbury lakes, and near Hesse and Kissing lakes, they completely cover the bedrock over tens of square miles of area. Crag and tail structures form behind isolated hills near Boulder and Cherny lakes. Glacial polish and striae are preserved on hills of quartzite and hypersthene granulite. Both the striae and the crag and tail features show glacial movement to S 30°E.

Much of the drift is moulded into low ridges and depressions imparting a south-southeasterly grain to a large part of the area.

Glacial melt water flowed in north-south valleys, leaving sorted deposits and eskers on the valley floors. Virot, Huguette and Kissing lakes lie in a glacial drainage channel in the eastern part of the area, and Cherny lake lies in one in the west. The fine material has been washed from till south of Boulder lake leaving a large boulder field.

GENERAL GEOLOGY

The rocks of the area can be divided into three main groups:

- 1) Archean granulite and acidic intrusives.
- 2) Proterozoic metasedimentary rocks, stratigraphically equivalent to the sediments of the Labrador Trough.
- 3) Igneous intrusions into the Proterozoic rocks.

The Archean rocks underlie most of the northwestern corner of the area. They consist of hypersthene granulite, and the acidic rocks and migmatites which intrude them. Two types of granulite are recognized; an intermediate hypersthene-quartz-orthoclase-oligoclase granulite, and a basic hypersthene-augite-andesine granulite. The intermediate type is much more common than the basic type. These rocks reached their high grade of metamorphism during Archean time. Subsequent retrograde metamorphism has affected them all at least slightly and has strongly altered some of them.

Proterozoic rocks occur throughout the southeastern two thirds of the area, and wedge out over the basement rocks in the northwest. From the base to the top they include a sequence of gneisses and schists, a group of chemically precipitated sediments called the Gagnon Group, and more schists, including some distinctive aluminous varieties. Gabbro sills intrude parts of the Gagnon Group, and granites are found in the gneiss.

Table of Formations

PLEISTOCENE AND RECENT	Glacial and Fluvioglacial Deposits			
	u n c o n f o r m i t y			
P R E C A M B R I A N P R O T E R O Z O I C	Granitic Intrusives			
	SHABOGAMO	Gabbro and Metagabbro Amphibolite		
	i n t r u s i v e c o n t a c t			
	Biotite-Hornblende-Garnet Schist Mica-Garnet-Kyanite Schist † Graphite Biotite Gneiss (homogeneous)			
	GAGNON GROUP	oxide iron formation (Wabush Lake) formation silicate-carbonate iron formation Muscovite Quartzite (Wapussakato) Quartzite (Duley) Marble	METAMORPHIC FACIES CHANGE	Siderite-Quartz-Stilpnomelane Iron Formation
	Porphyroblastic Biotite Schist Biotite Gneiss homogeneous Biotite Gneiss segregated			Albite-Epidote-Chlorite Schist and Grit
	u n c o n f o r m i t y			
	ARCHEAN	Altered Archean Gneiss Acidic Intrusives and Migmatites		
	Pyroxene Granulite			hypersthene-augite variety hypersthene-quartz variety

Directly over the Archean rocks the Proterozoic sediments are weakly metamorphosed schists or grit, containing fragments of the basement rocks in a matrix of fine grained epidote, chlorite, quartz and albite. A thin layer of slightly metamorphosed iron formation accompanies the basal grit near Jackson and Boulder lakes.

Farther southeast the sequence thickens and becomes more highly metamorphosed. Mica-quartz oligoclase gneiss underlies most of the area. The gneiss has a well developed bedding foliation, but no mineral segregation. Deep in the section, in the valley of the rivière aux Pékans the gneiss contains hornblende, and has a more segregated texture.

The gneiss is overlain by the Gagnon Group, composed of the Duley Marble, Wapussakatoo Quartzite, and Wabush Lake Iron Formation. The formations of the Gagnon Group were deposited in several sedimentary facies zones. In the north only iron formation was deposited. Quartzite accompanies the iron formation in a zone trending northeast across the central and southern parts of the area, and gives way to marble in the area's southeastern corner. The quartzite and marble generally underlie the iron formation, but may also occur above it.

The composition of the iron formation also changes across the area. Quartz-hematite iron formation was deposited in the southwestern quarter, and silicate-carbonate iron

formation throughout the rest of the area. A gradational quartz-magnetite facies separates the two main groups.

In the north, where metamorphism was weak, the silicate-carbonate iron formation contains quartz, siderite, magnetite and stilpnomelane. Progressing southward grunerite and actinolite, then diopside-hedenbergite, and finally hypersthene were developed.

Several distinctive types of schist occur within the common gneiss. A very porphyroblastic quartz-feldspar-mica schist is interlayered with the gneisses below the Bloom Lake syncline. Two types of aluminous schists occur in the upper gneiss south of Kissing lake. One of these schists is felsic, composed of quartz, mica, garnet and kyanite, and the other is a basic hornblende-garnet-plagioclase schist.

Gabbro occurs within the Tupper Lake, Bloom Lake and Daigle Lake synclines. It was probably injected into the competent quartzite and iron formation at the time of their deformation. Most of the gabbro in the synclines south of Mogridge lake and west of Hesse lake has been recrystallized to amphibolite.

Thin sills of white biotite-muscovite granite occur in the gneisses in the southern part of the area. Larger granitic masses intruded the gneiss west of the north end of Kissing lake and on the eastern limb of the Daigle Lake syncline.

ARCHEAN ROCKS

Archean Granulites

The oldest rocks in the area are Archean pyroxene granulites and acidic intrusives. They form the basement on which the Labrador Trough sediments were deposited, within the present area, and for a considerable distance northeast and southwest, (Fahrig, 1960, Duffel and Roach, 1959). The Archean rocks are exposed in the northwestern corner of the present area.

The granulite is brown to greenish brown, with a medium grained, granoblastic texture. Mineral layering is common, but the rock lacks fissility and stands as smooth, round outcrops. All outcrops contain some granitic material, which may form thin layers on foliation planes (Plate IIa), or completely surround blocks of the granulite (Plate IIb). At two places, near the northern and western borders, the injected material comprises more than half of the rock mass, and the rock is classified as a charnockitic migmatite.

Two types of granulite are recognized, hypersthene-quartz-oligoclase granulite, or intermediate granulite, and hypersthene-augite-andesine granulite, or basic granulite. Both types have uniform granoblastic textures and show most of the characteristic of granulite facies rocks.

Both types contain hypersthene, blue quartz, and tan to grey feldspar. In addition to these minerals biotite and some garnet occur in intermediate granulite, and horn-



A- Isoclinal folds in Archean granulite. Thin granitic layers follow bedding foliation.

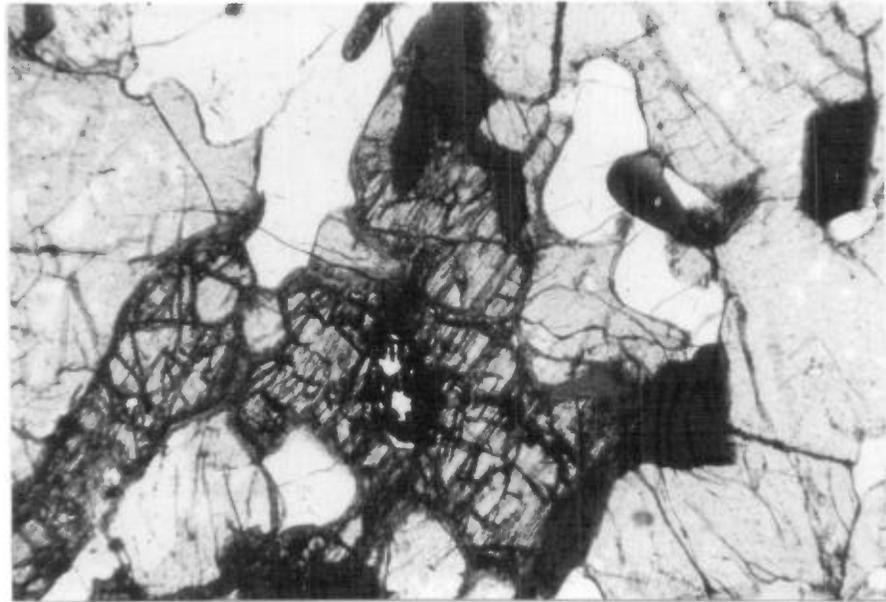


B- Rounded inclusions of granulite in Archean migmatite west of Cherny lake.

blende and pyroxene in the basic variety. Accessories are opaque oxides, apatite, zircon and rutile. The primary minerals are partly altered to sericite, green uralitic amphibole, anthophyllite and talc. (Plate III).

Table II gives mineral compositions of six thin sections of the intermediate granulite. Typical sections have compositions in the range; plagioclase, An₂₅₋₃₂, 34 to 55 per cent, microcline 0 to 12 per cent, quartz 18 to 24 per cent, biotite 7 to 13 per cent, hypersthene 1 to 11 per cent, garnet 0 to 8 per cent, and traces of opaque oxide, apatite and zircon. Alteration of the primary minerals formed 4 to 8 per cent uralitic amphibole and traces of epidote, chlorite and sericite.

Mineral composition of thin sections of the basic granulite is shown in table (II). Typical samples are composed of 29 to 41 per cent plagioclase, An₃₀₋₄₀, 6 to 12 per cent biotite, 5 to 12 per cent hornblende, 0 to 12 per cent hypersthene, 19 to 31 per cent clinopyroxene, 4 to 8 per cent opaque oxide, and traces of apatite. Rare samples contain up to 20 per cent quartz. Alteration of the primary minerals may produce as much as 5 per cent of any of the secondary minerals uralite, anthophyllite, epidote or talc. The basic granulite differs from the intermediate type in containing primary hornblende and clinopyroxene, a more calcic plagioclase, and in lacking much quartz or microcline.



Photomicrograph of Archean granulite, showing hypersthene with uralite alteration surrounded by biotite, plagioclase and quartz. Parallel light, photo length 2.2 mm.

Table II

MINERAL COMPOSITION OF ARCHEAN GRANULITE

Intermediate Granulite

Sample	Location	Plagioclase				K-spar	Qtz	Bio	Hnb	Opx	Cpx	Opx	Epi	Ap	Gar	Others
		An	20	30	40											
7a	52°55'N, 67°25'W	—	—	—	65		20	7 ^b	4(1)	4						
10a	52°54 ¹ / ₄ 'N, 67°28'W	—	—	—	55		20	15 ^b	3(1)	3				3	Zr tr	
C-25-107-59	52°55 ¹ / ₂ 'N, 67°28 ¹ / ₂ 'W	—	—	—	30	10	20	7 ^b	5(1)	10		5	tr	10	Ser tr	
C-25-108-59	52°55 ¹ / ₄ 'N, 67°30 ¹ / ₄ 'W	—	—	—	40	10	30	11	5(1)	4		tr	tr		Zr tr	
C-28-112-59	52°58'N, 67°25 ¹ / ₂ 'W	—	—	—	32	18	22	12 ^b	8(1)				9		Rut tr	
3-21-49-59	52°54 ¹ / ₄ 'N, 67°29'W	—	—	—	45		15	5 ^{rb}	10(1)	15			tr	10	Zr tr	
Mean					44.5	6.3	21.2	9.5	5.9	6.0					3.8	
Mean Dev.					10.5	6.3	3.2	3.2	2.2	4.7						

Basic Granulite

Sample	Location	Plagioclase				Qtz	Bio	Hnb	Opx	Cpx	Opx	Epi	Ap	Others
		An	20	30	40									
C-32-130-59	52°57 ¹ / ₂ 'N, 67°14 ¹ / ₂ 'W	—	—	—	25		15 ^b	10 ^o	20	25	5	tr		
C-33-139-59	52°59 ¹ / ₄ 'N, 67°23'W	—	—	—	30		2 ^b	5 ^o		35	10	15		Chl.3
C-34-141-51	52°57'N, 67°15 ¹ / ₂ 'W	—	—	—	40	5	10 ^{rb}	15 ^o		25	5	tr		Anth 5
C-35-151-59	52°59 ³ / ₄ 'N, 67°18'W	—	—	—	40		10 ^{db}	5 ^o	5	30	5	5		
C-35-152-59	52°59 ³ / ₄ 'N, 67°18'W	—	—	—	40	20	10 ^{ob}	5 ^{sec}	5	10	5	2	tr	Talc 5
Mean					35.0		9.4	8.0	6.0	25.0	6.0	4.5		
Mean Dev.					6.0		3.0	3.6	5.6	6.0	1.6	4.4		

(1) Metamorphic alteration of pyroxene

Plagioclase determinations

— by Rittmann method
 — by Tsuboi method

mineral colors and shales

b = brown o = olive
 d = dark r = red
 g = green y = yellow
 l = light bg = blue green

The minerals of both rock types show most of the features of the granulite facies. Their quartz is blue and their feldspars tan to grey in colour. Most samples contain hypersthene.

In thin section the quartz grains are seen to be made up of many small segments of slightly different orientation. The plagioclase is unzoned. Some grains contain both albite and pericline twins. The twins are narrow, and commonly pinch out within the grain. Microcline is very finely perthitic, generally untwinned, and shows undulatory extinction. The hypersthene is pleochroic from pink to green, and has an Fe/Fe + Mg ratio of about 0.55. The clinopyroxene is light green augite. Primary hornblende is greenish brown, and secondary uralite blueish green. Biotite forms irregular or tabular grains, with light brown to dark reddish brown pleochroism, and (ny) refractive index of about 1.653. The garnet forms large pinkish brown grains. One sample had the cell edge (11.517 Å) and the refractive index (1.793), of a pyrope-rich almandine.

Secondary alteration products attack some of the primary minerals but were never found to replace them completely or to greatly change the granulitic texture of the rock. The main effects of retrograde metamorphism are the breakdown of the hypersthene and plagioclase. The hypersthene is cut by veinlets of fine grained colourless anthophyllite, and is rimmed by green uralite where it

touches plagioclase. Tablets of colourless clinozoisite and flecks of sericite grow in the plagioclase. Microcline is unaltered. In strongly altered specimens, biotite is bleached; and contains sagenitic rutile. Fine grained mixtures of secondary biotite and quartz replace the hypersthene in these samples. Secondary garnet is common in more altered granulite, farther south, (Clarke, 1967,) but was not recognized in the present area.

The granulites are thought to have formed by very high grade metamorphism of a sedimentary and volcanic sequence. Minerals indicative of sedimentary origin have not been identified in them, but their strongly layered texture probably represents relic bedding. Chemical composition of two intermediate granulites is shown in table (III). The analysis made for Roach and Duffel is taken from an as yet unpublished study of the granulites.

The two analysed granulites closely resemble average greywacke in composition, containing slightly more alumina and ferrous iron and less water than the average greywacke. Igneous rocks closest to the granulite in composition are hypersthene granodiorite and hypersthene tonalite. These rocks contain less water, and more ferric iron, titanium phosphorous, and calcium than the granulite, so have more magnetite, ilmenite, apatite, a more calcic plagioclase and no corundum in their norm. No basic granulites were analysed here, but these are thought to represent metamorphosed basic volcanic rocks.

Table III

CHEMICAL COMPOSITION OF INTERMEDIATE GRANULITE

	1	2	3	4	5
SiO ₂	65.85	62.8	64.2	62.64	63.92
Al ₂ O ₃	15.06	16.1	14.1	15.82	15.60
Fe ₂ O ₃	1.07	1.0	1.0	1.59	1.70
FeO	4.38	5.22	4.2	4.31	4.61
CaO	3.38	3.7	3.5	4.72	5.23
MgO	2.46	3.5	2.9	2.83	2.54
Na ₂ O	3.59	3.5	3.4	3.37	3.54
K ₂ O	2.19	1.9	2.0	2.62	1.22
H ₂ O*	0.94	0.76	2.1	0.42	0.33
TiO ₂	0.52	0.6	0.5	1.32	1.03
P ₂ O ₅	0.13	0.1	0.1	0.27	0.21
MnO	0.08	0.1	0.1	0.09	0.07
CO ₂	0.05	-	0.6		
BaO	0.13	-	-		
SrO	0.12	-	-		

	MOLECULAR NORMS			CIPW NORMS	
qtz	22.1	18.0	21.6	17.7	22.1
or	13.2	11.5	12.5	15.6	7.2
ab	32.7	32.1	32.0	28.3	22.9
an	16.3	17.5	17.6	20.3	23.1
c	1.0	2.2	0.2	-	-
CaSiO ₃	-	-	-	0.6	0.7
MgSiO ₃	7.0	9.9	8.5	7.1	6.3
FeSiO ₃	5.4	6.8	5.7	4.7	5.4
mt	1.1	1.1	1.1	2.3	2.5
il	0.7	0.9	0.7	2.4	2.0
ap	0.2	0.2	0.2	0.7	0.5
py	0.1				

1. Sample #C-25-108-59 Collected at 52°55'N, 67°30'W. Analyst H. Boileau.
2. Composite specimen of intermediate granulite from Mt. Wright Region Roach & Duffel G.S.C. Lab#A-749. Analyst K. Hoops.
3. Average(of 11) Greywacke Pettijohn(1949) p. 250.
4. Average(of 10) Hypersthene Granodiorite Nockolds(1954) p. 1014.
5. Average(of 10) Hypersthene Tonalite Nockolds(1954) p. 1015.

Archean Intrusives Rocks

The Archean granulite is cut by stocks, dikes, and sills of a medium to coarse grained leucocratic igneous rock. The intrusive rock is best exposed $\frac{1}{2}$ mile north of Jackson lake and in the hills west of Cherny lake. Gill et. al. (1937) describes a large batholith of the rock about 15 miles northeast of the Normanville area.

The Archean intrusives are leucocratic rocks composed of pink microcline, blue quartz, greenish plagioclase, and fine clots or stringers of muscovite and biotite. They are white or pink on the fresh surface, and weather white. Mostly granitic, they also include slightly gneissic and pegmatitic varieties. In coarse grained varieties the feldspar cleavage is visibly warped.

Composition estimates of 8 thin-sections are given in table IV. A typical rock of this type contains about 45 per cent plagioclase, 10 to 15 per cent microcline perthite, 10 to 25 per cent quartz, 5 to 10 per cent biotite, and traces of muscovite, epidote, magnetite, apatite, sphene and leucoxene. A pink pegmatitic or aplitic phase contains 50 to 60 per cent microcline perthite, 10 to 20 per cent plagioclase, 20 to 30 per cent quartz, and generally less than 5 per cent mafic minerals.

Table IV

MINERAL COMPOSITION OF ARCHEAN INTRUSIONS

Sample	Location	Plagioclase					K-spar	Qtz	Bio	Epi	Hnb	Ser	Cpx	Opx	Others
		An	10	20	30	40									
C-25-109-59	52°54 $\frac{3}{4}$ 'N, 67°28 $\frac{1}{2}$ 'W					5	60	20	10 ^{rb}					Saus 5	
C-28-113-59	52°58 $\frac{1}{2}$ 'N, 67°24 $\frac{3}{4}$ 'W	+				40	20	30	tr ^b	2		5		Chl 3, Carb tr	
C-32-125-59	52°58'N, 67°14 $\frac{1}{2}$ 'W			-		45	15	10	15 ^o	5		5		Ap 2, Py tr	
C-35-147-59	52°59 $\frac{1}{2}$ 'N, 67°16 $\frac{1}{2}$ 'W					10	45	30	5 ^{vdb}	10				Sph tr	
C-35-150-59	53°00'N, 67°17'W		-			45	5	33	10 ^o	10					
J-23-56-59	52°59 $\frac{1}{2}$ 'N, 67°24 $\frac{1}{2}$ 'W	-				20	60	15				5			
C-6-13-59	52°57 $\frac{3}{4}$ 'N, 67°16 $\frac{1}{2}$ 'W				-	65		25		5		5			
C-7-16-59	52°58 $\frac{1}{2}$ 'N, 67°14'W	-				45	10	35	5 ^{vdb}	2		3		Leuc tr	
Mean						34.4	26.9	20.6	5.7	4.3		2.9			
Mean Dev.						17.1	21.1	8.5	4.3	3.3		2.3			

MINERAL COMPOSITION OF ALTERED ARCHEAN GNEISS

C-28-115-59	52°58 $\frac{1}{2}$ 'N, 67°24'W			-		35	10	10	10 ^{ob}	5		2	15	5	Trem 10
C-33-135-59	52°58 $\frac{3}{4}$ 'N, 67°21 $\frac{1}{4}$ 'W			-		45			10 ^{ob}	20	5 ^{bg}			5	Chl 15, Rut tr
C-33-137a-59	53°00'N, 67°23 $\frac{3}{4}$ 'W			-		25		35	10 ^{ob}	10		10			Leuc 5, Rut 3, Carb 2
C-35-153-59	52°59 $\frac{3}{4}$ 'N, 67°18'W					50		15	7 ^o	10	1	7			Leuc 3, Rut 1, Ap 1
C-35-155-59	52°59 $\frac{1}{4}$ 'N, 67°25'W					45		15	2 ^{ob}	5			10	2	Chl 10, Trem 5, Ap 1, Rut 1
C-36-157-59	52°57 $\frac{1}{4}$ 'N, 67°26 $\frac{1}{2}$ 'W			-		60		10	10 ^o	10	10 ^{sec}			tr	Ap tr, Zr tr
Mean						43.3		14.1	8.2	10.0	2.7	3.2		2.1	
Mean Dev.						9.2		7.5	2.4	4.2	3.2	3.6		1.9	

Thin sections show large quartz grains composed of many small welded segments. The microcline has shadowy extinction or is very finely twinned. Flame or hair perthite forms approximately one-third of the microcline grains, and rims of clear albite have formed at microcline-plagioclase. Most of the plagioclase is altered to sericite or clinozoisite. Plagioclase composition ranges from An₂ to An₃₅, but is generally less calcic than An₂₀. Biotite occurs in both primary and secondary forms. Most of the primary biotite is reddish brown, and some is frayed and altered at the edges. Fine grained, euhedral, epidote, olive green biotite, chlorite, quartz and sphene fill fractures and pockets between the coarser grains.

Charnockites and granulite facies rocks all show mineralogical features, developed by them in response to their high temperatures of formation, or from internal strain caused by cooling from these temperatures. Fine perthitic intergrowths, shadowy extinction, and warped cleavages result when orthoclase inverts to microcline. Blue iridescent quartz grains, made up of many subparallel segments, may also result from internal strain caused by cooling from high temperatures. The primary minerals are often altered to lower temperature secondary minerals on cooling. The Archean intrusives of the Normanville area have all these features in common with other high temperature intrusives.

Altered Archean Gneiss

Some of the Archean rocks near the northern border of the area are too altered to be grouped with the other basement rocks. They have a wide range of texture and composition, and were probably derived from several rock types. The most common type is a greenish-grey mottled rock containing clots of yellowish-green feldspar and blueish quartz in a mixture of fine grained uralite, epidote, chlorite, and coarser biotite. Conversely the mafic minerals may form streaks in a felsic groundmass. Wherever it lies beside less altered granulite the mottled gneiss is weakly foliated parallel the layering of the granulite.

The mineral compositions of 6 thin-sections of the altered gneiss are shown in table (IV). A typical sample contains 44 to 52 per cent plagioclase, An₂₅₋₃₀, 7 to 21 per cent quartz, 6 to 10 per cent olive biotite, 5 to 15 per cent epidote, 0 to 5 per cent hornblende, 0 to 15 per cent augite, 0 to 5 per cent opaque oxide, and small amounts of apatite, zircon and rutile. Alteration products such as epidote, uralite, sericite, anthophyllite, chlorite and sphene or leucoxene generally form 20 to 25 per cent of the rock.

Primary constituents resemble those of the Archean granulite and intrusive rocks. The quartz is blue; the microcline is perthitic, and rimmed with albite. Plagioclase is clouded with

fine clinozoisite and sericite. Hornblende is brown. The biotite is olive brown and full of fine sagenitic rutile. It is the fine grained alteration minerals that give the rock its distinctive appearance. The augite is everywhere rimmed with anthophyllite and uralite. Fine grained biotite, epidote quartz and carbonate form in pockets between the coarse crystals, or in places surround them.

These rocks occur farther from the Grenville Front than less altered granulites, so their strong alteration can not have been caused by the Grenville orogeny alone. They are associated with outliers of slightly metamorphosed Proterozoic schist and grit, to which they bear a strong mineralogical resemblance. The altered gneisses may have been weathered, or adsorbed water during the pre-Proterozoic erosion, and recrystallized during the folding of the Proterozoic rocks.

PROTEROZOIC ROCKS

Proterozoic sediments, deposited in the Labrador Trough, cover the Archean rocks in the southeastern two-thirds of the area, and are preserved in small outliers in the northern part of the area. They now consist of a thick gneissic sequence, overlain by quartzite, marble, iron formation and more gneiss and schist. The Proterozoic

(Grenville) metamorphism was strongest in the southeast, weakening northwestward, and ending over the main Archean mass. The Proterozoic rocks in the southern part of the area have reached the mid-almandine amphibolite facies (kyanite zone); those in the northern part are in the mid-greenschist facies (biotite zone).

Sills of gabbro and amphibolite are found in the quartzite and iron formation, and small granitic intrusions cut the gneisses in the southern part of the area.

Description of the Gneisses and Schists

Albite-epidote-chlorite Schist and Grit

Outliers of slightly metamorphosed Proterozoic iron formation and grit overlie the granulite near Boulder and Jackson lakes. South of Boulder lake the grit passes into a linear textured schist, which in turn grades into common homogeneous gneiss.

The grit contains clastic fragments of blueish quartz, altered plagioclase, and biotite, from the underlying Archean rocks, held in a matrix of fine grained epidote, biotite, quartz and albite. The schist contains the same minerals as the matrix of the grit. Its epidote and biotite are elongated and oriented to give the schist a strong lineation. In some samples spindle shaped clots of quartz and feldspar accentuate the linear appearance of the rock.

Thin-sections of the rock contain 1 to 3 mm. fragments of strained quartz, altered feldspar, and brown sagenitic biotite. Surrounding the fragments is a fine grained matrix of epidote, green biotite, chlorite, albite and quartz, (Plate IVa). Pockets of fine quartz and albite grow in strain shadows beside large fragments. The quartz in the matrix differs from that of the fragments in being clear and extinguishing evenly. In some samples the albite is myrmikitic. Composition estimates of 4 thin-sections are given in table (IV).

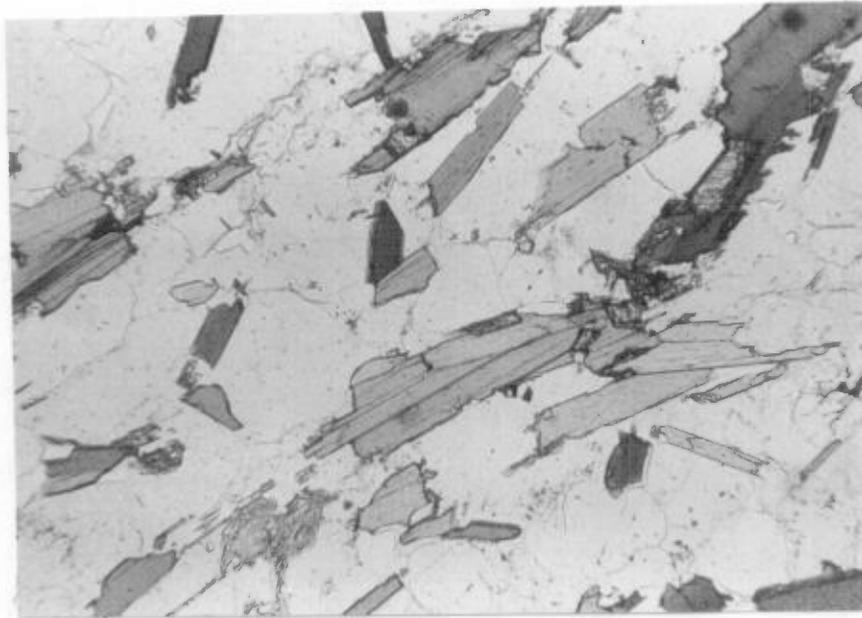
Compositions are varied, but most rocks of this type contain about 10 per cent altered feldspar, 15 per cent strained quartz, and 0 to 5 per cent biotite in coarse grained fragments, surrounded by an additional 10 to 15 per cent quartz, 15 to 35 per cent albite, 10 to 20 per cent biotite, 0 to 15 per cent chlorite and 5 to 20 per cent epidote. Allanite, zircon and magnetite occur in most specimens, and calcite in one.

The occurrence of stable epidote, albite, and biotite places the rock in the middle greenschist facies of metamorphism (Fyfe et al. 1958 p. 223), the lowest grade recognized in the area.

The clastic texture and low metamorphic grade of the grit, and associated iron formation contrast sharply with the highly metamorphosed granulites below them. The

La photo est manquante

- A- Photomicrograph of Proterozoic grit, showing quartz fragment surrounded by fine grained epidote, chlorite, quartz and biotite. Parallel light, photo length 4.4 mm.



- B- Photomicrograph of homogeneous gneiss. Parallel light, photo length 2.2 mm.

unconformity between the granulite and grit was not seen, but is indicated by the fragments of granulite in the grit, and the abrupt drop in metamorphic grade.

The rock is similar to the schistose grit described by Gill et. al. (1937) in the area northwest of Wabush lake.

Gneisses and Schists

Followed southward into the Grenville Province, the Proterozoic grit passes into more highly metamorphosed gneisses and schists. Albite and epidote give way to oligoclase, clastic fragments disappear, and the rock develops an even foliation. Plate IVb.

The common gneisses are grey, and medium grained, with a generally homogeneous texture. Most outcrops are marked by a coarse flaggy fissility and erode into a series of steps. Mica flakes lie parallel to the foliation, and in some samples felsic, porphyroblasts, lenses and thin layers accentuate the mineral foliation.

Several types of distinctive schists are inter-layered with the common gneiss. Graphitic, kyanitic and hornblende-garnet rich bands occur above the Gagnon Group in the southeastern corner of the area. A quite continuous band of very porphyroblastic biotite schist forms part of the lower gneiss sequence south of Sudbury lake. Apart

from these layers, the gneiss above and directly below the Gagnon Group is similar in texture and composition. Far below the Gagnon Group, in the valley of the rivière aux Pékans, the gneiss is coarser grained, more strongly segregated, and more calcic than the common gneiss.

Mineral compositions of thin sections of the common gneisses are shown in table (V). Most of the (upper and lower) homogeneous gneisses contain 21 to 47 per cent plagioclase (An_{20-30}), 5 to 17 per cent microcline, 21 to 33 per cent quartz, 10 to 19 per cent biotite, 4 to 11 per cent muscovite, several per cent epidote, a little apatite, traces of zircon, and rarely garnet and carbonate.

The minerals are generally free of inclusions or alteration. Plagioclase is fresh and evenly twinned, microcline shows coarse grid twinning. Quartz grains are clear and unstrained, and may be elongated parallel the foliation. The micas form subhedral grains evenly dispersed through the rock, and oriented at a slight angle to the foliation. Muscovite also forms large irregular patches apparently replacing plagioclase. Euhedral grains of epidote with allanite cores have grown beside the biotite.

Biotite is brown or olive brown in the lower gneiss, and reddish brown in the upper gneiss. This colour difference and the occurrence of more epidote in the lower gneiss and

Table V

MINERAL COMPOSITION OF GNEISSES

Well Segregated Gneiss

Sample	Location	Plagioclase					K-spar	Qtz	Bio	Hnb	Musc	Epi	Carb	Ap	Others
		An	10	20	30	40									
C-13-46-59	52°45'N, 67°26½'W			-			45	5	15	10 ^{ob}	15 ^{lg}	10			Sph tr, Opq tr, Zr tr
C-13-47-59*	52°45'N, 67°22½'W			-			43		22	18 ^b	5 ^g	5	4	tr	Ser 3, Opq tr, Zr tr
G-3-7-59	52°47½'N, 67°27½'W			-			30		55	7 ^o		3	4	3	
Mean							39.3	1.7	30.7	11.7	6.7	1.0	6.3	2.3	
Mean Dev.							6.2	2.2	16.2	4.2	5.6	1.3	2.4	1.6	

Poorly Segregated Gneiss Below Iron Formation

Sample	Location	Plagioclase					K-spar	Qtz	Bio	Hnb	Musc	Epi	Carb	Ap	Others
		An	10	20	30	40									
C-7-21-59	52°50½'N, 67°5½'W			-			30	5	10	30 ^{ob}		15	5	5	Py tr
C-13-44-59	52°45'N, 67°24½'W			-			10	40	20	10 ^b		10	5	3	Zr tr, Rut tr
C-37-162-59	52°47½'N, 67°10'W			-			20	25	30	10 ^b		10	2	2	Zr tr
C-37-164-59	52°48½'N, 67°9½'W			-			30	10	40	15 ^o		5			
C-45-209-59	52°49'N, 67°18½'W			-			40	14	34	6		4	tr		Zr tr
J-22-55-59	52°52½'N, 67°19'W			-			45		30	20 ^{ob}		5		tr	Zr tr
J-30-74-59	52°48'N, 67°18½'W			-			45		25	10 ^o		15	tr	3	Gar 3
G-2-3-59	52°49½'N, 67°29'W			-			50		30	15 ^{rb}			7		
Mean							33.8	11.8	27.4	14.5		8.0	2.5	0.6	1.1
Mean Dev.							11.9	11.0	6.8	5.5		4.5	2.4	1.0	1.0

Poorly Segregated Gneiss Above Iron Formation

C-10-37-59	52°46'N, 67°8'W			-			25	15	25	15 ^{rb}		5	1 ^{all}	8	1	Gar 5
C-47-214-59	52°46½'N, 67°8'W			-			25	10	33	15 ^{rb}		12		5	1	Zr tr
J-36-101-59	52°45'N, 67°18½'W			-			55	3	20	15 ^{rb}		5	1 ^{all}		2	
Mean							35.0	9.3	26.0	15.0		7.3	0.6	4.3	1.3	
Mean Dev.							13.3	4.2	4.7	0		3.1	0.5	2.9	0.4	

* Average of mafic and felsic layer.

more carbonate in the upper gneisses are the only observed differences between the two groups of common gneiss in the present area. The gneisses in the Normanville area contain more microcline, muscovite and quartz, and less plagioclase, hornblende and garnet than equivalent gneisses further south, Clarke (1967). They were probably derived from more shaly sediments than the southern gneisses.

The homogeneous gneiss underlying Hesse hill passes downwards into a coarse grained well segregated hornblende biotite gneiss. This gneiss is well exposed in a chute in the rivière aux Pékans 400 yards south of the southern border, and in several places west of Hesse lake and near the rivière aux Pékans. It is the predominant rock-type in areas to the south.

The most common variety of this gneiss contains $\frac{1}{4}$ to $\frac{1}{2}$ inch bands of quartz and white plagioclase alternating with bands in which 2 mm. flakes of black biotite are mixed 1 part to 2 with quartz and feldspar. It has been more intensely deformed and reorganized than the homogeneous gneiss.

The average composition of 3 thin-sections of the gneiss, shown in table V, is 44 to 51 per cent plagioclase, (An₁₅₋₂₅), 17 to 27 per cent quartz, 8 to 16 per cent biotite, 1 to 12 per cent hornblende, 4 to 9 per cent epidote, a few per cent carbonate, microcline and muscovite, and traces of opaque, zircon, and sphene.

The biotite is olive brown, hornblende is blueish green. Epidote accompanies the mafic minerals. The most basic of the samples contains light green augite or diopside.

Biotite and hornblende are ragged and slightly altered to chlorite. The plagioclase is sodic oligoclase with inclusions of biotite, sericite and clinozoisite. Quartz shows undulose extinction.

No such alteration effects are found in the common homogeneous gneiss. Moreover, the well segregated gneiss has a more basic composition than the local homogeneous gneiss. It probably represents a deeper horizon in the gneissic sequence, perhaps separated from the homogeneous gneiss by an unconformity. Whether it represents completely recrystallized Archean granulite is not known.

Distinctive Schists

Three distinctive types of schist can be recognized within the gneissic sequence. The most continuous is a very porphyroblastic schist interlayered with the lower gneiss in the central part of the area. Two mineralogically distinctive schists are interlayered with the upper gneiss in the southeastern corner of the area. Both are alumina-rich. One is a felsic quartz-mica kyanite schist, the other is a basic biotite-hornblende-garnet schist. Similar aluminous rocks are common above the iron formation in areas to the south.

Porphyroblastic Biotite Schist

The porphyroblastic schist forms part of the gneissic sequence surrounding the Bloom Lake syncline, and the small syncline southeast of Boulder lake. In it clots of coarse grained quartz and feldspar are surrounded by equally coarse muscovite, and shiny black biotite. The micas are crenelated, and the quartz may be stretched into thin contorted lenses. In places the felsic clots are so abundant that the rock resembles a metamorphosed conglomerate plate V a, but they most likely formed by metamorphic segregation.

Mineral composition of 5 thin-sections, table {VI}, averages 21 to 41 per cent plagioclase, (An₁₅₋₂₅), 18 to 39 per cent quartz, 12 to 26 per cent biotite, 6 to 14 per cent muscovite, 2 to 6 per cent epidote, up to 15 per cent microcline in one sample, and small amounts of apatite and opaque oxide.

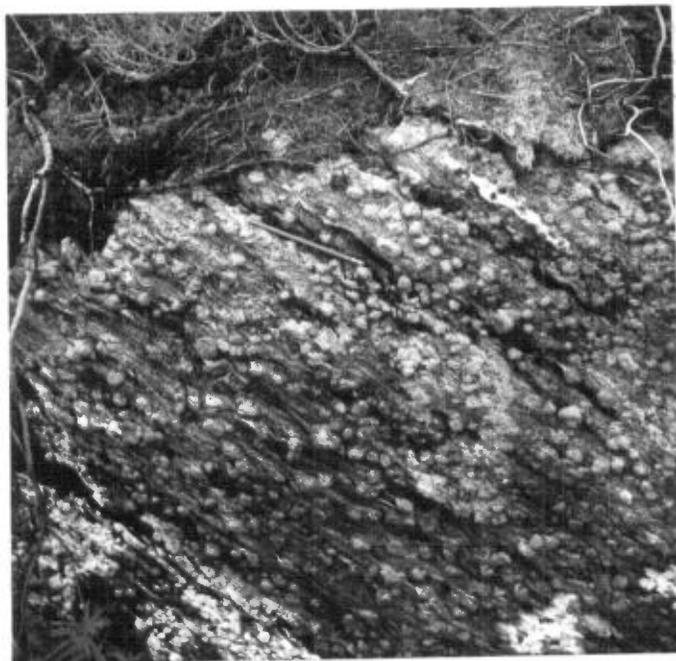
Reddish-brown biotite and muscovite are bent around porphyroblasts of clear quartz, and plagioclase packed with small inclusions of epidote and biotite. Fine quartz and feldspar have crystallized in the pressure shadow near the coarse grains. The porphyroblastic schist contain slightly less feldspar and more mica than the enclosing gneiss.

Quartz-mica-kyanite Schist

A lens-shaped body of quartz-mica-kyanite schist



A- Porphyroblastic biotite schist, 1 mile south of Sitting Bear Lake.



B- Hornblende, garnet, biotite schist, near Simone Lake.

Table VI

MINERAL COMPOSITION OF DISTINCTIVE SCHISTS

Sample	Location	Plagioclase					K-spar	Qtz	Bio	Hnb	Musc	Epi	Ap ^{GnB.}	Others
		An	10	20	30	40								
<u>Epidote and Chlorite Schist and Grit</u>														
C-32-128-59	52°57 $\frac{3}{4}$ 'N, 67°14'W					55		12	20 ^{vg}			15	Zr tr	
C-32-131-59	52°58'N, 67°16'W					15		35	10 ^g			25	Chl 15, Opq tr	
C-35-148-59	52°59 $\frac{1}{2}$ 'N, 67°16'W					20		55	20 ^g			2	Zr 1	
J-24-63-59(1)	53°0 $\frac{1}{4}$ 'N, 67°28 $\frac{1}{2}$ 'W					55		15	10 ^g			5	1 Trem 10, Carb 3, Sph 2	
Mean						36.3		29.3	15.0			11.8		
Mean Dev.						18.7		15.7	5.0			8.2		
<u>Porphyroblastic Biotite Schist</u>														
C-8-29-59	52°49 $\frac{3}{4}$ 'N, 67°04'W					37	3	10	25 ^b			15	8 Opq tr	
C-39-173-59	52°50 $\frac{1}{4}$ 'N, 67°12 $\frac{3}{4}$ 'W					7	15	40	30 ^o				tr Carb 5	
J-16-34-59(2)	52°51 $\frac{3}{4}$ 'N, 67°25 $\frac{3}{4}$ 'W					35		42	10 ^{rb}			10	3 1 Lim 1	
J-22-51-59(2)	52°52 $\frac{1}{4}$ 'N, 67°21'W					40		30	15 ^{yb}			10	5 Opq tr	
J-25-65-59	52°50'N, 67°30 $\frac{1}{4}$ 'W					35	5	20	15 ^b			15	3 5	
Mean						30.8	4.6	28.4	19.0			10.0	3.8 1.4	
Mean Dev.						9.5	4.3	10.7	6.8			4.0	2.2 1.5	
<u>Hornblende Garnet Schist</u>														
													<u>Gar</u> <u>Others</u>	
C-47-216-59	52°45'N, 67°7 $\frac{1}{2}$ 'W					5		25		60 ^{lg}		4	Carb 3, Ky 3, Zr tr	
G-1-1-59	52°45'N, 67°2'W					25		15	15 ^{rb}	25 ^g		2	15 Il 1, Sph 3, Zr tr	
Mean						15		20	7.5	42.5		2	1 7.5	
Mean Dev.						10		5	7.5	17.5		2	1 7.5	
<u>Quartz Mica Kyanite Schist</u>														
C-10-38-59	52°46 $\frac{1}{4}$ 'N, 67°7 $\frac{1}{4}$ 'W					30		20	15 ^{br}			20	2 tr 8 Ky 3, Gra 1, Chl 1, Zr tr	

(1) cg. fragments in fg. matrix.

(2) $\frac{1}{2}$ plag. in porphyroblasts.

lies within the upper gneisses in the southeast corner of the area. It is a tough rock, and forms a ridge northeast of Hook lake. The rock has a homogeneous, coarse grained, texture, and is characterized by glassy quartz, coarse books of greenish muscovite, and the occurrence of kyanite and garnet. Some varieties are graphitic and rusty weathering.

The composition of a single thin-section of the rock is shown in table (VI). The biotite is red-brown and interleaved with muscovite and graphite. Quartz is clear and unstrained. Garnet is poikilitic with biotite and feldspar. The kyanite, which may reach an inch in length, is generally concentrated near quartz pods or layers.

Quartz-mica-kyanite schist becomes more common in areas to the south, where it overlies the silicate-carbonate iron formation. Samples from the southern areas are more quartzose than the one studied (Clarke, 1965).

Biotite-hornblende-garnet Schist

The other aluminous schist is also found among the upper gneisses in the southeastern part of the area. It is a biotite-hornblende-rich rock studded with red garnets as much as an inch in diameter (Plate V b). The garnet is generally poikilitic, and coated in some samples by fine grained quartz and feldspar.

Mineral compositions of two thin sections are given in table VI. Other samples contain more biotite and garnet, and less hornblende than the sections studied. The felsic minerals occur as clots or lenses in a matrix of hornblende and biotite. The hornblende is brownish green, and the biotite reddish brown.

Similar basic gneisses are common above the iron formation in areas to the south. There they have more uniform textures and contain clinopyroxene, more garnet, and less quartz and biotite than the ones in the present area.

Gagnon Group

The name "Gagnon Group" is proposed to cover the mainly chemically deposited metasedimentary formations of the Labrador Trough that have been metamorphosed by the Grenville orogeny. Rocks of this type extend from north of Wabush lake to Matonipi lake, a distance of 170 miles. The town of Gagnon, built to exploit the iron formation of the group, lies near the middle of the belt. The Gagnon Group includes the Duley Marble, Wapussakatoo Quartzite and Wabush Lake Iron Formation, all of which occur in the Normanville area. The marble and quartzite generally underlie the iron formation, but also overlie it in several places.

Duley Marble

White, buff-weathering marble occurs on both sides of the iron formation in the southeast corner of the area. It is best exposed along the river draining Kissing lake, and on the hill west of Simone lake.

The marble is composed of 2 to 5 mm. grains of white dolomite, and thin layers or nodules of quartz and calc-silicate minerals. The calc-silicates, white tremolite and diopside, formed by reaction of quartz and carbonate, and have replaced the quartz completely in some places. The carbonate portion is almost entirely dolomite. Staining reveals tiny blebs or films of calcite on the dolomite, but these were never found to exceed a few per cent of the rock. Minor amounts of calcite generally accompany the calc-silicates.

Rocks mapped as marble contain between 5 and 80 per cent combined quartz and calc-silicates. However, most of the marble is composed of about 80 per cent dolomite, 10 per cent calc-silicates, and 10 per cent quartz.

In this area the marble passes into quartzite to the west, an abrupt change along strike may be seen about 1 mile north of Hook lake.

Wapussakatoo Quartzite

The quartzite is a medium grained, light grey to milky white rock, with a relic bedding in the form of faint

colour bands or a strong joint set. The faint layering seen in outcrops also shows in thin-sections as alternating bands of coarser and finer grained quartz. Some varieties are micaceous and schistose, or coarsely crystalline resembling vein quartz. The muscovite-rich variety is distinguished on the accompanying

map. The quartzite is generally resistant and stands as hills above the surrounding gneiss. However, in places the coarse grained quartzite is deeply weathered and may be crumbled in the hand.

The pure quartzite contains at least 95 per cent quartz and minor amounts of mica, calcite, hematite, cummingtonite, zircon, tourmaline and apatite. In thin section foliation shows as rude bands of coarse (2-3 mm.) grains, with sutured borders and sectoral extinction, interlayered with finer (0.5 mm.) mosaic quartz. The accessory minerals occur between the quartz grains or are included in them, and elongate or foliate minerals lie parallel to the foliation. Any originally clastic grains have been destroyed by metamorphism.

The muscovite-quartzite contains about 70 per cent quartz, 20 per cent muscovite, 5 per cent microcline, and minor amounts of specularite, kyanite and green tourmaline. Alignment of the muscovite and kyanite produces a foliation which is further emphasized by alternating layers of coarse and fine grained quartz.

The origin of the quartzite is not clear. Gross (1955) believes it represents a recrystallized pure quartz sand, as it contains rounded zircon grains. Murphy (1961) thinks that its carbon content, and similarity to the quartz layers of the iron formation indicate development from chert.

In less metamorphosed parts of the Labrador Trough, the iron formation (Sokoman) is underlain by both chert (Fleming) and quartz sandstone (Wishart). The same situation likely existed in more metamorphosed areas, and the Wapussakatoo quartzite probably contains both cherty and sandy components. However, in the opinion of the author, the gradation between quartzite and iron formation, suggests that it is mostly a recrystallized chert.

Wabush Lake Iron Formation

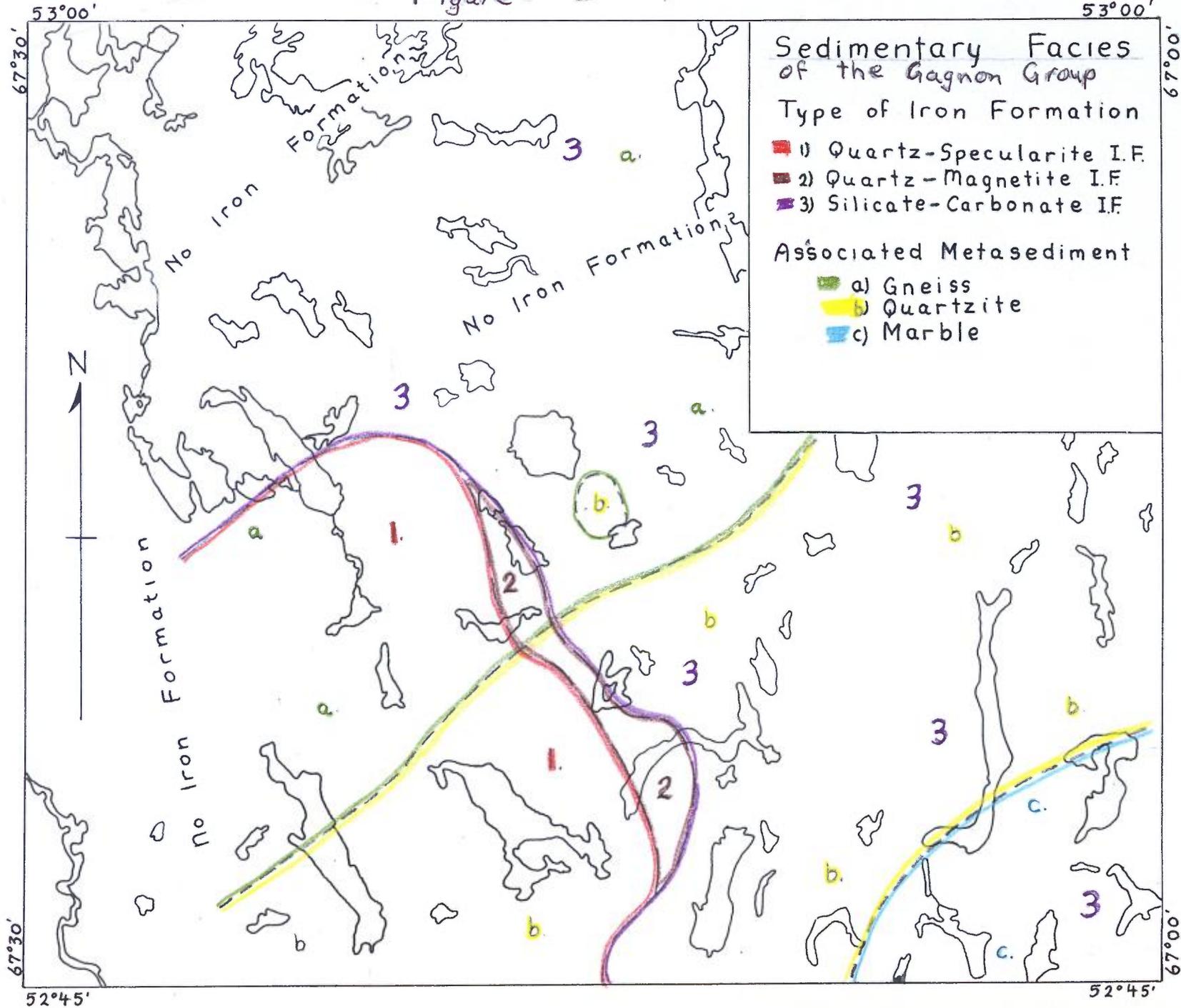
The Wabush Lake Iron Formation contains the ores for which the Mt. Wright district is known. The formation is found throughout much of the area, but its composition is variable, and only certain types are of one grade. Different types of iron formation were deposited in different parts of the sedimentary basin, depending on the local oxydation potential. In places where the sea bottom received sufficient oxygen, chert and ferric iron were deposited, and were later metamorphosed to quartz-specularite iron formation. In more reducing environments the iron

remained in the ferrous state and now occurs as magnetite, and siderite, or iron silicates.

The sedimentary facies zones are shown in Fig. I. Quartz-specularite iron formation occurs in the southwestern part of the area in a zone bounded by the south end of Boulder lake, Bloom lake, and the east bay of Mogridge lake. Silicate-carbonate iron formation was deposited to the east of this zone, and a thin zone of quartz-magnetite iron formation lies between the two major facies. There are two bands of iron formation in the northern part of the area. Near Boulder lake, a lower band of silicate-carbonate facies is overlain by gneisses and an upper band of the oxide facies.

The metasediments associated with the iron formation were deposited in a facies zones having a somewhat different configuration than the iron formation. In the northwestern half of the area the iron formation is underlain by metasedimentary gneiss. Southeast of this zone, quartzite is associated with the iron formation, and still further southeast the quartzite gives way to marble. The facies zones of the metasedimentary rocks trend parallel to the main Archean-Proterozoic contact and probably represent the general configuration of the sea floor better than the iron formation facies. On facies maps of the whole district, Gastil and Knowles (1960), Clarke (1967), the (overall) trend of iron formation facies zones is also northeast-southwest and the local pattern (is seen to be) an embayment of silicate-carbonate facies into the oxide facies.

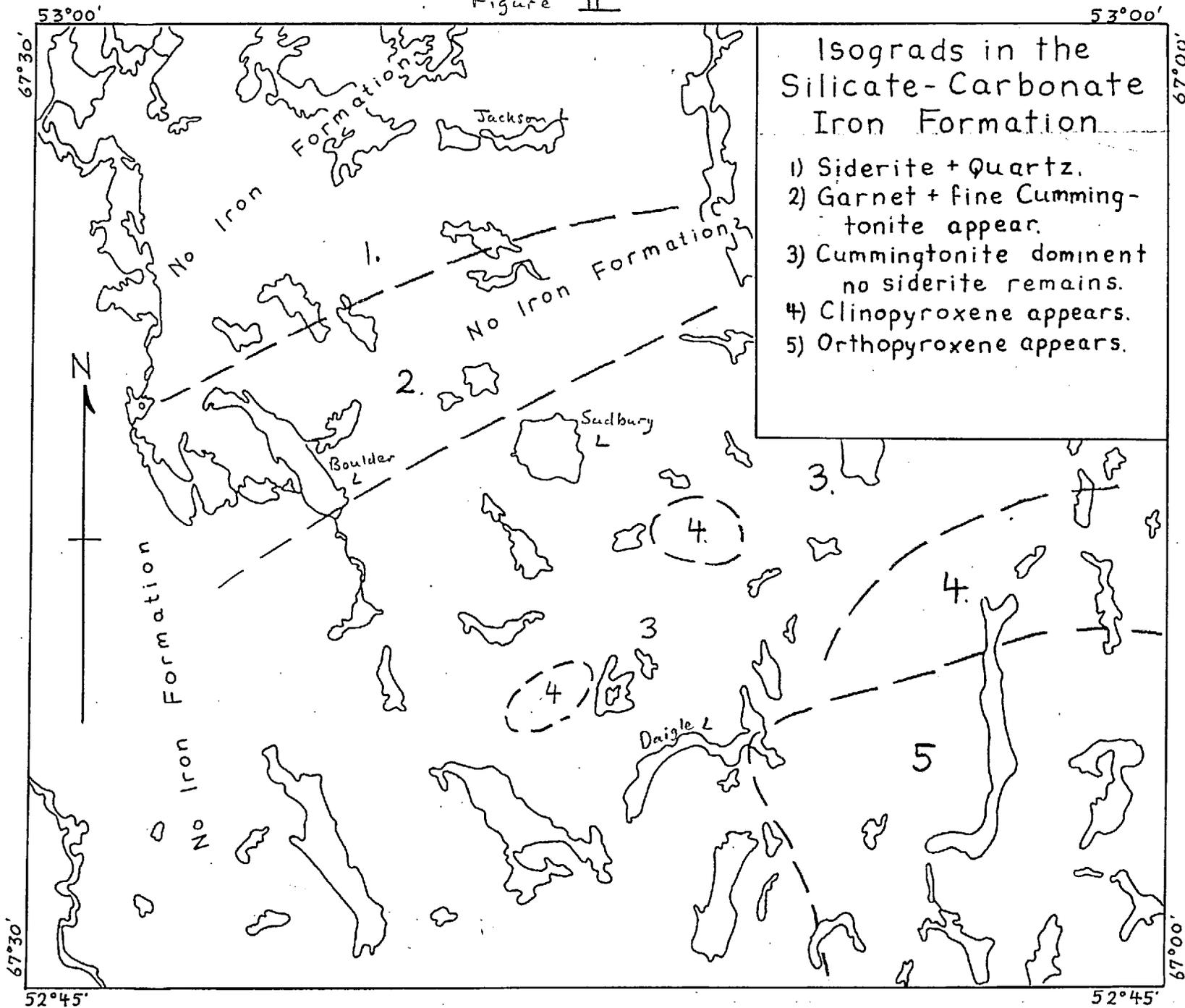
Figure I



Several different mineral assemblages occur in the iron formation in response to different degrees of Grenville metamorphism. Quartz and iron oxides are stable through the metamorphic range, and it is in the silicate-carbonate iron formation that most metamorphic changes occur, Fig. II. The most northerly iron formation, near Jackson lake, is composed of fine grained quartz, magnetite and siderite. Farther south, near Boulder lake, large garnets, and some very fine grained cummingtonite appear and stilpnomelane becomes more common. In the area between Sudbury and Daigle lakes cummingtonite is the main silicate mineral and siderite is no longer present. If the rock contains sufficient calcium actinolite forms in place of cummingtonite. Orthopyroxene and clinopyroxene are developed in the southeast corner of the area. Orthopyroxene is first developed north of Kissing lake by contact metamorphism around gabbro sills, (Jackson, 1962). Further south it becomes the most common iron silicate formed by the regional metamorphism.

Gneisses associated with the iron formation show that the change from quartz and siderite to orthopyroxene takes place between the middle greenschist facies (biotite zone) and middle almandine amphibolite facies (kyanite zone) of metamorphism, Fyfe et. al. (1958). Thus, orthopyroxene is stable at a much lower grade in iron formation than it is in pelitic gneiss.

Figure II



Description of the Iron Formation

Silicate Carbonate Facies

The silicate carbonate iron formation is composed of various proportions of quartz, magnetite, iron-rich silicates and carbonate. Because of the metamorphic gradient, the composition and appearance of these rocks changes across the area. The least metamorphosed variety is exposed south of Jackson lake, and only slightly more metamorphosed deposits occur near Boulder and Roach lakes.

The slightly metamorphosed iron formation is a fine grained, iron grey, massive to thin-bedded rock, composed essentially of quartz, magnetite and siderite or very fine grained cummingtonite with lesser amounts of garnet and stilpnomelane. Altered surfaces are flecked with limonite.

Bedding shows as elongate clusters of siderite and magnetite grains, and as slight differences in grain size (0.1 to 0.3 mm.) in the surrounding quartz. The quartz is clear and unstrained. The siderite is partly altered to limonite, and is distinguished from dolomite by this alteration, and by its darker colour and higher refractive index ($n_e = 1.635$, $n_o = 1.87$). The development of cummingtonite in the Boulder Lake iron formation gives some of these rocks a weak schistosity.

Composition of thin-sections from the Jackson Lake, Boulder Lake and Roach Lake deposits is given in table VII. At Jackson lake the iron formation is composed of quartz, magnetite, and siderite, and minor cummingtonite and stilpnomelane. The siderite is altered to limonite on weathered surfaces. An average rock of this group contains 56 to 67 per cent quartz, 13 to 27 per cent magnetite, 10 per cent siderite and 3 to 9 per cent limonite.

Near Boulder lake, siderite has disappeared, there is less quartz, and cummingtonite is a major constituent. Large porphyroblasts of pink garnet grow in some samples. The garnet replaces cummingtonite, and incorporates the magnetite layers, which are left undisturbed.

A rim of stilpnomelane forms between the cummingtonite and garnet. The garnet of one sample had a refractive index of 1.818, and a cell edge of 11.62 Å. Cleavage fragments of cummingtonite from the same sample had refractive indices of 1.676 and 1.696. These properties indicate a $\frac{\text{Mg}}{\text{Mg} + \text{Fe}}$ ratio of 0.28 in the cummingtonite, (Parker, 1961) and suggest that the garnet is andranitic almandine (Winchell, 1958). The stilpnomelane forms small flakes with parallel extinction. They are length slow, pleochroic from yellow (X) to green (Z), and optically negative with a very small 2V.

The average composition of the thin-sections studied is 15 to 55 per cent quartz, 9 to 50 per cent cummingtonite, 6 to 36 per cent magnetite, 1 to 6 per cent stilpnomelane, 0 to 6 per cent limonite, and some garnet.

Table VII

MINERAL COMPOSITION OF IRON FORMATION

<u>Sample</u>	<u>Location</u>	<u>Qtz</u>	<u>Mag</u>	<u>Cumm</u>	<u>Opx</u>	<u>Carb</u>	<u>Stilp</u>	<u>Lim</u>	<u>Others</u>
<u>Silicate-Carbonate Facies</u>									
C-37-159-59	52°48 $\frac{2}{4}$ 'N, 67°11'W	70	2		20	8			
C-38-167-59	52°51'N, 67°11'W	60	8	30					
C-38-166-59(1)	52°51'N, 67°11'W		15	30					a.c. 55
C-43-198-59	52°50'N, 67°15 $\frac{1}{2}$ 'W	40	40	20					
C-43-199-59	52°50'N, 67°15 $\frac{1}{2}$ 'W	55	35	10					
Mean		45.0	20.0	29.0					
Mean Dev.		20.0	14.0	22.8					
<u>Jackson Lake Deposit</u>									
C-32-126-59(2)	52°58'N, 67°14 $\frac{3}{4}$ 'W	70	10			10		10	
C-44-142-59(1)	52°57 $\frac{1}{4}$ 'N, 67°16 $\frac{1}{2}$ 'W	55	30			10		5	
G-6-14-59	52°57 $\frac{1}{2}$ 'N, 67°16 $\frac{1}{2}$ 'W	60	20	6		10	2	2	
Mean		61.7	20.0			10		5.7	
Mean Dev.		5.6	6.7			0		2.9	
<u>Boulder Lake and Roach Lake Deposits</u>									
G-59-Loc-6a	52°54 $\frac{2}{4}$ 'N, 67°23'W	58	15	23			3		
G-59-Loc-6b	52°55'N, 67°23'W	35	45	9			2	4	
60-9-F-54-A(3)	52°52'N, 67°24 $\frac{1}{4}$ 'W	20		30			10	10	Gar 35
60-9-F-54-C	52°52'N, 67°24 $\frac{1}{4}$ 'W		10	80			2	tr	Gar 10
60-9-F-54-D	52°52'N, 67°24 $\frac{1}{4}$ 'W	60	35	5				2	
Mean		34.6	21.0	29.5			3.5	3.3	
Mean Dev.		20.0	15.2	20.3			2.7	2.9	

(1) polished section

(2) average of thin section and polished section

(3) rough estimate

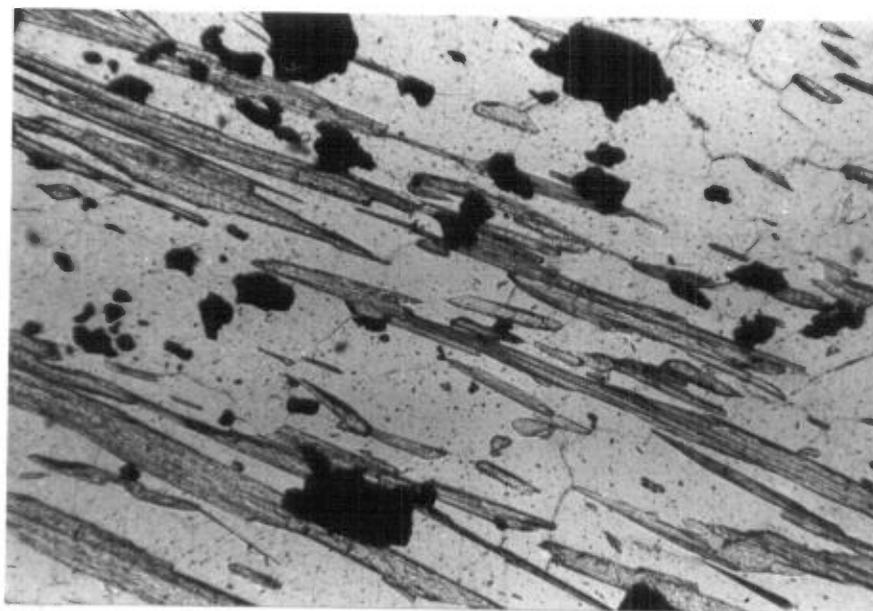
Farther south near Sudbury and Bloom lakes the iron formation becomes a strongly schistose rock composed of honey-coloured cummingtonite needles in a fine quartz mosaic, Plate VI. The rock is speckled with magnetite octahedra and blotches of limonite (after siderite?). Compositions of four sections of cummingtonite schist are given in table VII-a. The rock varies in composition between the limits 40 to 60 per cent quartz, 8 to 40 per cent magnetite, 10 to 30 per cent cummingtonite, and contains up to 55 per cent actinolite in calcic layers.

The cummingtonite is colourless to light brown, commonly twinned, and has an extinction angle (ZAc) of 17 to 23 degrees. Seven samples had $\frac{Mg}{Mg + Fe}$ ratios of 0.17 to 0.45. The $\frac{Mg}{Mg + Fe}$ ratio of 3 actinolite samples ranged from 0.40 to 0.88. The wider composition range, and more magnesium-rich composition of actinolite compared to cummingtonite is also noted by Mueller (1960).

In the southeastern corner of the area pyroxene is developed, and the rock becomes coarsely layered and granular instead of schistose, Plate VII. It is composed here of quartz, brown and green pyroxenes (hypersthene and ferrosalite), cummingtonite, magnetite and carbonate. The quartz and iron silicates form alternating layers or irregular masses. Near Tupper lake actinolite and magnetite have formed between the quartz and hypersthene layers. Rusty weathering carbonate layers take the place of quartz in some places.



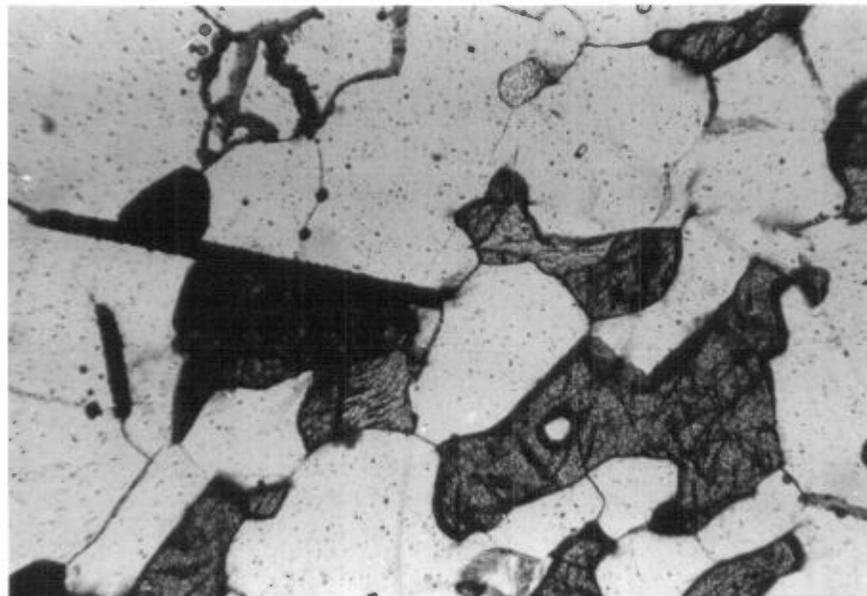
A- Shear fold in schistose quartz cummingtonite iron formation, south of Sitting Bear Lake.



B- Photomicrograph of quartz-cummingtonite-magnetite iron formation. Parallel light, length of photo 2.2 mm.



A- Interlayered quartz and silicate-carbonate bands in iron formation south of Kissing Lake.



B- Quartz, hypersthene, magnetite and graphite in silicate-carbonate iron formation. Parallel light, photo length 2.2mm.

The most common composition for this type of iron formation is about 55 per cent quartz, 20 per cent hypersthene, 10 per cent grunerite, 5 per cent dolomite, 5 per cent magnetite, several per cent diopside, some limonite, and traces of zircon. However its composition is extremely variable, and many outcrops differ greatly from this average.

The quartz layers are made up of 1.5 mm. equidimensional grains with sutured boundaries and generally even extinction. Layers of iron silicates and finer grained (0.5 mm.) quartz alternate with the coarse quartz layers. Magnetite occurs in both the quartz and iron silicate layers. The orthopyroxene is brownish pink, optically negative, and non pleochroic. Three samples had $\frac{Mg}{Mg + Fe}$ ratios between 0.18 and 0.22. The clinopyroxene is optically positive, with extinction angles (Z^Ac) from 42 to 55 degrees. Four samples had $\frac{Mg}{Mg + Fe}$ ratios ranging from 0.27 to 0.55. $\frac{Mg}{Mg + Fe}$ ratios of 0.11 to 0.85 in Bloom lake clinopyroxenes are reported by Mueller (1960).

The carbonate in the highly metamorphosed iron formation is dolomite or ferrodolomite (n_D 1.50 - 1.55, n_B 1.68 - 1.75), and siderite is presumably unstable.

Oxide Facies Iron Formation

The oxide facies is the most economically important.

variety of iron formation. It resists erosion, and its tendency to form hills results in the exposure of most of the large deposits. The best deposits occur in the hills near Hesse, Mogridge, Bloom, Boulder and Daigle lakes. The iron formation is as much as 250 feet thick in the hills south of Mogridge lake, Gross (1955).

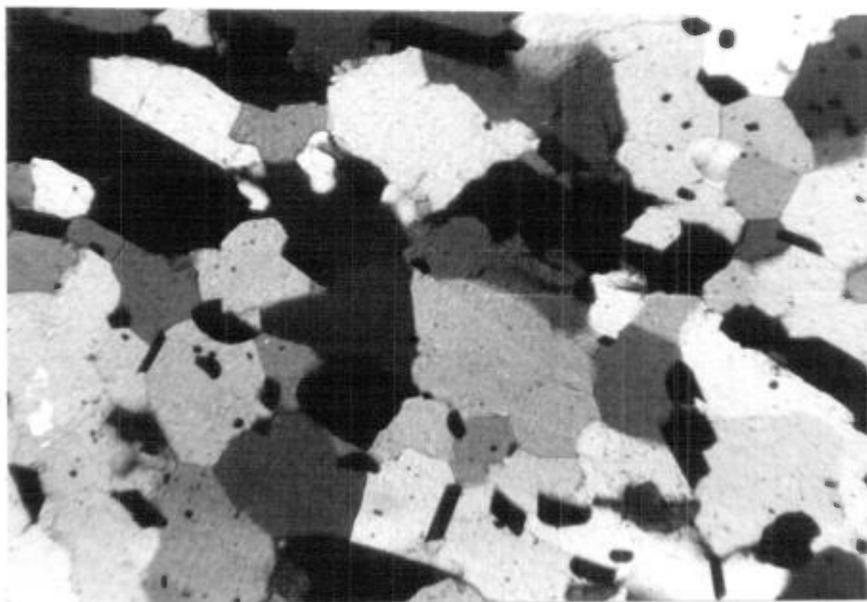
The iron may occur either as blue grey specular hematite or as magnetite, depending on the oxidation state of the original sediment. The quartz magnetite facies is less common than the quartz hematite facies, and is gradational between the quartz hematite and the silicate carbonate facies.

Most outcrops are composed of mixed quartz and iron oxide interlayered with grey glassy quartz. Thin layers or streaks of green actinolite form beside the hematite, and cummingtonite accompanies the magnetite. The iron formation contains between 10 and 45 per cent iron oxides, and generally averages about 30 per cent. Some migration of quartz and hematite has occurred. South of Mogridge lake 6 inch vugs in the iron formation are lined with coarsely crystalline striated hematite and quartz. On Hesse hill a large lens of milky quartz is surrounded by an 18 inch rim of residual hematite, Plate VIII.

Thin-sections of the oxide iron formation show layers of mixed quartz and coarse grained (0.2-2 mm.)



A- Segregation pod of milky quartz surrounded by residual specularite, in iron formation 1 mile west of Hesse Lake.



B- Photomicrograph of quartz specularite iron formation.
Crossed nicols, photo length 2.2 mm.

Table VIII

MINERAL COMPOSITION OF IRON FORMATION

<u>Sample</u>	<u>Location</u>	<u>Qtz</u>	<u>Hem</u>	<u>Mag</u>	<u>Cum</u>	<u>Act</u>	<u>Others</u>
							<u>Oxide Facies</u>
C-12-39-59	52°45 $\frac{1}{4}$ 'N, 67°22 $\frac{1}{2}$ 'W	50	35	10			Felds 5, Zr tr, Ap tr
C-30-119-59	52°52'N, 67°23'W	65	35				
C-30-121-59(1)	52°52 $\frac{3}{4}$ 'N, 67°19 $\frac{1}{4}$ 'W	32	18				
C-41-181-59(1)	52°46'N, 67°16 $\frac{3}{4}$ 'W	85	4	6	5		
C-42-194-59	52°47 $\frac{1}{2}$ 'N, 67°13'W	70		25	5		
C-42-188-59(2)	52°47 $\frac{3}{4}$ 'N, 67°13'W	65	17	8		10	
C-42-194-59(2)	52°47 $\frac{1}{2}$ 'N, 67°13'W	55		40	5		
J-37-118-59(2)	52°50 $\frac{1}{4}$ 'N, 67°16 $\frac{1}{2}$ 'W	78	15	2		5	
Mean		70.9	15.5	11.4	1.9		
Mean Dev.		11.0	10.1	10.5	2.3		

(1) average of thin section and polished section

(2) polished section

hematite, or magnetite, alternating with thicker quartz layers. The quartz has slightly undulose extinction and a mosaic texture. Grains in the pure quartz layers may be slightly elongated parallel the foliation, and are coarser than grains in the mixed layers. Hematite forms coarse tabular grains parallel the foliation or finer grains included in the quartz Plate VIII b. Magnetite occurs as equant, anhedral grains which are generally rimmed and veined by late hematite. Minor amounts of muscovite, dolomite, actinolite, tourmaline and zircon occur in the hematite-iron formation cummingtonite and hypersthene occur in magnetite-rich samples.

Compositions of thin and polished sections of oxide iron formation are listed in table VIII. Average samples contain 60 to 82 per cent quartz, 5 to 25 per cent hematite, 1 to 22 per cent magnetite, plus 5 to 10 per cent actinolite, and cummingtonite, in some samples, and traces of mica, tourmaline, and zircon. These are volume per cents. Weight per cents of iron oxides are higher, and of quartz are lower in proportion to the specific gravity of the mineral. Individual rocks are rich in either hematite or magnetite, and it is in the magnetite-rich rocks that iron silicates are most common.

IGNEOUS ROCKS

Two groups of igneous rocks intrude different parts of the Proterozoic sequence. Sills of coronitic gabbro and metagabbro amphibolite occur in synclines containing a thick quartzite formation, and thin granitic bodies inject the gneisses in the southeastern part of the area.

Granitic Intrusives

Small, generally conformable bodies of white to pale pink, slightly gneissic, quartz monzonite occur in the southeastern quarter of the area. They are most abundant in the lower gneisses but also intrude rocks of the Gagnon Group. Few of the bodies are homogeneous, most contain gneissic remnants and may grade through migmatite into gneiss.

The rock is composed essentially of medium grained (0.5-2.0 mm.) anhedral of feldspar and quartz interspersed with flakes of mica. The alignment of its biotite flakes, and thin quartz lenses give the rock a weak foliation. Muscovite occurs as fine inclusions in the plagioclase, and as large ragged grains replacing it. Microcline is fresh and evenly twinned.

Five thin-sections show an average composition range of 25 to 43 per cent plagioclase, An_{15-30} , 11 to 39 per cent microcline, 26 to 36 per cent quartz, 2 to 5 per cent biotite, 3 to 6 per cent muscovite, up to 1 per cent epidote, and traces of zircon and apatite, figure IX a.

Table IX

MINERAL COMPOSITION OF IGNEOUS ROCKS

Quartz Monzonite																	
Sample	Location	Plagioclase					K-spar	Qtz	Bio	Musc	Hnb	Epi	Cpx	Gar	Oth ers		
		An	10	20	30	40										%	
C-7-26-59	52°50 ³ / ₄ 'N, 67°05'W			—			35	20	35	2 ^b	5		1				
C-13-47-59 ⁽¹⁾	52°46'N, 67°22 ¹ / ₂ 'W		—				50		40	5 ^{db}			tr	Ser 2, Zr tr			
C-37-165-59	52°48'N, 67°10'W				—		30	40	20	2 ^{db}	8						
C-45-205-59	52°49 ¹ / ₄ 'N, 67°18 ¹ / ₂ 'W	—	—				15	45	30	5 ^{db}	5						
J-37-116-59	52°49 ¹ / ₂ 'N, 67°18'W				—		40	20	30	3 ^b	5		1				
Mean							34.0	25.0	31.0	3.4	4.6		0.5				
Mean Dev.							9.2	14.0	5.2	1.3	1.8		0.4				
Gabbro																	
Sample	Location	Plagioclase					K-spar	Qtz	Bio	Musc	Hnb	Epi	Cpx	Gar	Oth ers		
		An	40	50	60	70										%	
C-37-160-59 ⁽²⁾	52°48 ¹ / ₄ 'N, 67°10 ¹ / ₂ 'W						15			7 ^{yb}		20 ^{lg}	2	10	2	Chl 25, Scap 15, Ap 2, Sph 1	
C-37-161-59 ⁽²⁾	52°48 ¹ / ₄ 'N, 67°10 ¹ / ₂ 'W				—		45			3 ^{rb}		5 ^{lg}	3	7	1	7	Chl 10, Opx 12, Ol 2, Idd 5
C-45-208-59 ⁽²⁾	52°49 ¹ / ₂ 'N, 67°18'W	—	—				65			5 ^{rb}		3 ^{lg}		5		5	Ol 10, Ant 3, Idd tr, Myrm 5, Ap 3
Mean							41.7			5		9.3	1.7	4.0	3.7	4.7	
Mean Dev.							17.8			1.3		7.1	1.1	2.7	4.2	1.8	
Amphibolite (Metagabbro)																	
Sample	Location	Plagioclase					K-spar	Qtz	Bio	Musc	Hnb	Epi	Cpx	Gar	Oth ers		
		An	10	20	30	40										%	
C-12-43-59	52°45 ³ / ₄ 'N, 67°23'W		—				30			10 ^{yb}		40 ^{lg}		5	10	Ap 5	
C-41-187-59	52°46'N, 67°18'W				—		35			10 ^{rb}		45 ^g	3	5	5		
C-46-213-59	52°50'N, 67°16'W				—		40			10 ^{yb}		35 ^{bg}	tr	2	2	Ap 3, Sph 3	
Mean							35			10		40.0	1.2	4.0	5.7		
Mean Dev.							3.3			0		3.3	1.2	1.3	2.9		

(1) Felsic band in gneiss

(2) Hornblende is secondary

The Proterozoic quartz monzonite differs from the Archean intrusives in containing muscovite and less quartz. Its microcline is evenly twinned, its quartz unstrained, and its plagioclase is relatively fresh, in contrast to the strained and altered minerals of the Archean intrusives.

The quartz monzonite contains more potash feldspar and less mafic minerals than the lower gneiss, but its mineralogy reflects that of the gneiss. In areas to the south, Clarke (1967), both the gneiss and quartz monzonite contain less quartz and muscovite, and more hornblende and garnet than they do in the present area. The quartz monzonite probably formed by partial melting of the gneiss, followed by injection into, and some mixing with, its host rock.

Gabbro

Bodies of medium grained gabbro and amphibolite stand as hills among the quartzose rocks of the Gagnon Group. They were apparently injected into the competent rocks during deformation, and themselves altered during the later stages of metamorphism. The gabbro was originally ophitic in texture but now grades through successively altered coronitic and speckled textures into foliated amphibolite. Gabbro is more common in the northern part of the injected zone and amphibolite in the southern part. In places gabbro cores remain in the centres of thick amphibolite sills.

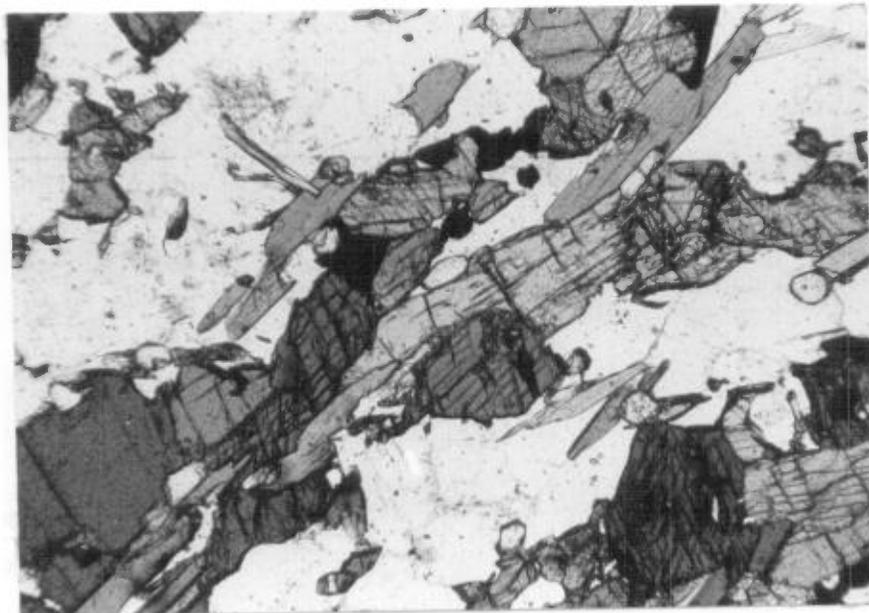
In the less altered samples euhedral laths of labradorite penetrate augite, hypersthene and olivine. The augite is clouded with magnetite dust and the hypersthene contains schiller magnetite. The primary mafic minerals are rimmed with successive coronas of fine alteration products. Colourless fibers of orthopyroxene radiate outward from corroded olivine cores. These are surrounded by green pleochroic uralite, and in some samples by an outer rim of garnet. Magnetite, albite, and quartz are interstitial to the early crystallizing grains. Plate IX a.

The typical gabbro of this type contains 50 to 65 per cent plagioclase (An_{55-75}), 7 to 10 per cent olivine, 5 to 7 per cent augite, 5 to 7 per cent opaque oxide, 5 per cent hypersthene, 3 to 5 per cent biotite, and a few per cent antigorite, iddingsite and apatite. The coronas add about 5 per cent of both secondary orthopyroxene and uralite, and traces of garnet.

In one sample the phitic texture has been destroyed, and much of the plagioclase is replaced by scapolite. The mafic minerals are converted into felted clusters of green amphibole with cores of light brown biotite, magnetite and sphene. Larger (1-2 mm.) plagioclase crystals, and small, colourless euhedral garnets occur between the mafic clusters. The plagioclase is full of tiny epidote laths, and partly replaced by scapolite. Continued alteration yields a foliated metagabbro amphibolite.



A- Photomicrograph of coronitic gabbro, showing double rim of orthopyroxene and uranalite formed on reaction of olivine and plagioclase. Plane polarized light, photo length 2.2 mm.



B- Photomicrograph of amphibolite. Plane polarized light, length of photo 2.2 mm.

Amphibolite

The change from gabbro to amphibolite involves the addition of water, recrystallization of the original minerals to oligoclase, hornblende and garnet, and the development of foliation parallel that of the surrounding rocks.

The amphibolite is a medium grained, dark green rock, composed essentially of plagioclase and hornblende, with smaller amounts of biotite, garnet, ilmenite and rare quartz. A weak foliation results from the alignment of hornblende and biotite and small lenses of mafic and felsic constituents, (Plate IX b.)

Mineral compositions of amphibolite are given in table IX.)) Average samples contain 32 to 38 per cent plagioclase (An₂₀₋₃₀), 37 to 43 per cent hornblende, 10 per cent biotite, 3 to 10 per cent opaque oxide, 3 to 5 per cent garnet, and small amounts of apatite and sphene. Similar rocks in the south have more variable compositions.

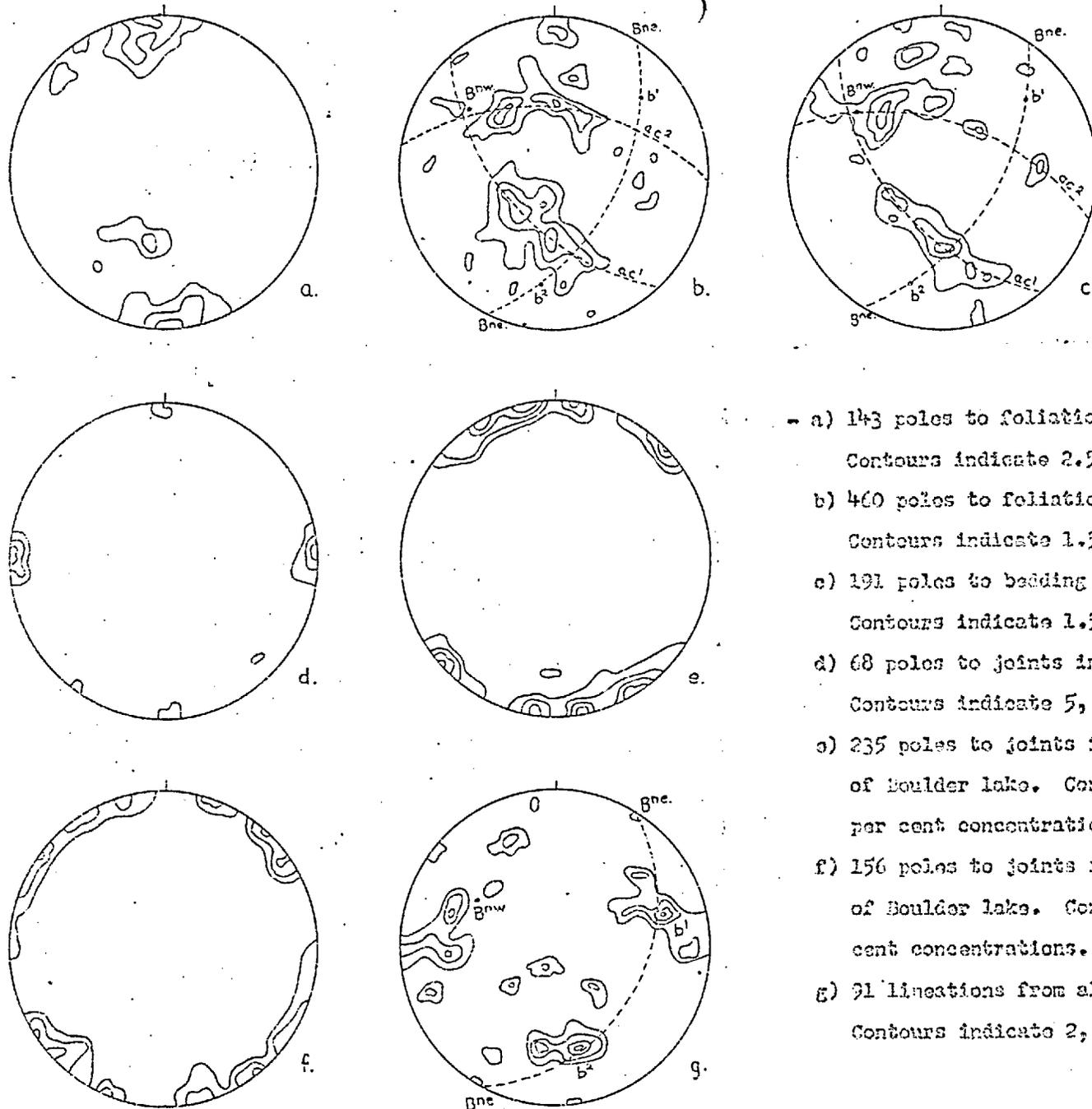
The plagioclase is generally fresh, poorly twinned, and zoned from relatively calcic borders to a sodic core. The hornblende occurs as subhedral grains in mafic clusters. It is pleochroic from yellow green to dark green, and has an extinction angle of about 28 degrees. Biotite is brown or red brown and aligned parallel the foliation. Sphene occurs with the mafic minerals, and is generally accompanied by ilmenite.

STRUCTURAL GEOLOGY

Rocks in the area have been involved in at least three deformations. Those in its northwestern part lie within the Superior Province and were deformed during the Archean. The southeastern part of the area forms part of the Grenville Province, and contains two main structural trends, northeast and northwest, in its Proterozoic rocks. The structures here are complex, but formations of the Gagnon Group make good marker horizons and outline many structural details that would otherwise be obscure. This combination of complex folding and good marker horizons makes the area ideal for a structural study. The orientations of foliations, joints and lineations of the area rocks are presented in southern hemisphere equal area net projections, (Fig. III). The diagrams are based on a synopsis of field data rather than a statistical sampling, but are believed to represent the structure fairly well and have been used in its interpretation.

Archean Structures

The Archean rocks underwent strong deformation at very high temperatures and pressures. Their structural pattern, developed under these conditions, is relatively simple and uniform over large areas. Most of the Archean rocks are isoclinally folded about shallowly plunging axes,



- a) 143 poles to foliation of Archean gneiss.
Contours indicate 2.5, 5, 7.5 per cent concentrations.
- b) 460 poles to foliation of all Proterozoic rocks.
Contours indicate 1.5, 2, 2.5 per cent concentrations.
- c) 191 poles to bedding of Proterozoic Gagnon Group rocks.
Contours indicate 1.5, 2.5, 3.5 per cent concentrations.
- d) 68 poles to joints in Archean gneiss.
Contours indicate 5, 7.5, 10 per cent concentrations.
- e) 235 poles to joints in iron formation hill southeast of Boulder lake. Contours indicate 2.5, 5, 7.5, 10 per cent concentrations.
- f) 156 poles to joints in iron formation hill southwest of Boulder lake. Contours indicate 2.5, 5, 7.5 per cent concentrations.
- g) 91 lineations from all Proterozoic rocks.
Contours indicate 2, 3, 4, 5 per cent concentrations.

STEREOGRAPHIC PROJECTIONS OF STRUCTURAL ELEMENTS

Plate IIa, p.15. Foliations trend to the northwest in the area west of Boulder lake, and approximately eastward in the rest of the Archean area. A plot of foliation attitudes, (Fig. III-a) shows that most of these rocks strike about N 80°E and dip steeply.

Mineral lineations are not developed in the granulite but the axes of small folds reflect the axial trend of the group. Most small fold axes plunge between 10 and 50 degrees to the east-southeast.

The joint pattern is simple consisting of a nearly vertical set perpendicular to the foliation, and a weaker set about parallel to it. Cross joints are especially common in layers of basic granulite. They are believed to be tension joints formed perpendicular to the main fold axes. Since most of the foliations strike about east-west, most the joints strike about north-south, Figure III-d).

The Archean-Proterozoic Contact, and the Grenville Front

The main contact between Archean and Proterozoic rocks crosses the area in an east-northeasterly direction. Duffel (1959) shows the contact continuing in the same direction to the southwest of the area, and Gill et, al. (1937) shows it continuing northwestward to pass about 5 miles north of Wabush lake. The contact runs parallel to, and has been influenced by the Grenville Front and is therefore

partly stratigraphic and partly structural in nature.

The Archean rocks west of Boulder lake trend southeast to where they are cut off by Proterozoic gneisses, striking northeast parallel to the contact, and dipping away from it. Northeast-striking shears cut the gneisses about $1\frac{1}{2}$ miles southeast of the contact. The main Proterozoic outlier at Jackson lake is also folded about a northeasterly axis. Thus, although the contact was not exposed, it lies within a zone along which the Proterozoic rocks were folded into and thrust against the basement. The movement could not have been very great however, as the same iron formation occurs on both sides of the main contact zone, and the original configuration, with basement rocks to the northwest and Proterozoic sediments to the southeast, has not been changed by the deformation.

Structural changes were apparently of secondary in the development of the main geological features of the area. The Archean-Proterozoic contact is mainly stratigraphic, and the Grenville Front is mainly metamorphic. The metamorphic gradient runs parallel to the main Archean-Proterozoic contact and raises the Proterozoic rocks from middle greenschist to middle almandine amphibolite facies in a distance of about 12 miles.

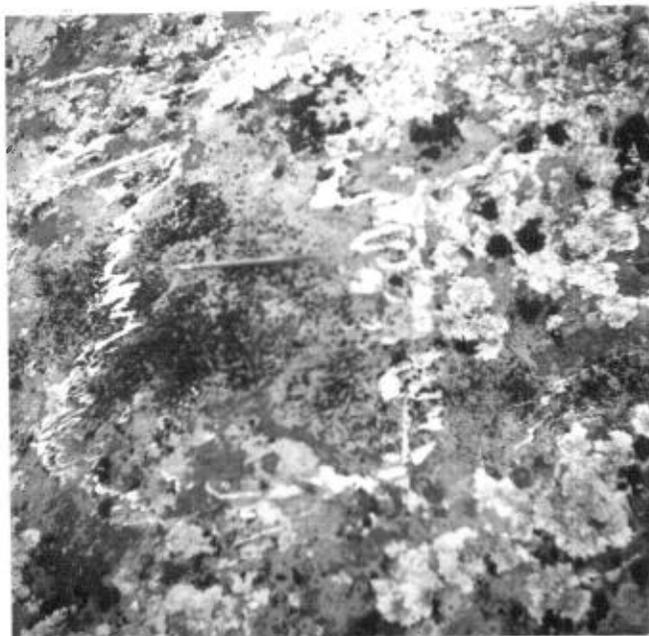
Proterozoic Structures

The Proterozoic rocks are folded about two main

directions; northeast to east-northeast and northwest. The resulting cross folds are evident in the twisted syncline near Daigle lake and the brassiere-shaped syncline near Bloom lake. Smaller scale cross folds can be seen in single outcrops, Plate X.

Although the fold pattern is complex, it shows some regularity when viewed on a regional scale. Mutual interference of the two fold systems produced a series of domes at anticlinal intersections and basins at synclinal intersections. Rocks of the Gagnon Group are preserved in structural basins which formed at about 4-mile intervals on a grid with northwest- and northeast-trending axes.

The regular system of domes and basins was only developed where the two fold systems were of similar strength. Regionally this occurred in a southwest-trending belt roughly coincident with the zone of deposition of quartzite and quartz-specularite iron formation. Within the present area it occurred in the area north of, and including, the Bloom Lake syncline. Southeast of the cross folded zone one or other of the two systems predominates and the folds are elongated. The systematic occurrence of basins of iron formation can be used to guide exploration and is more fully described in an accompanying report, Clarke (1967).



Small cross fold outlined by quartz layer in iron formation near Boulder Lake. Main fold trends northeast, pencil points northwest parallel to the ~~XXIX~~ axes of the secondary folding.

Stereonet Diagrams of Proterozoic Structures

Lineations and poles to foliation of the Proterozoic rocks are plotted in Fig. III-g,b,c. Most of the plotted lineations are crenulations and small fold axes from the gneisses, schist^s and iron formation, but mineral elongation in the epidote schist, and streaking in the iron formation and schist are also included. All these types of lineation are believed to have formed parallel to fold axes. Foliation surfaces are parallel to rock contacts and are believed to have formed parallel to original bedding planes.

The poles to foliation (Fig. III-b,c) form two incomplete girdles, ac^1 and ac^2 , with poles at b^1 and b^2 . The lineations (Fig. III-g) lie in three maxima, two of which correspond to b^1 and b^2 , and a third which is poorly defined and plunges to the northwest. This configuration could result if rocks folded about horizontal northeast-trending axes, B^{ne} , were refolded about northwest-plunging axes, B^{nw} . The second folding would split the original pole girdle in two, $ac^1 + ac^2$, and would rotate the original lineation, B^{ne} , to two new positions, $b^1 + b^2$. The northwest-plunging lineations would be scattered because they formed on an already folded surface.

Strong northwest-trending cleavage forms axial planes of small folds, and cuts earlier northeasterly trends in the Proterozoic rocks lying within 6 miles of the main

Archean contact Plate VI a, p.50. The cleavage is best developed in the cummingtonite schist variety of silicate iron formation. It seems probable that the northwesterly folds formed by shear folding in this part of the area, and that they post-date the northeasterly folds. In other rocks and in parts of the area where metamorphism was more intense the cleavage is not recognized, although the fold mechanism may have been the same.

Whether the two fold systems were formed by the Hudsonian and Grenville orogenies, as suggested by Stockwell (1963), is not definitely known. If they were, the north-east-trending folds are probably Hudsonian and formed during the deformation of the Labrador Trough. They trend parallel to the Proterozoic sedimentary shelf, and deform the rocks near Jackson lake, beyond the reach of the main Grenville metamorphism. They are strongest in the northwest and weaken southeastward as the rocks pass deeper into the Grenville province.

However, northeast is generally accepted as the main direction of Grenville deformation. The Grenville Front trends northeast throughout its length, and Grenville isograds trend northeast in the present area. The northeasterly folds may have formed at an early stage of Grenville metamorphism, and the northwesterly folds been superposed as deformation continued.

Joints

Joints are present in most of the rocks but are

especially common in the Archean granulite, and the Proterozoic quartzite and iron formation. The joints in the Archean rocks have already been described.

The joints patterns in the iron formation hills southeast of Boulder lake are shown in Figure III- e,f. At both places the pattern consists of two systems of predominantly vertical joints trending northeast and northwest, respectively. In the hill southwest of Boulder lake (Fig. III-f) both systems contain three sets, probably two sets of conjugate shear joints bisected by a set of tension joints. On the hill southeast of the lake (Fig. III-e) there are also three northeast-trending sets but only one set of northwest-trending joints. These patterns are representative of the joints in the Proterozoic rocks throughout the rest of the area.

Faults

Small northwest-trending shears cut the schist southwest of Boulder lake. These are the only evidence of faulting seen near the Grenville Front in the area. The lack of obvious shears contrast strongly with the extensive shearing parallel the Grenville Front near Pletipi lake at the southern end of exposure of the Gagnon Group, Berard (1964) and Chown (1964).

Northwesterly shears were mapped south and southwest of Mogridge lake, east of Moiré lake, and in the Bloom lake, and Tupper lake synclines. The faults near Bloom lake

and southwest of Mogridge lake show right hand separation, indicating either right hand wrench movement, or vertical movement lifting the east side relative to the west. In either case the movement was less than a few tens of feet.

ECONOMIC GEOLOGY

Iron Ore

In the early 1950's increased demand for iron ore, and the use of beneficiating techniques made the mining of remote and formerly sub-grade iron deposits profitable.

Several very large low grade deposits occur in the metamorphosed extension of the Labrador Trough. Mining activity in this region has so far resulted in the Lac Jeannine, Carol Lake and Wabush Lake projects, and in outlining many other deposits.

Shipments of concentrates from Lac Jeannine and from Carol Lake began in 1961 and 1963 respectively. Deposits in the present area are as large as these others but are farther from transport facilities, and will probably not be developed until the more accessible deposits are exhausted.

The region's iron deposits were first prospected by the United Dominion Mining Company. The company explored much of the area between 1947 and 1949, but decided that it was not practical to develop its claims and allowed them to lapse. In 1952 the United States Steel Company began the massive program that acquired the ground now being developed by its subsidiary the Quebec Cartier Mining

Company. The exploration rush began that year and continued until about 1957, by which time most of the promising iron occurrences had been staked. The territory north of $52^{\circ}48'N$ and west of $67^{\circ}15'W$ was withdrawn from staking in 1958. Recent activity has included detailed geological and geophysical surveys, diamond drilling, and mill tests aimed at evaluating the deposits.

Of the different types of iron formation, the quartz-specularite type makes the best ore material. It contains between 25 and 35 per cent iron over thicknesses of 30 to 300 feet, and is mostly coarse enough to allow concentration from a -20 mesh grind. Structural thickening and repetition produce mining widths several times greater than the original stratigraphic thickness. The quartz-magnetite type is equally rich but is generally thinner and requires finer grinding for concentration. Both types of oxide facies yield concentrates grading 65 to 67 per cent iron and containing little phosphorous, sulfur or titanium.

The silicate-carbonate iron formation contains as much iron as the oxide facies. However, most of the iron is combined in insoluble silicates from which it can not be recovered, and the soluble iron content is generally low.

Approximate property boundaries, as of January 1964, are shown on the claims location map, page 96. The area has now been thoroughly prospected. All of the obvious deposits have been staked, and most of the uneconomic claims

have been allowed to lapse, so the property boundaries shown here should be reasonably permanent. A brief description of the company properties follows.

Quebec Cartier Mining Company

This company, a subsidiary of the United States Steel Corporation, holds a group of about 340 claims south of Hesse, Mogridge, and Moiré lakes. The claim group covers most of the iron formation ridge from which Mount Wright projects.

Most of the claims were staked in 1952. That summer, the company began a program of topographic, aeromagnetic and geological surveys. By 1954 the property was mapped on a scale of 660 feet/1 inch, and 35 holes totalling about 12,700 feet had been drilled. Analyses, and concentration tests of ore samples were run at the Oliver Research Laboratory in Minnesota.

This work outlined a structure 7 miles long containing an almost continuous bed of iron formation averaging about 30% iron and ranging up to 300 feet thick. Tight folding repeats the bed several times within the structure. With this deposit outlined and protected, the company directed its efforts elsewhere in the region.

In 1957 the outside boundary of the claim group was surveyed, and the group was divided into 5 blocks of approximately 1000 acres each and 3 odd-sized blocks. Mining concessions, 457, 484, and 498 have been granted for 3 blocks totalling 2554.5 acres. At the time of writing only preliminary estimates of ore potential were available. These estimates, based on the work done before 1955,

indicate well over 500 million tons of ore grading better than 30% iron, within the 3 mining concessions. Tonnages in the rest of the claim group are large but no estimates of these tonnages are known.

In 1963 the company carried out a program of systematic drilling to accurately outline the deposit in preparation of mining. The program included detailed surveys for mapping and drilling control, 200' = 1" topographic, magnetometer and geological mapping and a total of 61,699 feet of diamond drilling. The results of the work had not been reported at the time of writing.

The Normanville Mining Co. and the Boulder Lake Mining Co.

These companies, wholly owned subsidiaries of Jones & Laughlin Steel Corporation and Cleveland Cliffs Iron Company, respectively, hold equal shares in 3 claim groups in the area. The largest group consists of 98 claims, covering most of the Bloom Lake syncline; two smaller groups, totalling 28 claims, cover two iron iron formation zones in the vicinity of Boulder lake.

The Bloom Lake deposit was staked in 1952 by geologists of Quebec Cobalt and Exploration Limited, who were in this area to investigate a sulfide occurrence. The claims over the sulfide showing, and including some of the iron formation, had been staked the previous year. By 1956, geological and magnetometer surveys had outlined a synclinal structure 4 miles long, containing two iron formation beds between 10 and 200^(?) feet thick.

In 1956, Quebec Cobalt optioned the property to Jones & Laughlin Steel Corporation. The more important ore zones were remapped, some 19,600 feet of diamond drilling was done, and metallurgical tests were carried out on the ore.

In 1957, the iron formation hill southeast of Boulder lake was staked, and claims were added to the group southwest of the lake. The first claims of this group were staked by Quebec Cobalt in 1954. Subsequently, geologic and magnetic surveys of the new holdings were carried out, and, in 1960, 9 diamond drill holes, totalling 2,490 feet, were drilled into the two iron formation zones near the south end of Boulder lake.

In 1958, Jones & Laughlin, in partnership with Cleveland Cliffs, exercised their option, and the Quebec Cobalt properties in this area were transferred to Normanville Mining Company and Boulder Lake Mining Company.

In 1961, a network of lines, spaced 200 feet apart, was cut over an area approximately $\frac{1}{2}$ mile x 1 mile, immediately west and northwest of Bloom lake, and over the island in the lake. This grid served as a control system for a detailed geological and magnetic survey of this section of the property.

Ore Reserves

The 1956-57 drilling program outlined approximately 400 million tons of crude ore on the Bloom lake property. Some additional ore has been indicated by geological and magnetic mapping. Drilling of the iron occurrences in the vicinity of Boulder lake was disappointing, and much of the iron formation was found to be marginal or below ore grade. Total reserves of open pit crude ore on the Normanville properties probably approach 500 million tons, grading about 28% Fe.

Quebec Cobalt and Exploration Co.

One of the first companies active in the area, Quebec Cobalt staked iron properties near Bloom and Boulder lakes in 1952 and 1954, respectively. These properties have been optioned and are being developed by the Normanville Mining Company and the Boulder Lake Mining Company. Quebec Cobalt retains one small iron deposit. It lies about one mile north of Boulder lake, and is covered by 6 claims staked in 1957. The property was mapped geologically in 1957 and was surveyed by dip needle in 1960.

The surveys indicated lean iron formation underlying much of the claim group. No accurate assessment of the deposit can be made until it is drilled and sampled, and no such program was known at the time of writing.

Mount Wright Iron Mines Limited

In 1956 Mount Wright Iron Mines staked a block of 189 claims in the open ground between the Quebec Cartier and Normanville Mining properties. A ground magnetometer survey of the property revealed major anomalies south of Mogridge lake and south of Bloom lake, and trenching exposed oxide iron formation at both places. The two iron formation occurrences are referred to as the companies southern and northern deposits, and are covered by groups of 50 and 30 claims, respectively. The rest of the original claims have been allowed to lapse.

In 1959 the company drilled 8 holes into the southern deposit, and 4 holes into the northern deposit, for a total of 4910 feet of drilling. Metallurgical and economic studies of the ore were carried out in 1960 and 1961.

The drill program outlined about 147 million tons^x of ore grading between 29 and 30 per cent iron in the southern deposit, and an additional 7 million tons containing about 28 per cent iron in the northern deposit. A concentrate containing 68 per cent iron and negligible sulfur, phosphorous, or titanium can be obtained from - 20 mesh material by high tension electrical separation. This method recovers about 93 per cent of the iron.

A mining concession for the southern deposit has been applied for.

^x calculated to 800 feet below present surface.

Bellechasse Mining Corporation

Bellechasse Mining Corporation staked 122 claims near Moiré lake in 1952 and 1953. Early assessment work outlined 3 zones of ore grade iron formation on the property. 55 claims covering these deposits have been retained and the rest allowed to lapse.

By 1956 aeromagnetic, and detailed ground magnetometer and geological surveys of the property had been made. That year, W.S. Moore and Co. took a 75 year lease to develop the property. The exploration program has included further geological and magnetic surveys, and the drilling of 16 holes totalling almost 7400 feet. Concentration tests were made on samples of the drill core in 1960 and 1961.

The assessment work served to outline 3 ore zones with a total surface area of 8,648,800 square feet. Not enough drilling has been done to establish accurate tonnage estimates. However, by combining the results of diamond drilling, surface mapping, and the magnetometer surveys, company geologists estimate the two largest deposits to contain about 100 million tons of iron formation averaging 25 to 30 per cent iron.

Mill tests on the ore samples yield concentrates containing more than 66 per cent iron with better than 90 per cent recovery. The best gravimetric separation was made by centrifuging - 65 mesh material in a medium with a density of 4.0.

Consolidated Fenimore Iron Mines

In 1957 Consolidated Fenimore Iron Mines acquired 75 claims north of Bellechasse Mining Corporation's Moiré lake property. Preliminary studies that year showed the only economically interesting iron formation to be located within 14 claims in the southwestern part of the group. These claims were transferred to Ferrous Iron Mines, a subsidiary of Consolidated Fenimore, and the others were allowed to lapse.

By 1959 detailed geological and ground magnetometer surveys had been made, and ten diamond-drill holes, totalling 3257 feet, were drilled. All core containing appreciable quantities of iron was split and assayed.

The survey outlined 5 zones of potential iron ore. Not enough drilling has been done to accurately evaluate the ore reserves. However, one zone of which a complete section was sampled, averaged 25 per cent iron over 902 feet. Tonnage estimates based on the geological and geophysical mapping and on limited diamond drilling, are given as 70 million tons to a depth of 300 feet.

Holannah Mines Limited

In 1956 this company staked a group of 56 claims north of Kissing lake. A reconnaissance survey was made that year, and the following summer the iron-bearing areas were remapped and surveyed by dip needle, on a 200-foot scale. Geological mapping and magnetometer surveys were continued in 1958 in conjunction with the drilling of 22 holes totalling 1765 feet. All but 8 of the claims, have now lapsed.

This exploration indicated oxide facies iron formation occurring in two bands aggregating 3650 feet in length, and 575 feet in average width. Sampling indicated an average of 31 per cent iron.

Jubilee Iron Corporation

This company, a subsidiary of Canadian Javelin Limited, holds a total of 33 claims in the southeastern corner of the area. The claims were staked as a result of a surface geological-magnetic survey in 1956. Reconnaissance mapping that summer located several iron formation occurrences, and mill tests were run on samples from the most promising zone. A more detailed magnetometer survey was carried out in 1957 on the Kissing Lake group.

During the summer of 1961 the company outlined the iron formation immediately north of Simone lake with a ground magnetometer survey and 3 exploratory drill holes totalling 208 feet.

This work indicated two magnetite-rich bands associated with lean silicate carbonate iron formation. The bands are about 80 feet thick and apparently continuous for about 4500 feet. Assays of 20-foot core sections vary from about 8% to about 33 % iron. A bulk sample taken in 1956 assayed 35.5% iron and gave magnetic concentrates containing 66% iron and 5.4% silica, with recovery of 78.5% of the iron. The best concentrate was made from - 200 mesh material.

The magnetite content of this occurrence varies both laterally and horizontally. Not enough work has been done to properly outline the deposit, however, company geologists hope that future drilling will prove a body of approximately 11 million tons of 28 to 30 per cent iron.

After drilling the Simone Lake deposit, the company tested the magnetic anomaly west of Kissing lake with two drill holes totalling 450 feet. Both holes cut lean silicate carbonate iron formation, but no ore grade material.

Kelly Desmond Mining Corporation

In 1960 Kelly Desmond Mining Corporation acquired a T-shaped group of 138 claims east of Bloom lake. Ground magnetometer surveys located 4 zones of iron formation on the property. One of the zones (zone D), occurs on the northern limb of the Daigle Lake syncline, the other three are associated with the Bloom Lake syncline. These are called, from east to west, zones A, B, and C.

Fifteen holes, totalling 4482 feet, were drilled into zones A and B, in 1960 and 1961, and magnetic concentration tests were run on a composite sample from each of 3 drill holes in zone A. The sampling of zone A indicates a possible content of 35 million tons grading 16.9 per cent iron, above a depth of 200 feet. The magnetic concentrates made from - 200 mesh material grade better than 67 per cent iron, with less than 3.5 per cent silica, and an iron recovery between 83 and 92 per cent.

In 1962 a gravity survey over the area containing the magnetic anomalies revealed a strong high over zone C. Drilling is planned for this zone, but at the time of writing no drill results had been reported.

All the claims except two small groups (7 claims) covering zones A and C have been allowed to lapse.

Trans Canada Exploration and Roman Corporation

These companies staked large claim groups in the spring of 1957, Trans Canada Exploration claims centered around Kissing lake, and Roman Corporation claims surrounding the Quebec Cartier holding south of Mogridge and Hesse lakes. In the winter of 1958-1959 the groups were surveyed aeromagnetically. A field party investigated the anomalies the following summer.

All the claims, except 2 near Kissing lake have now expired. Quebec Cartier Mining Company staked over the Roman Corporation claims after they lapsed.

Mallen Red Lake Gold Mines Limited

History: In 1957 this company acquired a group of 100 claims south of Hook lake. Detailed geological mapping and a magnetometer survey during 1958 resulted in the dropping of all but 35 of these claims. No further work was done, and the claims expired in 1960.

Sulfides

Although the area is of primary interest for its iron ore, deposits of sulfides also occur at several places. The most important occurrence is found about 1800 feet northwest of Bloom lake. The deposit was staked in 1951. Quebec Cobalt and Exploration limited controlled the claims until 1956 when they were leased to Jones & Laughlin Steel Corporation for development of their iron ore. Minerals other than iron are reserved for Quebec Cobalt.

Mineralization in the form of pods of massive white sulfides occur in and generally conformable with coarsely recrystallized quartz-grunerite-magnetite-iron-formation. The iron-formation appears to be a roof pendant in a gabbro sill.

The best mineralization has been removed by trenching but, judging from large blocks lying nearby, the pods varied from several inches to 2 feet long and up to 1 foot wide. Most of the sulfide is massive, white, cobalt-rich arsenopyrite with minor amounts of cobaltite, pyrite and native bismuth reported, (Quebec Cobalt report on file). Several of the pieces show films of cobalt bloom. Analyses of samples taken from the mineralized zone yield:

Table X

Metal content of Samples from the Bloom Lake Sulfide Deposit

Sample	Co%	Bi%	Bi%	Cu%	An or/ton	Ag or/ton
1	6.0	.16	.43	nil	0.000	0.000
2	6.5	.33	.23	nil	0.000	0.000
6	0.28	0.12	0.04	0.01	0.02	0.01
7	0.01	n.d.	0.01	n.d.	nil	0.01
8	0.01	n.d.	tr	n.d.	nil	tr
9	nil	nil	tr	nil	nil	tr.

Samples 1 + 2 are grab samples of pure sulfide material taken by the author.

Sample 6 vein material containing a streak of sulfide mineral.

Sample 7 chip sample over 30 inches of trench wall with no sulfide seen in place.

Sample 8 chip sample over 18 feet of trench.

Sample 9 chip sample over 30 feet of rusty grunerite schist, at north end of trench.

Samples 6 to 9 were taken in 1951 by Dr. B.T. Denis of the Quebec Department of Mines.

Coarse grained, pink and buff coloured calcite and coarse grained, dark green amphibole and pyroxene accompany the sulfides. The iron-formation close to the deposit is coarse grained and rusty weathering. In places it contains oriented, $\frac{1}{4}$ inch ellipsoidal porphyroblasts of magnetite, in a matrix of coarse grained quartz and grunerite. Jackson (1962) describes cobalt bloom in the quartzite about $\frac{1}{2}$ mile northeast of Bloom Lake.

Several occurrences of sulfides were also found in the Archean hypersthene granulite, and one in the iron-formation near the nose of the Daigle Lake syncline. These showings were all small in size and composed of fine, disseminated pyrite.

The pyrite occurrences in the Archean granulite are arranged around the gabbro-amphibolite body from which they are probably derived. Detailed prospecting about this body ~~probably~~ could uncover additional, possibly more interesting, deposits.

Non-Metallic Minerals

Minor amounts of graphite and kyanite occur in the schist

between Hook and Kissing lakes. The kyanite occurs as a widespread accessory mineral, in places forming up to 5 per cent of the rock. The largest concentration of graphite was found in the shear northeast of Hook lake. Here it occurs throughout the schist and comprises between 5 and 10 per cent of the rock.

Consolidated Fenimore holds a group of 3 claims in the Kyanite- and graphite-bearing schist northeast of Hook lake.

An outcrop of rusty weathering schist containing 10 per cent graphite crops out on the hillside east of crescent lake.

The quartzite of the area is generally very pure and could provide a source of silica.

Sand and Gravel

The many eskers and sorted fluvio-glacial deposits will provide construction material when the iron deposits of the region are developed.

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