GEOLOGY OF THE MOUNT REED QUADRANGLE

QUEBEC

by

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ABSTRACT

The Mount Reed quadrangle occupies 183 square miles in southern Quebec-Labrador. It is extensively covered by glacial drift and outwash with about 5 percent exposure. The ice sheet margin retreated northwards. The most extensive rock type is the biotite-quartz-oligoclase gneiss with garnetiferous and graphitic varieties. The gneiss consists of mafic-rich foliations of biotite and minor hornblende and felsic-rich foliations of white quartz and oligoclase. Garnets are associated with the mafics. Intrusion and/or metasomatic replacement by quartzofeldspathic pegmatites changed the gneiss locally to migmatite gneiss. With the introduction of potash feldspar, the garnet and mafic content decreases. Two small bodies of amphibolite have intruded the gneiss. The metasediments are a series of marine sediments which overlie the gneiss. Locally called the Cartier series, they are analagous to the low metamorphic rank metasediments of Knob Lake in stratigraphic sequence and bulk chemical composition.

The Cartier series and gneisses have been highly metamorphosed and folded by, at least, the Grenville orogeny. The mineral phases present indicate that the gneiss crystallized or recrystallized under almandine-amphibolite facies conditions. The metasediments possibly have been metamorphosed

to the same grade but the difference in carbon dioxide and water content resulted in the epidote amphibolite facies.

Structurally the gneissic foliations dip about 30 degrees to the northeast or southwest. In the vicinity of the metasediments the gneissic filiations are generally steeply dipping. The metasediments have been tightly folded into synclines and anticlines. Overturning to the southwest is characteristic of the metasediment structures in the southern part of the quadrangle.

INTRODUCTION

GENERAL STATEMENT

This thesis presents the results of a reconnaissance survey of the Mount Reed quadrangle which constitutes a 183 square mile area in southern Quebec-Labrador.

This study is based on field work carried out during the summer of 1958 for the Quebec Department of Mines and a petrographic thin section study of 77 slides during the winter of 1958-59. The data was compiled on an accurate planimetric map using a scale of two inches to one mile.

The object of this paper is to present a general geological study of the area with emphasis on the petrology of the gneisses and metasediments. It is concluded that the metasediments are metamorphosed Labrador Trough-type metasediments that have been tightly folded and metamorphosed by the Grenville orogeny. The gneisses and metasediments are metamorphosed to almandine-amphibolite facies and epidote-amphibolite facies of dynamothermal metamorphism respectively. The glacial evidence indicates that the margin of the ice sheet retreated northwards through the area at the end of the last glaciation period.

LOCATION, ACCESSIBILITY, SETTLEMENT

The Mount Reed quadrangle, approximately 183 square miles in area, is bounded by latitudes 52°00'N and 52°15'N, and longitudes 68°00'W and 68°15'W.

Mount Reed, the principal hill in the southeast sector of the quadrangle, is approximately 140 miles bearing 30 degrees west of true north from the town of Sept-Iles, Quebec, on the North Shore of the Gulf of Saint Lawrence.

The western two thirds of Laussedat township and the eastern one third of Clement township constitutes the southern two thirds of the quadrangle. The remainder of the quadrangle includes the southeastern corner of Surveyer township, formerly township 2351, and the southwestern sector of Claudel township. The quadrangle is in Saguenay County, Quebec.

Two base lines had been surveyed in the region by the summer of 1958. The first was cut in 1956 and follows latitude 51°59'53". A north-south line was surveyed in 1958 parallel to and 40 chains (2640 feet) east of longitude 68°10'W. The north-south line marks the boundary between Clement and Surveyer townships on the west and Laussedat and Claudel townships on the east.

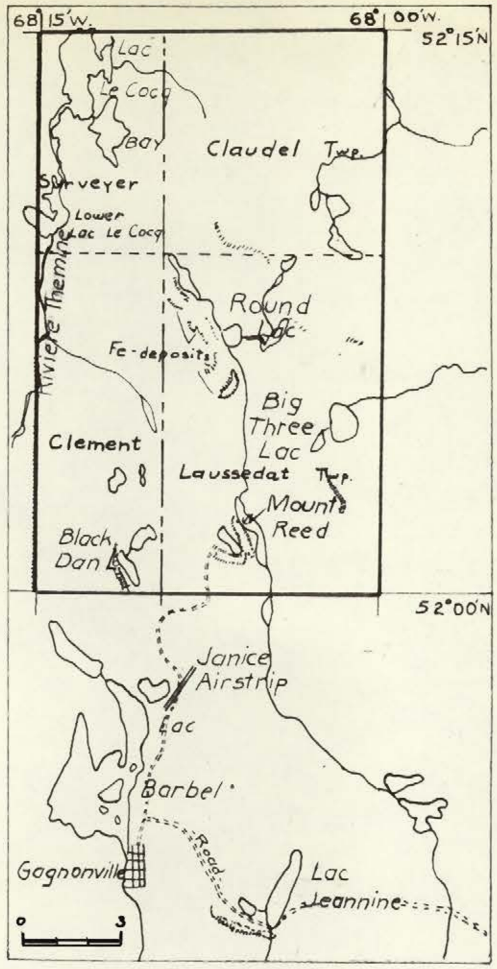
Lac Le Cocq in the northwestern corner, Round Lake in the centre, Black Dan Lake in the southwest, Snakehead Lake at Mount Reed, and Big Three Lake in the southeast are all large enough to accommodate the de Havvilland "Beaver"- and "Otter"- type float aircraft. All other areas must be reached by foot. The rivers are too small and swift for the use of canoes.

During the winter of 1958-59, a road was built from Janice Lake, about five miles south of Black Dan Lake, to Mount Reed. This road is the continuation of the road from Shelter Bay, Quebec which was completed the year before, extending north-northwest 188 miles through the highly dissected region between the Gulf of Saint Lawrence and the Labrador Plateau.

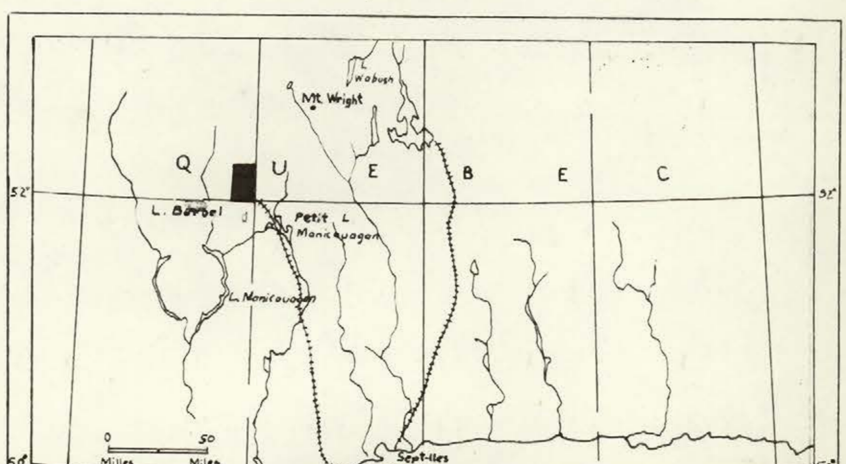
A railroad is being built from Shelter Bay parallel to the road to Little Lake Manicouagan east of Janice Lake. From Little Lake Manicouagan three spur-lines will be built to Quebec Cartier Mining Company's three main iron-ore bodies, at Jeannine Lake, at Mount Reed, and at Mount Wright. The railroad is to be completed by the fall of 1960.

An airstrip at Janice Lake is being lengthened to accommodate four-engined transport planes. During the summer of 1959 there were daily flights by two commercial airlines from Sept-Iles, Quebec and Baie Comeau, Quebec.

For the development of the Mount Reed and nearby Jeannine Lake iron-ore bodies by Quebec Cartier Mining Company, a subsidiary of United States Steel Corporation, a town is being built at Barbel Lake three miles south of Janice Lake,



a.



b.

Figure 1. - a). Mount Reed Region

b). Index Map

The town is called Gagnonville after Onesime Gagnon, the Lieutenant Governor of the Province of Quebec. A mill to refine and concentrate iron-ore is being built at Jeannine Lake eight miles south of Mount Reed. Power will be provided by the new Hart Jaune Hydro-electric development where Little Lake Manicouagan discharges into the Hart Jaune River.

PREVIOUS WORK

A number of private mining companies are interested in the iron deposits between Mount Reed and Wabush Lake, about 80 miles to the northeast. Quebec Cartier Mining Company is the most important iron producer in the Mount Reed region. Unfortunately, the private mining companies are reluctant to release their geological information.

The Geological Survey of Canada published a regional map on a scale of one inch to four miles (Dufell, 1959), that includes the Mount Wright quadrangle.

The Geological Survey Branch, of the Province of Quebec, has initiated a reconnaissance geological mapping survey to be published on the scale of one inch to one mile. The published preliminary reports by Phillips (1957, 1958) and Murphy (1958), are available while those of Murphy (1959), MacKean (1958, 1959), Clarke (1959), and Sinclair (1959) will appear during the winter of 1959-60.

FIELD WORK

The Mount Reed quadrangle was mapped on a reconnaissance basis for the Quebec Department of Mines during the summer of 1958. The quadrangle was surveyed by pace and compass traverses. Control points were obtained from R.C.A.F. air photos on a scale of approximately one inch to 3000 feet. The traverses were generally in an east-west direction at 2000 foot intervals across the structural and morphological trends. In areas containing magnetite iron-formations the traverses were controlled by sun shadows. The claim lines on the metasediment formations, staked by the private mining companys, were "walked out" when possible, so that the metasediments were mapped in greater detail than the gneisses.

All geological data was plotted on an accurate planimetric map on the scale of two inches to one mile constructed from air photos by the Department of Mines. A contour map of similar scale having a contour interval of 50 feet was used to complement the planimetric map. The geological map will be published on a scale of one inch to one mile.

The field party consisted of two geologists, three junior geological assistants, two canoemen, and one cook.

ACKNOWLEDGMENTS

The writer wishes to acknowledge the invaluable and patient advice and assistance received from DR. J. A. Elson, of McGill University, his thesis director.

The field work was carried out under the Quebec

Department of Mines to which thanks is expressed for the defrayment of the cost of thin sections and the opportunity to work in the Mount Reed area. The field assistance offered by party chief J. T. Jenkins, and the three assistants, Jacques Beauregard, Roch Cadieux, and Michael Feeney is greatly appreciated.

PHYSIOGRAPHY

TOPOGRAPHY AND DRAINAGE

The Mount Reed quadrangle is in the southern Quebec-Labrador plateau, north of the highly dissected plateau edge which, in this region, is called the Manicouagan Hills. The rolling topography of the quadrangle has an average relief of 350 feet. Concordant summits form an even horizon about the 2500 foot altitude. Wherever present, the hard, compact metasediments are the ridge-forming rocks trending northwest parallel to the structural trend. The slope of the land above 2250 feet approximates 16 feet per 100 feet in comparison with 6 feet per 100 feet for those areas below.

The latter are covered by glacial deposits, whereas, above 2250 feet, the glacial erosional features including roche moutonnee, glacial striations and groovings are common.

The drainage is controlled by parallel trending geological structures and superimposed glacial deposits. Extensive glacial and outwash deposits were left as the margin of the ice sheet retreated towards the north at the end of the last period of glaciation. Large quantities of meltwater flowed south developing a drainage system of broad, flat-bottomed channels about 50 feet deep and 150 feet wide.

The present drainage system occupies and is in the process of downcutting narrow steep sided channels about 3 to 4 feet deep in the bottom of the former glacial drainage channels. This is particularly marked in the sandy terrain in the western part of the quadrangle.

The divide separating the Kaniapiskau watershed system, flowing north into Ungava Bay, and the Manicouagan Lake system, flowing south into the Gulf of Saint Lawrence, is about 20 miles north of the quadrangle. Riviere Themine flows south through Lac Le Cocq in the northwest corner varying from a series of rapids and falls to a slow, meandering river which flows into the northern tip of Lake Manicouagan. The central area is drained by Blough River flowing south from Round Lake past Mount Reed and eventually into the Hart Jaune River. The northeast and east sectors are drained by small streams flowing eastward into Little Lake Manicouagan which discharges into the Hart Jaune River. The Hart Jaune River flows southwest parallel to the Manicouagan Hills to Lake Manicouagan. Muskegs are characteristic of the northern third of the quadrangle, occupying broad flat areas between the 2000 and 2250 foot altitudes.

The preglacial topographical and drainage features are difficult to construct because of the glaciation effects. The Quebec-Labrador plateau, according to Cooke (1929), is an uplifted, warped and tilted peneplain. The plateau slopes gently from the 3000 foot dissected plateau edge south of the quadrangle northward to Ungava Bay and Hudson Bay. The present topography within the quadrangle with its concordant summits, rolling topography and low relief support this theory that the area is an uplifted peneplain.

VEGETATION AND CLIMATE

The southern part of the Quebec-Labrador plateau is predominantly boreal forest, a vegetation type stretching across the northern part of the subarctic latitudes of North America. It lies between the Great Lakes - Saint Lawrence forest on the south and the tundra on the north (Halliday, 1937).

The work of Hare (1950a) will be followed in the discussion of vegetation and climate of the Mount Reed quadrangle. Hare (1950a, p. 615) has subdivided the boreal forest into three structural zones: "each with its characteristic type of cover and each standing in a definite and predictable relationship to climate". The subdivision is made on the basis of structural features such as spacing of trees, layering of vegetation, and nature of ground cover. Therefore, the zonal subdivisions is determined by the relative frequency of the forest types.

Zonal Division	Forest Type
Open Boreal Woodland.	Lichen-woodland.
Main Boreal Forest.	Close-Forest.

The quadrangle contains about equal proportions of close-forest type and lichen-woodland type vegetation placing it on the boundary of the open boreal woodland and the main boreal forest zonal divisions.

Lichen-Woodland Type

This forest type is characteristic of the interior of the Quebec-Labrador plateau. Within the quadrangle the lichen-woodland type vegetation occupies sandy, well-drained areas below the 2250 foot altitude. The trees are widely spaced giving it the name of "woodland". Black and white spruce are predominant but tamarack is not characteristic. A few jack pine in the area and in a large expanse 14 miles south of the quadrangle on a well-drained sandy slope were recognized. This is interesting because Halliday (1937) has established the northernmost extent of jack pine to be about 25 miles southwest of the quadrangle. The ground vegetation consists of pale gray, purple, orange, or green fruiting berries of the *Cladonia* spp. moss, colloquially called "reindeer moss".

Close-Forest Type

Above 2250 feet in the quadrangle, the forest type is a closely spaced mass of white and black spruce and balsam fir. The mature trees have an average diameter of 12 inches at the base. The soil is well drained but water retentive. Deciduous trees, in particular birch, aspen and poplar, grow on the slopes and tops of the higher hills. The ground veg-

Figure 2. - Lichen-woodland vegetation characteristic of ridge-moraine area in central north part of quadrangle.

Figure 3. - Junction of proglacial channels in central western part of quadrangle.

etation is rich in moss, bunchberry and wood sorrel.

Muskeg Type

All poorly drained areas in the boreal forest have a muskeg vegetation. There are several extensive flat areas in the northern part of the quadrangle which are composed of (Sphagnum) moss; Labrador tea, (Ledum groenlandicum); leatherleaf, (Chamaedaphne calyculata); and heath, (Kalmia angustifolia) vegetation that are encroaching upon the open water. Black spruce and tamarack surround the low-lying muskeg areas. Ridges composed of (Sphagnum) moss and sedge commonly with a dense shrub layer of dwarfted tamarack and black spruce form "string" bogs.

Birch and aspen are known to be of greatest significance in areas that were recently burned, and they are eventually replaced by a more mature growth stage consisting of spruce and fir. The coniferous trees found in Mount Reed region and common to the boreal forest are:

Black spruce	Picea mariana
White spruce	Picea glauca
Larch or Tamarack	Larix laricina
Balsam fir	Abies balsamea
Jack pine	Pinus banksiana

and the deciduous trees are:

White birch	Betula papyrifera
Balsam poplar	Populus balsamifera
Aspen	Populus tremuloides
Alders	Calnus

Correlation between vegetation and climate was impossible in Quebec-Labrador due to the lack of climatological data until 1948. Using data from several new meteorological stations and a new climatological classification proposed by C. W. Thornthwaite (1948), Hare (1950a, p. 630) demonstrates the climatological controls on the forest divisions of the boreal forest. Thornthwaite's classification is a function of the total monthly precipitation and monthly evaporation resulting in a relation called potential evapotranspiration. The zonal forest division between the open boreal woodland and the main boreal forest in the Mount Reed region approximates the 16.5 - 17.0 inch isopleth of potential evapotranspiration. Wide variations in precipitation occur within these zonal forest divisions with no apparent effect on vegetation indicating that the midsummer temperature controls the growth rates (Hare, 1950a). The growing season is very short and a good supply of water is always available at that time.

The climate of Quebec-Labrador is influenced by the Icelandic low-pressure area, centered between Iceland and Greenland, and the Arctic high-pressure area, located over the northwestern part of Canada in winter and over the Arctic ice pack in summer. The paths of cyclonic and anticyclonic air disturbances are controlled by these pressure areas. In winter cyclones, travelling from the mid-continent, cross southern Quebec-Labrador bringing heavy precipitation. Anticyclones, originating in northwestern Canada, tend to intensify the existing weather. Until it freezes in December the Hudson Bay has a warming effect on the predominant continental air. The mean annual snowfall is 150 inches in the Mount Reed region (Hare, 1950b). During April and May the Icelandic low-pressure area, reduced in size and intensity, moves westward. The Arctic high-pressure area moves out over the arctic pack ice. Cyclonic disturbances bring high summer rainfall in southern Quebec-Labrador which is cooled by the Hudson Bay. A mean annual rainfall of 35 inches is reported by Hare (1950b), for the Mount Reed region. Ice in the rivers and lakes in the Mount Reed area melts in late May.

GLACIATION

The Quebec-Labrador plateau was covered by the Labradorean or Laurentian ice sheet. Direction of movement and centres of origin of this ice sheet are discussed by Dresser (1944), Ives (1957) and Prest (1957). Recent air photo studies reported by Ives (1959b, p. 45) on the glacial drainage channel slopes suggest that the ice margin retreated from the north shore of the Gulf of Saint Lawrence to a region 25 to 35 miles northwest of Schefferville.

Evidence in the Mount Reed quadrangle suggests only one glaciation period. The Wisconsin ice sheet covered Quebec-Labrador; however, Ives (1957), from the morphological evidence in the Torngat Mountains, Labrador, suggests that there were two, and possibly three, separate glacial periods. Recent carbon-14 dating by Grayson (1956), reported by Twidale (1957, p. 35), indicates that the ice margin retreated northwestward from Schefferville about 5,000 years ago. Grayson's palynological studies of peat bogs support his carbon-14 dating.

The Mount Reed quadrangle has been completely glaciated. Two prominent glacial land-forms are evident:

a) Glacial erosion features above 2250 feet.
   Roche moutonees, glacial striations and grooves on bedrock, and glacial flutings in unsorted ground till, all trend approximately 5 degrees west of true north. These features indicate the direction of the last ice movement in the region and are aligned with the topographical features which may have controlled glacial movement.

b) Glacial deposit features below 2250 feet.
   Eskers, kettles, ridge moraines (ice-contact stratified drift forms); and glacial outwash were deposited in low-lying areas when the ice margin retreated. They indicate retreat towards the north.

Eskers

Five narrow sinuous sand and gravel eskers trend north to south (Fig. 4). These eskers were probably formed by the accumulation of englacial material deposited by subglacial rivers. They average about 3 miles in length and occupy low-lying areas in the region. In Figure 5 an esker is seen to cut a ridge moraine. Due to the lack of outwash on the "downstream" side of the moraine one might conclude that the two are contemporaneous. A low ridge of small

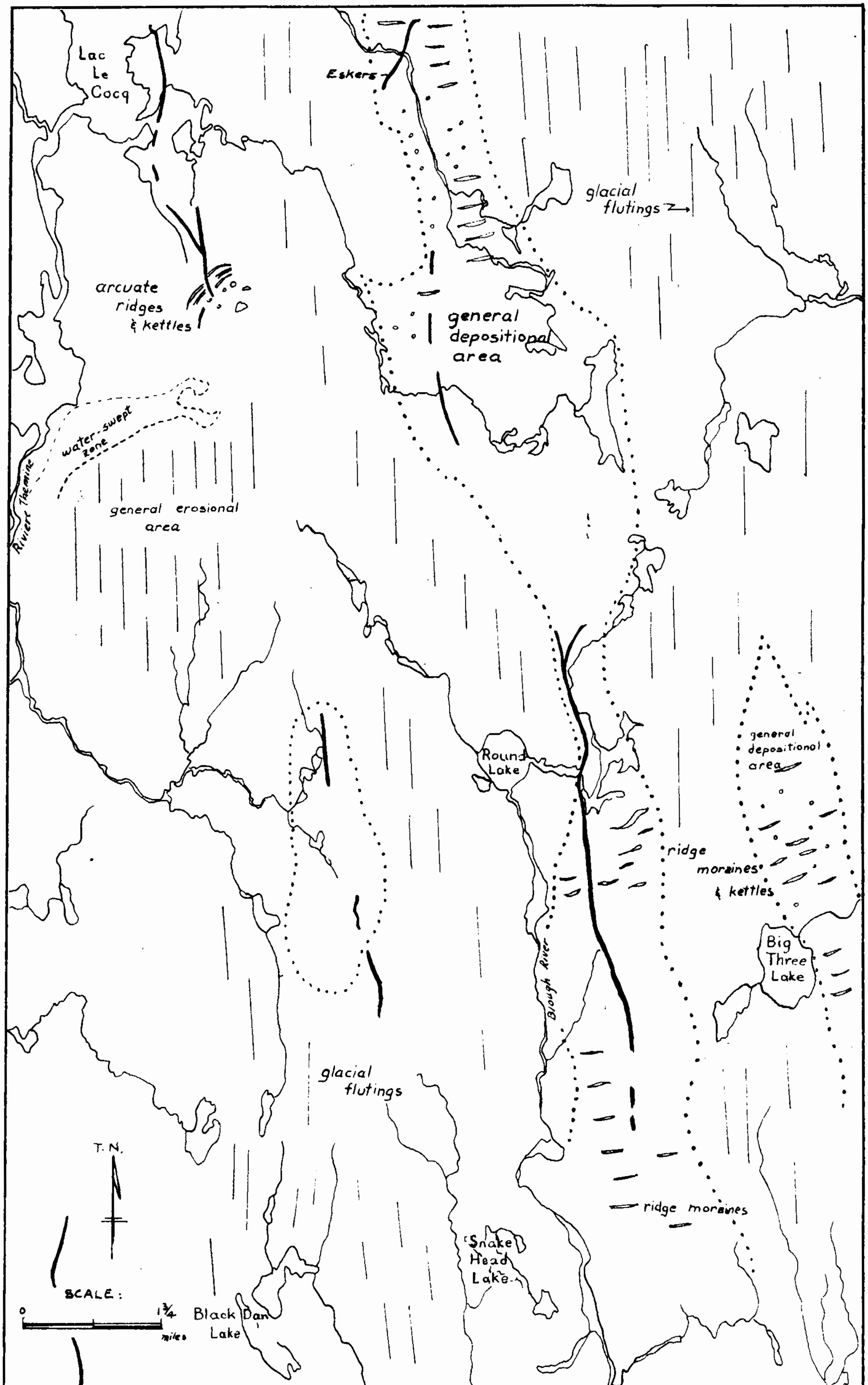


Figure 4. - Sketch Map of Glaciation Features

rounded cobbles at the north end of Lac Le Cocq Bay attests to the presence of an esker which was stripped of sand and gravel.

Glacial-Margin Lake

There is a flat, low lying area in the northern part of the quadrangle bordered on the south by a ridge over 2250 feet (Fig. 7). There is one low gap in this ridge occupied by the Riviere Themine. A small lake could have formed between the ice mass and this higher land by an ice lobe blocking the natural drainage channel. As the ice lobe retreated from the valley now occupied by the Riviere, the glacial lake water was released between the ice lobe and the hill south of it. The current created here eroded a zone seen in Figure 7. This zone which is 3 miles long lies above 2100 feet. Below this the thinning ice mass prevented erosion.

Dead-Ice Topography

Dead-ice topography, 5000 feet wide and stretching 9000 feet southeast is seen on the southern end of Lac Le Cocq Bay (Fig. 8). The feature formed when ice containing englacial debris separated from the retreating ice margin. The eskers from the north terminate in this kettle-pocked area.

The most striking feature here is a group of steep, northwest-facing, arcuate-shaped sand and gravel ridges with

Figure 5. - Esker cutting ridge moraine, viewed from the west in the central northern part of the quadrangle.

Figure 6. - Same esker as that of Figure 5, viewed from the south.

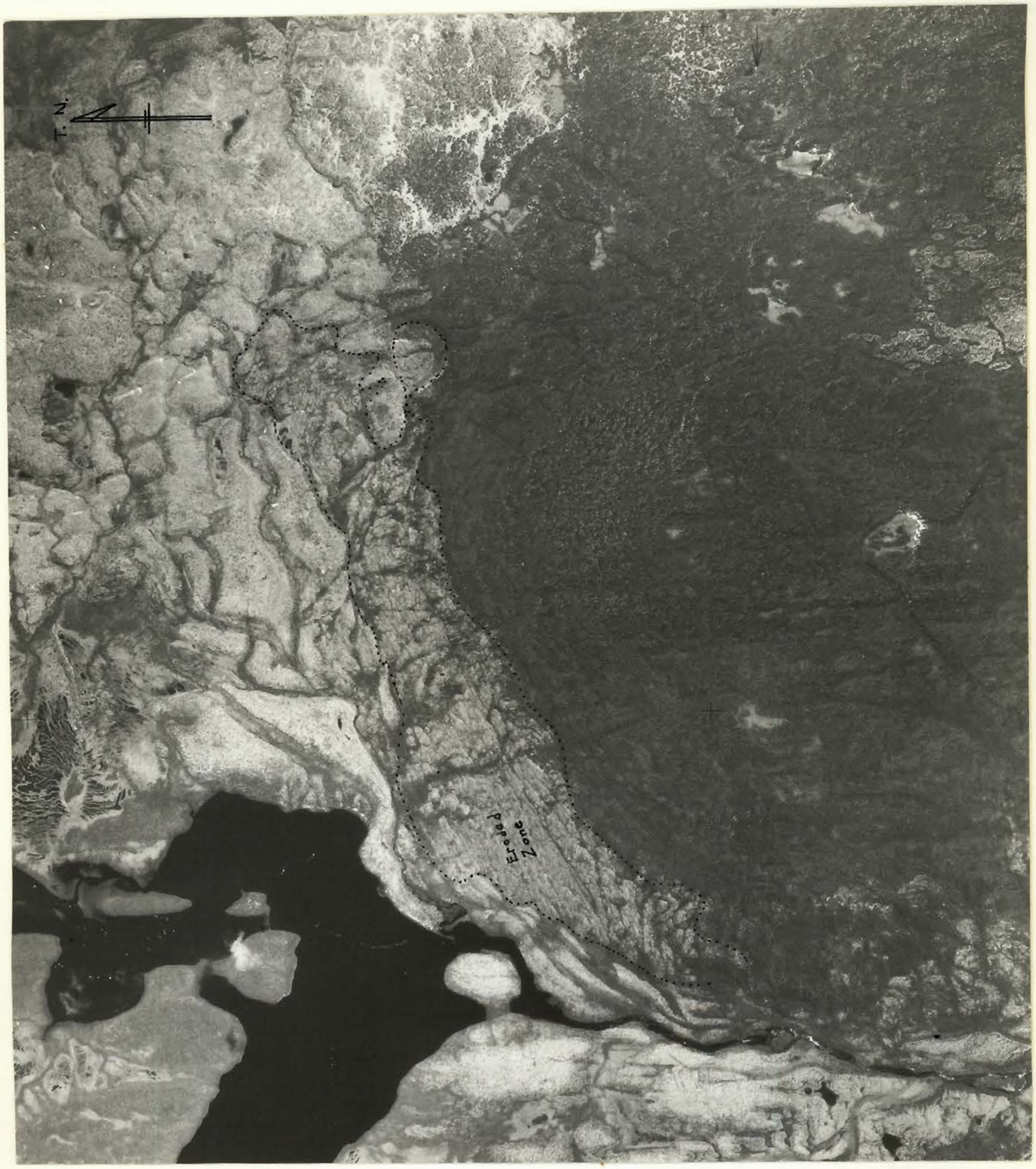


Figure 7. - Air photo (A12542-304) shows the eroded zone sloping towards the northwest. Below this zone (2100') are a few marginal drainage channels. One proglacial channel to the west has a outwash fan at its outlet. Scale 1"-3000'.

concordant tops. The esker separates the arcuate ridges into east and west members. In Figure 8, one will see that the east and west members are not aligned; rather, the east member is slightly north of the corresponding west member. Also the arcuate ridges truncate one another establishing that the ridges were deposited successively towards the northwest. The ridges have steep embankments to the northwest and several contain kettles which are numerous in the area southeast of these ridges. The ridges here suggest ice contact stratified drift deposits and the kettles are typical of "stagnant" or dead ice topography.

Ridge Moraines

The ridge moraines are associated with north-south trending eskers (Fig. 7). A series of these short, parallel, east-west trending ridges composed of unsorted debris occurs with the esker in the depression parallel to the 2200 foot contour in the centre of the northern part of the quadrangle. The ridges which are about 30 feet high and 250 feet apart at the northern edge of the quadrangle become higher (50 feet) and more widely spaced (800 feet) moving south. Kettle features appear with the larger ridges.

Large ridge moraines are also associated with the esker southeast of Round Lake. In the area between the esker and Blough River to the west is a series of small low minor moraines similar to the "ripple till" of Ives (1956, p. 26).

Figure 8. - Air photo (A12798 - 118) located in northwest corner of quadrangle shows arcuate sand and gravel ridges at right angles to the north-south trending esker. Kettles are in this area. Slope of land is to the northwest and west. Scale 1" - 3,000'.

Marginal Drainage Channels

A series of parallel channels, directly east of Lower Lac Le Cocq (Fig. 7), are marginal drainage channels. They are nearly parallel to the contours and have a typical broad (about 300 feet) flat base, steep sides (about 50 feet high), and are about 4000 feet long. Each channel was developed at successive positions of the reatreating ice margin (Derbyshire, 1958). The sand and gravel in which these channels were developed is even surfaced and slopes gently to the north (0.5 feet per 100 feet).

Similar drainage channels, 200 feet wide and 5000 feet long, are well developed in the northeast corner. They are particularly conspicuous because they occupy a zone where vegetation changes sharply from a lichen-woodland to a close-forest type; the former representing the position of the ice sheet which had remained stationary for a time. This is evident from the well developed drainage channels.

Proglacial Channels

Associated with the marginal drainage channels in the northwest corner is a broad (300 feet), deep (50 feet) channel with a flat bottom which carried meltwater directly away from the ice sheet. At the outlet of this channel is an outwash deposit (Fig. 7). A number of channels of simi-

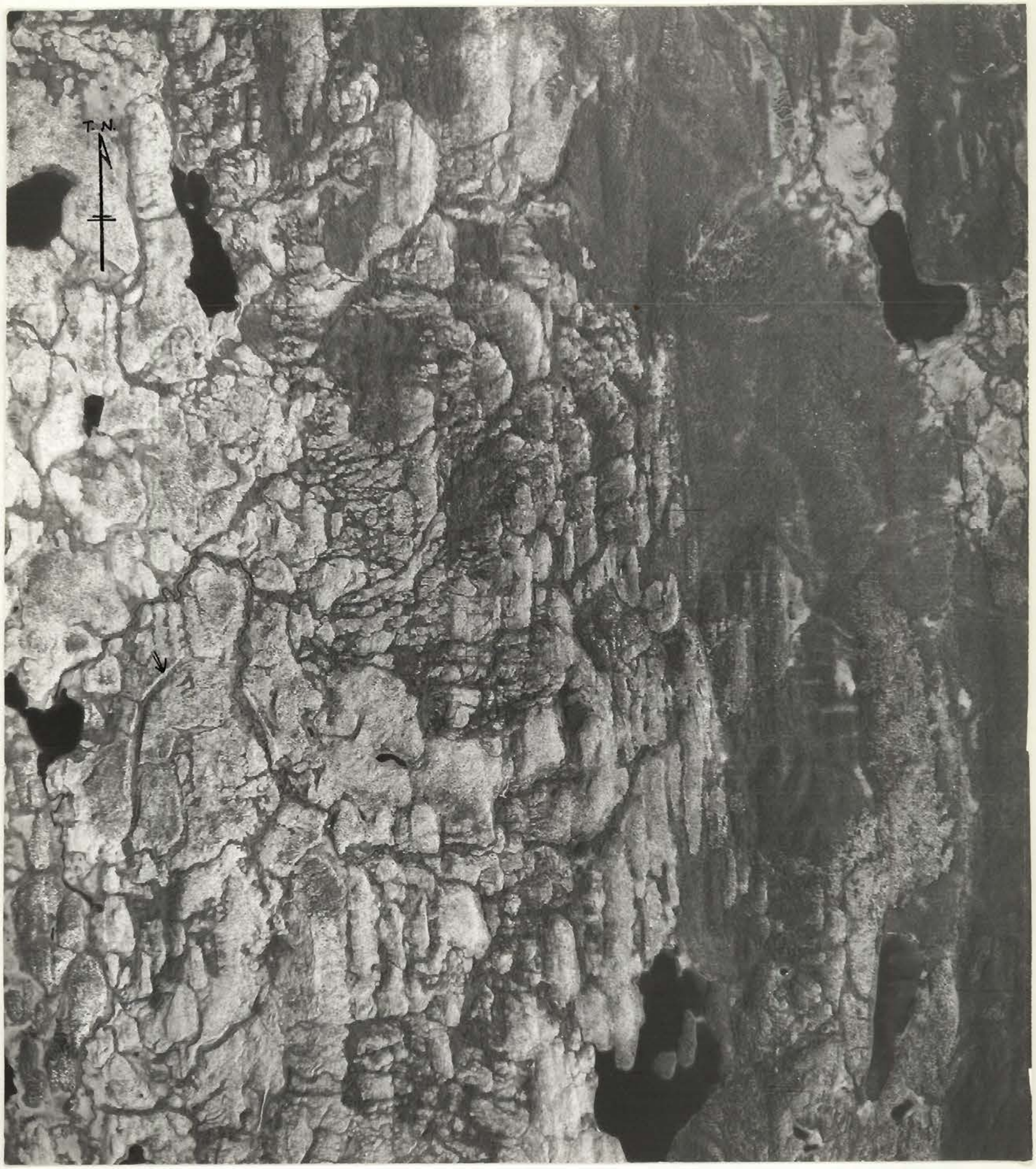


Figure 9. - Air photo (a12798-82), shows proglacial channels in the western part of quadrangle. Slope of land is to the west. Ice retreated towards the north, but high land to the east retained ice which provided the source of meltwater. Scale 1" - 3000'.

lar glacial origin are recognized in the central part of the western sector (Fig. 9). They are called proglacial channels. Figure 11 shows one of the larger dry river beds in the area developed at the time of glacial retreat.

Post Glacial Uplift

No evidence of post glacial uplift has been recognized within the quadrangle. Uplift has been recognized by Ives (1959a, p. 41) in the George River basin, about 200 miles northeast, where the southern end of the basin has risen to a greater extent than the north.

Figure 10. - Glacial outwash deposit bordering Riviere Themine in the western part of the quadrangle.

Figure 11. - Abandoned channel several hundred feet east and above the present Riviere Themine.

GENERAL GEOLOGY

Precambrian gneisses and metasediments underlie the Mount Reed quadrangle.

The gneisses, oldest and most extensive of the two rock types comprise sedimentary rocks that were so highly metamorphosed that the sedimentary structures were obliterated. Pirsson (1947, p. 302) classifies the gneisses formed in this way as paragneisses and differentiates them from orthogneisses which are of igneous origin. The paragneisses are termed simply gneisses in this report.

The metasediments, locally called the Cartier series (Black, 1958, p. 19), are highly metamorphosed sedimentary rocks that have retained their general sedimentary features. They form several narrow linear belts within the gneisses as a result of strong regional folding. Wherever gneiss and metasediments are in juxtaposition the metasediments form the high ground or ridges. This characteristic feature is due to the compact, weather resisting nature of the metasediments relative to the gneiss.

Only two types of intrusive rocks were seen. Amphibolites occur in two separate outcrops, but structural relations with the surrounding gneiss were obscured by glacial overburden. Quartzofeldspathic pegmatites intrude the gneisses and metasediments conformably and disconformably. Lit-par-lit injection along the gneissic foliations and subsequent metasomatic replacement change the light gray biotite gneiss to pink, coarsely-foliated biotite gneiss locally resembling a migmatite gneiss.

The structural features in the gneisses are difficult to interpret because they lack a key bed or recognizable horizon. The metasediment formations, on the other hand, display complex folding. They are folded into narrow synclines trending northwest to southeast parallel to the gneissic foliations. Overturning to the southwest suggests that the folding was due to movement from the northeast. A second phase of folding along axes trending northeast, oblique to the first phase, has affected the gneisses and metasediments to a lesser degree. Considering the amount of folding it is remarkable that no major thrust faults were recognized. No major faults could be identified in the field; however, faulting may account for the sharp change in regional trend of the three metasediment deposits, one at and two north-west of Big Three Lake. The north-south structural trend of these deposits changes abruptly at the southern end to a southwestward trend.

Because the ridges, generally composed of metasediments, have been swept clean of glacial debris, metasediments constitute a higher proportion of outcrop exposure than do the gneisses, the quadrangle is about 5 percent exposure.

The metasediments have strong lithologic similarities to the low rank metasediments of Knob Lake, Quebec (Dufresne, 1952, p. 26; Harrison, 1952, p. 3). The Kaniapiskau metasediments of Knob Lake can be traced southward without any change in metamorphic grade as far as the region of Sawbill Lake where there is a gap of a few miles before the iron formations again appear (Gastil and Knowles, 1958; Kranck, 1959). The iron-formations on the south side of the gap are metamorphosed to a higher degree. These metasediments are similar to the Cartier series. According to Gastil and Knowles (1958, p. 506):

> "this gap marks a zone in which a significant change in all rocks occur and which is considered to mark the point at which the Grenville Front crosses the Labrador geosyncline".

The Grenville front, a controversial thrust fault zone discussed by Wilson (1949) and Robinson (1956), marks the northern boundary of the Grenville subprovince. Recent gravimetric studies by Innes (1957, p. 156) indicate a strong negative gravity anomaly in the Sawbill region. Innes suggests that large stress differences within the crust, accompanied by negative gravity anomalies usually are associated with geologically recent crustal disturbances. The most popular estimate of the age of the Grenville orogeny is 800 to 1100 million years (Robinson, 1956, p. 17). Rose (1955) mapped folded Ordovician limestone intruded by andesine lavas about 30 miles south southwest of Mount Reed, still within the Grenville subprovince. This supports Tanners' contention (1944, p. 123) that the Taconic orogeny at the end of the Ordovician Period has affected the Precambrian rocks of Quebec-Labrador.

TABLE I

TABLE OF FORMATIONS OF THE MOUNT REED QUADRANGLE, QUEBEC.

CENOZOIC	Pleistocene	
	Drift	Outwash;
	Deposits	Ice-contact stratified drift;
		Till, glacial flutings and striations;
	Amphibolite	
	Pegmatite	Dykes, sills;
		Lit-par-lit injection and metasomatic replacement;
	Intrusive Contact	
PRECAMBRIAN	Metasediment	Quartz-specularite iron formation;
		Quartz-magnetite iron formation;
		Silicate iron formation: hypersthene pyroxene, diopside-hedenbergite pyroxenes, Cummingtonite-grunerite amphiboles, carbonate;
		Quartzite and quartz mica schist formations;
		Dolomite formation: tremolite amphibole, diopside pyroxene, phlogopite mica, graphite.
	Paragneiss	Gray biotite-quartz-oligoclase gneiss; Garnetiferous biotite-quartz-oligoclase gneiss; Graphitic biotite-quartz-oligoclase gneiss.

LITHOLOGY AND PETROGRAPHY

GNEISS

General Statement

The former sedimentary rocks that now comprise the gneisses of the area lost most of their original sedimentary structural and textural features when new fabrics and minerals were superimposed through dynamothermal regional metamorphism. The gneisses are soda rich, composed largely of plagioclase feldspar (oligoclase-andesine composition), biotite, and quartz. Some hornblende is present with the biotite. The formation of garnets and the presence of graphite provide the basis of subdivision of the biotite-quartz-plagioclase gneiss into zones broadly conformable with the regional structural trend:

1) Yellow-brown graphitic biotite-quartz-plagioclase gneiss, hereafter referred to as graphitic biotite gneiss, is characteristic of the southwest corner area.

2) Gray biotite-quartz-plagioclase gneiss, hereafter referred to as biotite gneiss, is the most common gneissic rock type in the broad central zone tren-

ding northwest to southeast.

3) Gray garnetiferous biotite-quartz-plagioclase gneiss, hereafter referred to as garnetiferous gneiss, is typical of the northeast corner area.

The gneisses have been metamorphosed to the same general grade of metamorphism; however, the northeast corner area represents a slightly higher degree. Because the three gneissic rock types have the same grade of metamorphism, the general mineral composition and structural appearances are similar. Therefore, the following discussion of structural and field relations and macroscopic and microscopic descriptions will apply to the gneisses as a whole except where qualified.

Structural and Field Relations

The gneissosity is marked by foliations, a term used here as defined by Holmes (1920, p. 101):

> "a structure due to the parallel disposition in layers or lines of one or more of the conspicuous minerals of the rock".

The foliations of these gneisses are mafic, composed mainly of biotite and hornblende; and felsic, composed of white plagioclase, quartz and sometimes pink orthoclase feldspar. The felsic foliations are dominant.

The gneisses have both contorted and uncontorted foliations. The thickness varies considerably from one locality to another. Generally the mafic foliations are approximately two inches wide and consist of fine laminations or bands. The felsic foliations average three inches thick but appear to be massive except where a slight banded effect is given by fine lenses and grains of biotite aligned parallel to the foliations. In contorted areas the gneisses show typical plastic deformation. The felsic foliations are thin along the fold limbs and considerably thicker in the fold crests and troughs. The mafic foliations generally do not show thinning and thickening effects except where thickening is due to crumpling of the foliations in the crests and troughs of the folds.

The thin bedding effect, characteristic of the mafic foliations, is distorted by the porphyroblasts of white plagioclase and garnets. The small biotite grains locally are pushed aside and appear to "flow" around the porphyroblasts. The porphyroblasts are due to metamorphic differential diffusion from the surrounding rock or to metasomatic replacement.

The graphitic biotite gneiss, characteristic of the southwest corner, has a regular foliation similar to that described above. But in some localities, the graphitic gneiss has an augen structure where the felsic minerals are in lenses rather than in foliations. Both even and contorted foliated zones are common. The gneiss weathers easily giving it a friable property. One zone about twelve inches thick conformable with the gneissic foliations is composed of about 35 percent graphite, 15 percent pyrite, and a groundmass of quartz, feldspar, and mica. This pyritic-graphitic zone is located about 3000 feet west of Black Dan Lake.

The biotite gneiss in the central zone is the main gneissic rock type. Some minor graphite and garnet are found scattered throughout the zone. Garnets are characteristic of highly contorted foliated zones where they form porphyroblasts about 0.5 inches in diameter in the mafic foliations. Widely scattered grains of pyrite have been noted. Migmatization is characteristic of the gneisses in this zone. Because of the localized nature of the migmatites, they have not been mapped as a rock unit. Migmatization is caused by the lit-par-lit injection and metasomatic replacement of the biotite gneiss by both magma and fluids rich in potash. Large amounts of pink orthoclase feldspar have been introduced.

The garnetiferous biotite gneiss is characteristic of the northeast corner area and the contact with the biotite gneiss is obscured by extensive glacial deposits. It is either (1) thinly or (2) coarsely foliated.

1) The more extensive thinly, foliated garnetiferous gneiss consist of thin mafic lenses in a felsic groundmass. The garnets are generally associated with the thin mafic lenses but also form thin bands within the felsic foliations which are low in potash.

2) One exposure at the south edge of a small lake in the northeast corner consists of two, thick and massive mafic foliations, interbedded with thick, thinly-banded felsic foliations. Garnets are abun-

dant; aligned parallel to the banding in the felsic foliation and evenly distributed in the mafic foliations. The mafic foliations here may be due to intrusion or to a sediment interbed that has been metamorphosed. Unfortunately, outcrop exposure in this area is small and scattered. It is interesting to note that there is a similarity between this coarsely foliated sector and the southwest and western sectors of the Jeannine Lake quadrangle, south of Mount Reed, mapped by the writer in 1959.

Macroscopic Description

The graphitic biotite gneiss weathers yellow brown by the oxidation of iron sulphides associated with the graphite. The gneiss is deeply weathered causing it to have a friable property. The composition of the rock is mainly quartz and plagioclase which constituted about 85 percent. Biotite and graphite make up about 12 percent and 3 percent respectively of the remaining composition. The graphitic zone west of Black Dan Lake comprises about 34 percent graphite and about 15 percent pyrite. The pyrite is estimated here from the number of cubic impressions in the graphite and the leached quartz, plagioclase and mica groundmass. This groundmass has a sugary texture.

The biotite gneiss ranges from light gray to dark gray depending upon the proportion of mafic to felsic foliations. The felsic foliations are composed of medium grained quartz and plagioclase. In some localities minor biotite is aligned parallel and in the felsic foliations giving it a finely gneissose appearance. In zones that have been highly contorted the felsic foliations are coarsely recrystallized. The mafic foliations are composed of biotite in which lenses of hornblende occur locally. Usually the mafic foliations are thinly and evenly layered with fine equigranular, interstitial quartz and plagioclase. The quartz and plagioclase composes about 85 percent of the rock.

In highly contorted zones the felsic foliations exhibit plastic flow and recrystallization. The biotite becomes coarsely crystalline here and irregularly aligned due to the formation of quartz and plagioclase augens. Garnet porphyroblasts force the thinly layered biotite aside indicating a metamorphic origin.

In migmatite localities, potash feldspar has been introduced by intrusion or by metasomatic replacement. Where potash feldspar is more abundant, the proportion of garnets and biotite is smaller. The garnets here are in the mafic foliations.

The thinly foliated garnetiferous biotite gneiss is usually pink. It is fine to medium grained and granular in texture. The mafic minerals comprise about equal amounts of biotite and hornblende and have some minor pyroxene. The thin mafic lenses are bordered by fine grained, granular pink garnets. The felsic foliations are composed of fine to medium grained, granular quartz and plagioclase. Small amounts of introduced potash feldspar give the rock a pinkish hue. Fine grained, granular pink garnets are more abundant in the white felsic foliations than in the pink. Garnets make up about 12 percent of the rock.

The coarsely foliated garnetiferous gneiss is dark gray in color. The massive mafic foliations are composed mainly of biotite, hornblende, and pyroxene with little quartz and plagioclase. The massive appearance is due to the medium to coarse grained, granular texture, with no alignment of the mineral constituents. Abundant, fine to coarse grained, granular pink garnets are associated with the mafic foliations. Also a minor amount of magnetite is present. The felsic foliations associated with the coarse textured mafic foliations are thinly and evenly laminated. Fine grained, granular garnets are aligned parallel to these laminations. The composition is fine grained, granular quartz and plagioclase. Garnets make up about 15 percent of the rock.

Microscopic Description

Gneissosity appears under the microscope as mafic foliations composed of aligned, inequigranular, fine-medium grained biotite interbedded with felsic foliations which are composed of equigranular, medium grained quartz and plagioclase. The mineral grains range from 0.5 mm. (fine-medium grained) to 5.0 mm. (fine-coarse grained) in diameter.

Figure 12.- Photomicrograph (X26) of saussuritized oligoclase intruded by or replaced by microperthitic orthoclase. (X nicol).

Figure 13. - Photomicrograph (X26) of oligoclase which is replaced or intruded by microcline feldspar. (X nicol).

The composition of the three gneissic rock types is similar with only proportional differences in the quantity and composition of some minerals which are sensitive to changing pressure-temperature conditions associated with metamorphism. The composition is:

Quartz

Quantity varies from 10 percent by volume in the garnetiferous biotite gneiss to about 20 percent in the graphitic and the biotite gneisses. A decrease in quantity of quartz indicates a relative increase in degree of metamorphism. The grains are anhedral, fine-medium to medium grained, and equigranular.

Two generations of quartz are recognized. The older quartz grains have a mosaic fabric with clear extinction, and the younger grains have a suture fabric with strained undulose extinction. The strained undulose extinction suggests secondary deformation.

Boehm lines or possible fractures perpendicular to the gneissic foliations are characteristic of the older quartz grains with clear extinction and mosaic fabric. There is no refraction of the boehm lines from one quartz grain to the next.

Plagioclase Feldspar

Plagioclase feldspar is the most abundant mineral present in the gneisses. Quantity ranges from 20 percent by volume to 45 percent, averaging 40 percent. The composition has been determined by the angle of extinction of albite twinning measured on the ordinary microscope stage. The composition is oligoclase-andesine; a slightly higher calcium content, though it is still oligoclase-andesine, occurs in the garnetiferous biotite gneiss.

Antiperthite texture, formed by exsolution of orthoclase in plagioclase is characteristic of the plagioclase in the garnetiferous biotite gneiss. Albite twinning is characteristic of the plagioclase with minor pericline and carlsbad twinning.

Decomposition of the plagioclase, particularly in the garnetiferous biotite gneiss, results in hydrous micas and calcite (Fig. 12). This turbid development on the plagioclase grains is called saussuritization.

Microcline feldspar

About 5 percent of the gneisses are composed of potash feldspar, mostly in the form of microcline. Some orthoclase has been recognized. The microcline is recognized by its characteristic grid-type twinning (Fig. 13).

Microcline when associated with plagioclase is clean and unaltered. Several slides clearly show microcline to be replacing plagioclase (Fig. 12).

Garnets

The garnetiferous biotite gneiss averages 12 percent garnet. The composition of the garnet is impossible to determine unless exact index of refraction, specific gravity, and amount of manganese are measured (Ferguson, 1957). The garnets here are probably almandine, following Turner (1958, p. 159).

The typically porphyroblastic garnets are lavender in color. They have a poikilitic texture with numerous fine-grained chlorite, quartz, epidote, and iron oxide opaque inclusions probably due to retrogressive metamorphism. Fractures perpendicular to the gneissic foliations are common.

In the garnetiferous biotite gneiss, garnets are of minor importance where potash feldspar has been introduced.

Biotite

Biotite is an ubiquitous mineral within the gneisses and averages 10 percent. It is aligned parallel to the gneissic foliations except in a few minor localities where the biotite is a secondary product. Biotite with both green and various shades of brown is present. The green or brown color depends upon the degree of metamorphism and chemical composition. Zircon inclusions are abundant in both the green and brown biotite.

Optical Properties:

Biaxial negative
$2V = 0^{\circ}$
pleochroism: light yellow brown to dull olive green.
$nY = 1.638$.

Pyroxene

Diopside pyroxene averages 4 percent in the garnetiferous biotite gneiss. Porphyroblastic crystals of pyroxenes are common and have sharp prismatic edges. The crystals have a poikilitic texture and appear to have crystallized in a calcite milieu. This calcite is probably an alteration product.

Optical properties:

Biaxial positive
2V = 60° (estimated).
z - c = 38°
pleochroism: pale green to colorless
Color: pale green to colorless.

Amphibole

Amphibole is found in all the gneisses but occurs in greatest amount in the garnetiferous biotite gneiss where it averages 20 percent. The crystals are subhedral, porphyroblastic, and have a poikilitic texture. The amphiboles contain fine-grained inclusions of quartz, zircon, apatite, garnet, and opaque iron oxide grains. The inclusions are aligned along the amphibole cleavages. The following optical properties suggest that the composition is common calcic hornblende.

Optical properties:

Biaxial negative
2V = large
z - c = 25°
pleochroism: light green to dark green.
color: medium green.
nY = 1.678

Minor minerals

The minerals associated with the gneisses but in minor amounts are: apatite, chlorite, epidote, zircon, calcite, and opaque iron oxides.

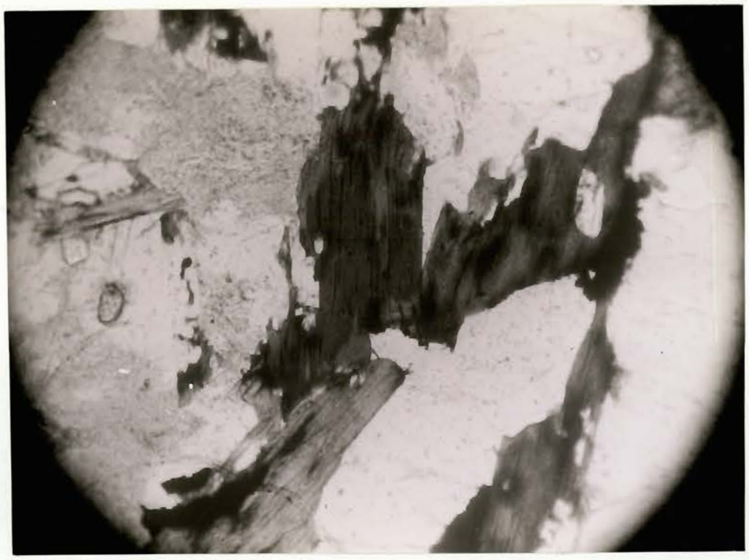


Figure 14. - Photomicrograph (X 26) which shows brown biotite (dark) replacing the green biotite.

Figure 15. - Photomicrograph (X 26) of zircons inclusions with pleochroic haloes in biotite. An aggregate of zircon crystals is on the side of the biotite.

METASEDIMENTS

General Statement

The Cartier series, in the Mount Reed quadrangle, is a series of metamorphosed sedimentary formations that have retained some sedimentary structures. Bedding is preserved but features such as crossbedding, graded bedding and intraformational breccia are scarce or nonexistent because of recrystallization. The dolomite, for example, has been completely recrystallized so that differentiation between bedding and structural planes is difficult.

Within the quadrangle there are eleven separate areas which contain the complete stratigraphic sequence of metasediment formations, and two small areas along Riviere Themine on the western boundary where dolomite alone is folded within the gneiss.

There are two slightly different stratigraphic sequences of metasediment formations within the quadrangle. Probably the difference results from a sedimentary facies change due to environmental control at the time of deposition. The most common sequence of formations, hereafter referred to as the Mount Reed-type, is well exposed at Mount Reed.

The other sequence of formations is located at Big Three Lake and is the only deposit of its type within the quadrangle. Because it is stratigraphically similar to the sequence of formations mapped by the writer in 1959 at Jeannine Lake, eight miles south of Mount Reed, it is referred to as the Jeannine Lake-type.

The Mount Reed-type sequence has a thick dolomite formation at the base, grading upward through a white calcium magnesium silicate zone into the thick overlying quartzite formation. This formation grades upward into the thin quartz silicate iron formation which underlies the uppermost interbedded quartz magnetite iron and quartz specularite iron-formations.

The difference between the Jeannine Lake-type and Mount Reed-type deposits lies in the thickness and stratigraphic sequence of formations. The dolomite at the base of the Jeannine Lake-type deposit is thin and grades quickly into the thin overlying quartz mica schist formation. Thin mica foliations in a quartz groundmass gives the rocks a schistose structure. This formation underlies the uppermost quartz specularite iron formation.

Minor green actinolite amphiboles mark the zone between the dolomite and quartz mica schist formations.

The metasediments originated in a marine environment. Whether they were deposited in one or several depositional basins is unknown because metamorphism has obliterated most sedimentary features than can be used to determine direction of deposition. The history has been further complicated by strong folding.

The structural relations depend upon the stratigraphic sequence accepted. The Cartier series generally resembles the less metamorphosed metasediments of the Kaniapiskau series of Knob Lake. Both have dolomite at the base overlain by quartzite and iron-formations; however, the Kaniapiskau series has the Menihek carbonaceous shales overlying the iron formations.

The corresponding member at Mount Reed is missing unless it is represented by the graphitic gneiss found in the southwest corner area. Volcanics, overlying the iron formations east of Knob Lake are absent from the Mount Reed quadrangle, but volcanics were mapped by the writer in 1959 in the Jeannine Lake quadrangle to the south.

The folding is complex. Strong regional movements from the northeast and southwest, identified here as the first phase of folding, have formed a series of anticlines and synclines trending northwest. Minor open folds with axes of deformation in a northeast direction is not clearly developed. The extent of this second phase of folding is not understood.

Dolomite

Structural and Field Relations

Dolomite is the most widespread of the metasedimentary formations in the quadrangle. Two small occurrences of metasediments along the Riviere Themine are dolomite synclinally folded within the gneiss. The other metasediment bodies have dolomite at the base of the stratigraphic sequence conformable with the foliations of the gneiss.

As formerly mentioned, the dolomite of the Jeannine Lake-type deposit is thin and is estimated to be 100 feet thick at the Big Three Lake deposit. The Mount Reed-type deposit is relatively thick and is estimated to be 600 feet thick at Mount Reed. Folding and possible flowage within the dolomite complicate these measurements.

The structure is relatively simple, with even bedding planes dipping an average of 40 degrees. Considering that the dolomite is completely recrystallized and acted as an incompetent rock during metamorphism and folding, it is surprising to observe well developed, even, "apparent" - bedding planes.

In the transition zone between dolomite and quartzite formations there are several zones composed of crystalline aggregates of tremolite and quartz. These zones have uniform thickness along the strike and are conformable to the dolomite. The zones are composed of sigmoidal crystalline aggregates that suggest drag folds. These zones may represent shear or thrust planes in the dolomite.

Further support of movement within the dolomite is the presence of tightly folded quartzite or chert lenses plunging parallel to drag fold axes. These folded lenses have been measured as b-lineations.

About 3000 feet west of Mount Reed is a linear depression marking the contact between the gneisses on the west and the metasediments on the east; however, the actual contact is covered by a small river. A zone 10 inches in thickness composed of coarsely crystalline diopside crystals dips 20 degrees west parallel to the apparent bedding in the dolomite.

The crystals measure 3 inches in crossection and have characteristic interpenetration twinning. This zone may be a fault.

Fractures in the quartz- and tremolite-rich bands in the dolomite are perpendicular to the apparent bedding planes. Tension cracks, filled with quartz, perpendicular to the bedding plane and parallel to the strike of the dolomite beds were observed in the dolomite formation along the Riviere Themine.

Macroscopic Description

The dolomite is black and has a rough texture on weathered surfaces. The rough weathered surface is characteristic of the recrystallized dolomite (Simpson and Tregidga, 1956, p. 239). The black color of weathered dolomite has been reported by Phillips (1958, p. 4) in the Peppler Lake quadrangle, 20 miles north northeast of Mount Reed, but other writers, in particular Dufresne (1952, p. 31); Ferguson (1958, p. 55); Gill et al. (1937, p. 573); and Murphy (1959) have reported that the dolomites of the Labrador Trough and the Mount Wright region, 60 miles north northeast of Mount Reed, have various shades of gray to buff. The black color on the weathered surface is probably due to manganese.

The fresh surface is crystalline, medium to coarse-grained, equigranular textured, and massive. The color is white with various shades of soft brown due to minor amounts of graphite, biotite, phlogopite, and iron oxides. One specimen of dolomite from Riviere Themine is fine grained, hard, compact, blue-white marble with very coarsely crystalline phlogopite mica parallel to the apparent bedding.

The white quartz lenses and bands in the dolomite vary from very fine grained almost aphanitic textured to medium grained, equigranular crystalline texture. An even quartz interband 3 feet thick west of Round Lake is thinly bedded locally showing isoclinal folding. The metamorphic reaction between the quartz and dolomite forms white, fine to medium grained, crystalline textured, subhedral to euhedral tremolite amphiboles. In the Jeannine Lake-type deposit, the metamorphic product is green calcium iron magnesium silicates (actinolite amphibole).

Microscopic Description

Ten thin sections of the dolomite were studied. The dolomite is the most abundant mineral with minor amounts of other minerals such as tremolite, diopside, phlogopite, and graphite.

Dolomite

The crystal grains are crystalline, medium grained, equigranular textured, and euhedral. Polysynthetic twinning, characteristic of dolomite,has a strong preferred orientation with respect to the apparent bedding plane. The twinning lamellae have not been bent. The dolomite is defined by the index of refraction, nO = 1.680.

Diopside

Of minor importance, diopside crystals are medium grained, euhedral, and prophyroblastic. The porphyroblasts have a poikilitic texture containing abundant calcite inclusions. Twinning is common. Alteration products of diopside are talc and antigorite.

Optical properties:

Biaxial positive
2V = 60° (estimated)
extinction: z-c = 36°
color: colorless to light green
pleochroism: little
nY = 1.678 nZ = 1.700.

Tremolite

The most abundant calcium magnesium silicate in the dolomite is tremolite. The crystals are fine to medium grained, subhedral to euhedral, and porphyroblastic. They have strong prismatic cleavages. Polysynthetic twinning is well developed and the crystals are not bent. The porphyroblasts have a poikilitic texture containing abundant calcite inclusions. The crystals appear to have been crystallized in a calcite groundmass. The calcite may be due to retrogressive metamorphism or to alteration. Antigorite and talc form by the alteration of tremolite.

Optical properties:

Biaxial negative
2V = 80° - 90° (estimated)
extinction: z-c = 13°
color: colorless.
birefringence: medium
pleochroism: nil.
nY = 1.614 nZ = 1.626

Talc

Talc is mainly associated with tremolite and calcite. It is of minor importance, less than 1 percent.

Optical properties:

Biaxial negative
2V = 10°
nZ = 1.577

Serpentine

Minor amounts of serpentine are formed by retrogressive metamorphism or as an alteration product of diopside and tremolite. The variety of serpentine identified is antigorite.

Phlogopite

Medium-grained phlogopite occurs in the fine-grained marble located at Riviere Themine. The quantity is of minor importance, less than 1 percent.

Optical properties:

Biaxial negative
2V = 10°
nZ = 1.580

Accessory Minerals

Quartz is of minor importance in the dolomite.

Oligoclase and microcline feldspar are anhedral, fine grained, and highly altered. The polysynthetic albite twins in the plagioclase have been bent. The plagioclase grains have been altered by saussuritization, and the microcline by sericitization. The feldspars are probably of sedimentary origin.

Biotite

Minor biotite near the dolomite-gneiss contact is dark brown and contains zircon inclusions. There is a high percentage of tremolite and diopside in the calcitic groundmass in this specimen.

Graphite

It is of minor importance.

Quartzite and Quartz Mica Schist

Structural and Field Relations

The quartzite and the quartz mica schist conformably overlie the dolomite. The quartzite is associated with the Mount Reed-type deposit whereas, the quartz mica schist is associated with the Jeannine Lake-type deposit.

Quartzite

The quartzite formation stratigraphically underlies the quartz silicate iron formation gradationally. The formation is estimated to be about 150 feet thick, but the thickness varies from one metasediment deposit to the next. The greatest thickness of this deposit is at Mount Reed.

Bedding is clearly indicated where iron silicate and calcium magnesium silicate at the contact zones are intercalated with the quartzite. However, bedding is poorly developed in the relatively pure quartzite. This is due to recrystallization, a characteristic feature of the more massive quartzites. Crossbedding (Fig. 16a,b) was recognized at the southern part of Mount Reed, on the northern limb of the syncline dipping steeply to the north. The crossbedding indicates that tops are down supporting a synclinal structure to the south.

Folding has affected the bedding and has caused considerable recrystallization, but there is very little flowage. Fractures are not generally well developed; however, within thinly bedded quartzites, the fractures are perpendicular to the bedding.

Quartz Mica Schist

The quartz mica schist stratigraphically underlies the quartz specularite iron by a thin gradational contact. The formation at Big Three Lake is about 70 feet thick.

Bedding is marked by thin foliations of light green mica giving a schistose appearance. The quartz-rich foli-

(a)

(b)

Figure 16. - Crossbedding in quartzite.
a) View is from the west, on north side of synclinal ridge, south end of Mount Reed.
b) Closeup of crossbedding indicates that the tops is to the south.

ations here do not retain other bedding features because of the degree of recrystallization. Folding is prominent in two localities at the Big Three Lake deposit resulting in recrystallization of the quartz groundmass and the orienting of desseminated specularite crystals parallel to the fold axis. Fractures are perpendicular to the bedding.

Macroscopic Description

The color of the quartz mica schist and the quartzite depends upon the mineral composition, the quantity of accessory minerals, and the texture of the quartz groundmass. The green mica, the dull green iron silicates, the black magnetite, the deep blue specularite, the white tremolite, and the reddish stain due to weathering of the associated carbonates and iron silicates all have a strong influence on the color. The quartz groundmass is white on weathered and fresh surfaces but with increasing degree of recrystallization the quartz groundmass takes on a bluish vitreous appearance.

The texture of the quartz groundmass is fine to medium grained and equigranular. Where affected by folding of the second phase, the quartz groundmass is recrystallized. It takes on a vitreous lustre and loses granularity. Minerals within the recrystallized quartz groundmass are themselves recrystallized and are orientated parallel to the secondary fold axis. The quartz groundmass if friable where the mica content is high and where weathering has affected the carbonates and iron silicates impurities in the upper quartzite.

Microscopic Description

Five out of eleven thin sections from the quartzite and quartz mica schists showed that there is a high degree of preferred orientation of the crystallographic axis in the quartz grains.

The texture is fine to medium grained and equigranular. Anhedral grains with clear extinction and mosaic fabric are typical. Such grains have an intense development of Boehm lines or fractures perpendicular to the bedding planes (Fig. 17).

In the localities particularly affected by the second phase of folding, the recrystallized quartz groundmass has a sutured fabric and associated straining effect represented by undulose extinction (Fig. 18).

Tourmaline

Finely crystalline, euhedral, tourmaline is found in minor amounts in the quartz mica schist. It shows no preferred orientation.

Zircon

In both types of formations, zircons are found desseminated and in clusters. The grains are subhedral to euhed-

Figure 17. - Photomicrograph (X26) shows boehm lines in quartzite. (X nicol).

Figure 18. - Photomicrograph (X 26). Shows recrystallized quartz with sutured fabric and undulose extinction. (X nicol).

ral and fine to medium grained.

Apatite

Fine grained, subhedral to euhedral crystals of apatite are widely dessiminated in both formations.

Muscovite

Abundant in the micaceous foliations in the quartz mica schist, the muscovite grains are euhedral, fine to medium grained, and strongly aligned (Fig. 19). The muscovite crystals mark the contacts between some of the quartz grains and are also found as inclusions within the quartz (Fig. 19).

Optical properties:

Biaxial negative
2V = 30° (estimated)
nY = 1.600

Quartz Silicate Iron

Structural and Field Relations

The quartz silicate iron is peculiar to the Mount Reed-type deposit. It is associated with the quartz magnetite iron formation and in this case, underlies it stratigraphically.

Due to the transgression and regression of the sea at the time of sedimentation, the iron silicates are interbedded with carbonate, quartzite, and magnetite layers which form broad lenses and intertonguing deposits. The thickness, therefore, varies according to location. An estimate of 150

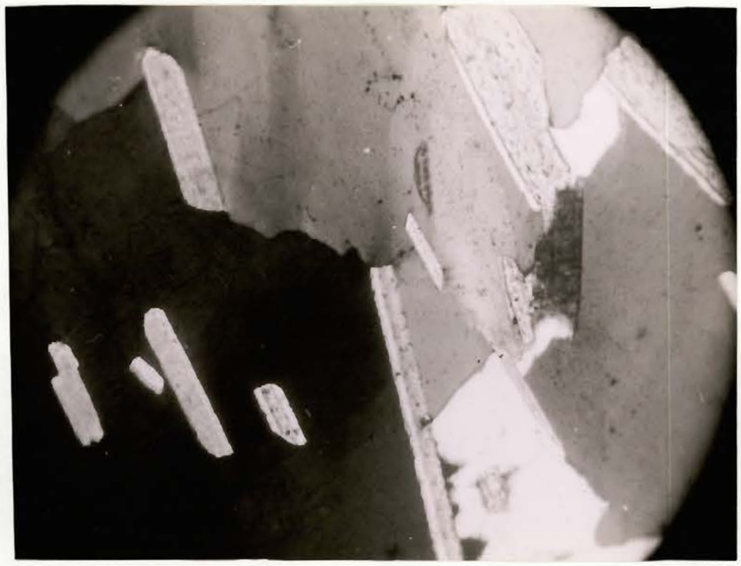


Figure 19. - Photomicrograph (X 26) shows aligned, euhedral muscovite grains in recrystallized quartz mica schist. (X nicol).

Figure 20. - Quartz silicate iron composed of thin bands of iron silicate (olive green), quartz (white), and magnetite (bluish black). West facing exposure, east side of metasediments and south of Round Lake, shows boudinage structure in iron silicate.

feet is suggested as an average thickness.

The formation has been folded by the first phase of folding into beds generally dipping steeply to the northeast or southwest. The thinly banded structure has not been distorted and probably represents the former bedding. The degree of metamorphism has changed the mineral composition and textural relations. The bedding is marked by changes in texture and mineral composition. James' (1954, p. 267) classification, which subdivides the iron silicate-rich foliations on the basis of texture into granular iron silicate type and nonequigranular iron silicate type is used. The latter is the most dominant iron silicate type in the quadrangle.

Granular Iron Silicate Type

One exposure one mile north of Mount Reed is composed of granular iron silicates. They form massive, irregular foliations about four inches thick, and are irregularly intercalated with quartzitic and dolomitic members. A reaction zone of fine fibrous amphibole, fine grained magnetite, and calcite borders the granular iron silicates. Differential erosion of the less resistant dolomite and iron silicates has left a rough textured weathered surface.

Nonequigranular Iron Silicate Type

The thinly bedded iron silicate is interbedded with very thin beds and lenses of magnetite, carbonates, and quartzite. Metamorphism has produced boudinage-type structure in the iron silicate-rich foliations (Fig. 20). Intraformational breccia, probably of sedimentary origin, is recognized at the northern tip of the quartz silicate iron south of Round Lake.

Differential erosion of the soft carbonate and iron silicate foliations, leaving the more resistant quartzite and magnetite foliations, accentuates the bedding.

Fractures are perpendicular to the bedding plane within the iron silicate-rich and quartzitic foliations.

Macroscopic Description

Granular Iron Silicate Type

The medium grained, granular, and green iron silicates constitute irregular zones are surrounded by thin half-inch thick reaction borders composed of dark green amphibole. Associated with the reaction borders are thin layers of fine-grained magnetite and irregular blebs of calcite.

The quartzite associated with the iron silicate foliations is coarse grained, and massive. It has vitreous luster, indicative of recrystallization.

Nonequigranular Iron Silicate Type

The texture of the iron silicate-rich foliations is nonequigranular, crystalline, fine to medium grained, and porphyroblastic. The porphyroblasts are aligned both perpendicular and parallel to the bedding plane. The porphyroblasts are both pyroxenes and amphiboles, the former forming euhedral crystals about one inch long. The color of the pyroxene fresh surface are dark brownish green with a greasy luster or dull light brown which probably are hypersthene. The amphiboles are dark green.

The above mentioned intraformational breccia consists of 1.5 inch by 0.5 inch angular pyroxene fragments of light brown color irregularly aligned in a greenish-brown, fine grained groundmass of amphibole. Associated with the iron silicate-rich foliations are prophyroblasts of pink garnets about 0.5 inch in diameter.

The boudinage features (Fig. 20) are a result of diagenetic movement or possibly of movement associated with metamorphism. This is evident from the laminated iron silicates and two thin magnetite bands parallel the bedding plane within each boudin. Where the constriction forming the boudin is located, the regular laminations including the magnetite bands are truncated indicating formation of the boudin after deposition. Thinly bedded quartzite interbedded with the iron silicate-rich foliations is fine grained, granular, and white. The magnetite bands are composed of black fine grained, granular grains. Veins of carbonate cut across the iron silicate-rich foliations and contain very coarsely crystalline magnetite. Carbonate constitutes thin lenses and bands parallel to the bedding and also is intersititial with the iron silicates.

Microscopic Description

From the study of fourteen thin sections and two polished sections, it is concluded that the dominant and most characteristic minerals present in the quartz silicate iron formations are amphiboles and pyroxenes. Quartz, carbonate, and magnetite are common mineral associations, and garnets, graphite, plagioclase, talc, and serpentine are of lesser importance.

Pyroxenes

Two forms of pyroxenes have been identified, the most prominent type is the hypersthene series and the other belongs to the diopside-hedenbergite series.

a) Hypersthene Series:

The magnesium iron silicates are medium to coarse grained, subhedral to euhedral, and porphyroblastic. Porphyroblasts show a high degree of parallelism to the bedding. Prismatic cleavages are well developed, but the crystal ends are poorly formed having a granulated texture in a calcite matrix. Poikilitic texture is characteristic of the hypersthene porphyroblasts containing abundant, small, calcite-filled vesicules. Inclusions of opaque iron oxides are parallel to the crystal cleavages.

The crystals are fractured perpendicular to the bedding. Alteration products such as secondary limonite occur in the fractures and cleavage planes. The limonite stain is yellowish in color, but another stain originating from opaque oxides in the pyroxenes causes a deep orange-red hue. This stain is similar to the alteration of manganiferous silicates described by Fermor (1909).

Optical properties:

Biaxial negative
2V = 80° (estimated)
color: faint pinkish
pleochroism: low
nZ = 1.74 to 1.76

b) Diopside Hedengergite Series:

Calcium magnesium iron silicates, medium to coarse grained, subhedral to euhedral, and porphyroblastic are characteristic of the iron silicate-rich foliations.

The porphyroblasts have a typical poikilitic texture with considerable calcite and minor quartz, feldspar, and magnetite. Calcite occurs as blebs and fracture fillings in the pyroxene and forms the matrix around the pyroxene crystals. Uncertainty exists as to whether the calcite is an alteration product or the remains of material from which the pyroxenes formed.

The porphyroblasts have a preferred orientation. The porphyroblast crystal ends are granulated and irregular in form. Fractures cut across the crystals perpendicular to bedding. Twinning on (100) is prominent.

Alteration products are calcite, talc, and serpentine. Staining by limonite is observed along crystal cleavages, fractures, and periphery. Remnants of oligoclase of sedimentary origin are being replaced by pyroxene (Fig. 21). Replacement is indicated by the plagioclase fragments having the same optical extinction values and albite twinning alignment.

Manganese is abundant in the iron silicate-rich foliations as indicated by the X-ray fluorescent spectrographic studies made on pyroxenes in air using a lithium fluoride crystal in the apparatus at 50 milli-amperes and 50 kilo volts setting with slit opening of 0.005 mm. This indicated that manganese and iron are abundant, also that copper is found in trace amounts. The writer notes a number of similarities between the above pyroxenes and the manganiferous pyroxenes described by Sundius (1931) and Tilley (1937); however, a detailed study of the optical properties of the pyroxenes is needed before identifying the above pyroxenes as pyroxmangite or Mn-hedenbergite.

Optical properties:

Biaxial positive
2V = 60° (estimated)
extinction: Z-c = 42° (also 24° and 32° were prominent values)
color: Colorless to faint greenish tint
pleochroism: buff to light greenish tint.
nZ = 1.72 to 1.75

Amphibole

Two forms of amphiboles that were recognized belong to cummingtonite-grunerite series and tremolite-actinolite series. The proportion of one mineral to the other cannot be determined because of their similarities. The amphiboles

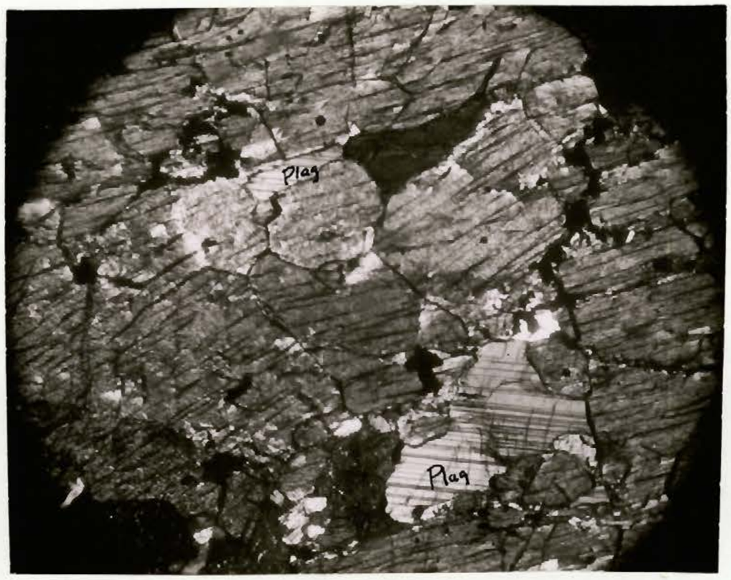


Figure 21. - Photomicrograph (X26), shows two of three oligoclase fragments in iron silicate groundmass. The fragments have similar optical properties and orientation suggesting that they are being replaced by the iron silicates. (X nicol).

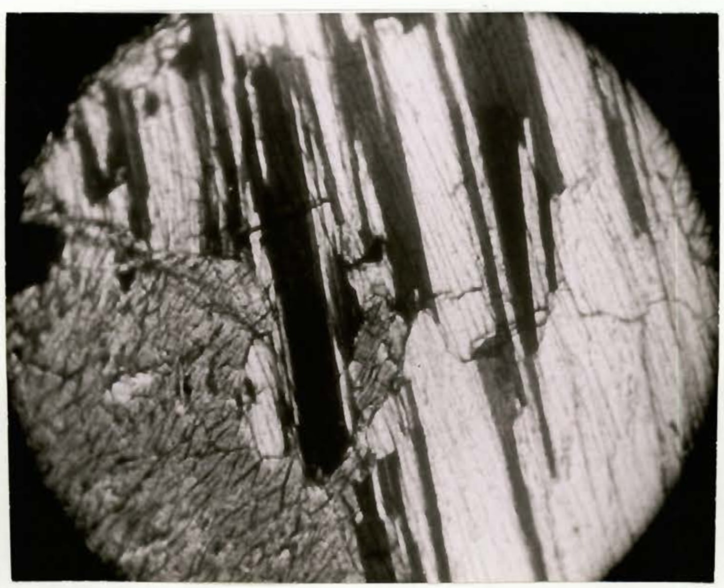


Figure 22. - Photomicrograph (X 26) shows twinned cummingtonite amphibole in iron silicate. (X nicol).

are less abundant then the pyroxenes and constitute about 20 percent of the iron silicates.

a) Cummingtonite-grunerite series.

The minerals of this series are medium to coarse grained and porphyroblastic. Preferred orientation is well developed. Twinning is characteristic (Fig. 22) giving an angle of 17 degrees from its position of extinction to the prismatic cleavage. The amphibole contains abundant calcite blebs giving it a poikilitic texture and appears to have crystallized in a calcite milieu.

Optical properties:

Biaxial Positive
2V = 90° (estimated)
extinction: z-c = 17°
color: colorless to slight buff
pleochroism: colorless to pinkish.
nZ = 1.670

b) Tremolite-actinolite series

The texture of these amphiboles is similar to the pyroxenes and amphiboles described above. Polysynthetic twinning is common and makes a very small angle with the prismatic cleavage. A considerable amount of calcite is present. Tremolite replaces the fractured diopside.

Optical properties:

Biaxial negative
2V = 70° - 90° (estimated)
extinction: z-c = 12° - 18°
pleochroism: little to none
nZ = 1.686

Accessory Minerals

Several anhedral fragments of oligoclase plagioclase are found in a pyroxene groundmass. (Fig. 21). There is no straining of the albite-twinned lamallae in the fragments and only minor saussuritization.

Quartz Iron Oxides

Structural and Field Relations

The iron oxides, comprising quartz magnetite iron and quartz specularite iron formations, are the important low-grade iron ore deposits of Mount Reed. The varying bedding thicknesses of the specularite-and magnetite-iron oxides represent sedimentary facies change at time of sedimentation. There is no transition between the quartz silicate iron and the quartz specularite iron formations. The quartz specularite iron of the Jeannine Lake-type deposit stratigraphically overlies the quartz mica schist, whereas, the quartz specularite iron of the Mount Reed-type deposit overlies the quartz magnetite iron.

The thickness of the iron formations of the Mount Reed-type is estimated to average about 300 feet and that of the Jeannine Lake-type at Big Three Lake about 100 feet.

The quartz specularite iron comprises alternating quartzite and specularite beds. The specularite beds average about 0.75 inches in thickness; however, the thickness of the quartzite varies from 0.25 to 3 inches.

The quartz magnetite is finely laminated and is composed of fine-grained magnetite oxide associated with carbonate and iron silicate. The magnetite-rich beds average 2 inches thick, and are interbedded with quartzite of varying thickness.

The bedding is uniform; however, a zone 12 inches thick within an evenly bedded quartz specularite exposure is composed of isoclinally folded specularite and quartzite beds. This zone suggests movement along the bedding plane at time of deformation.

Small fractures are developed perpendicular to the bedding in the quartzitic beds. Lenses of coarsely recrystallized, vitreous quartz parallel to the bedding in the quartz specularite iron have abundant fractures perpendicular to the bedding.

Pegmatites cut across the thinly-bedded magnetite formations west of Round Lake. There is no thermal metamorphism at the intrusive contacts but minor dragging on the magnetite bedding indicates slight movement.

Macroscopic Description

Quartz Specularite Iron

The specularite iron crystallized into subhedral to euhedral, medium to coarse grained crystals. The specularite crystals are dark blue and have a high metallic lustre. In localities where the quartz groundmass has been recrystallized, the specularite is rod-shaped with preferred orientation parallel to the axes of drag folds.

A drill core from Mount Reed indicates that coarsely crystalline rhodonite occurs in a two-inch band within specularite.

Quartz Magnetite Iron

The magnetite is fine to medium grained, granular, and subhedral to euhedral. The magnetite is finer grained than the specularite and is associated with iron silicates and carbonates.

On Mount Reed coarsely crystallized magnetite has altered to martite. Coarsely crystalline, euhedral grains of magnetite (0.25 inch) are associated with carbonate fissures.

Microscopic Description

Two thin sections and nineteen polished sections showed that the specularite is the more important of the iron oxides. No manganese oxides were recognized.

Recrystallized specularite occurs as euhedral crystals showing preferred orientation parallel to drag fold axes (Fig. 23). Twinning, inclined at an angle of approximately 45 degrees to the bedding is characteristic of the specularite (Fig. 24).

The quartz from the medium-grained quartz specularite iron has a mosaic fabric. Through recrystallization quartz becomes strained and takes on a sutured fabric.

Magnetite grains are euhedral, fine to medium grained. One specimen showed the magnetite to be replacing the hematite. Minor slumping along the bedding is recognized in a polished section of a magnetite-rich specimen. This feature was formed at time of deposition and is local.

INTRUSIVES

Pegmatites

Structural and Field Relations

Quartzofeldspathic dykes intrude the dolomite, quartzite, and quartz magnetite iron formations. Six intrusive contacts in the metasediments were observed but none was conformable with the bedding. There is no thermal metamorphism or replacement of the metasediments by the pegmatites. All the intrusive contacts are sharp. The bedding of the quartz magnetite iron formation west of Round Lake is bent sharply at the pegmatite contact but the remaining intrusive contacts show no disturbance.

The gneisses have been intruded by quartzofeldspathic dykes and sills with associated metasomatic replace-

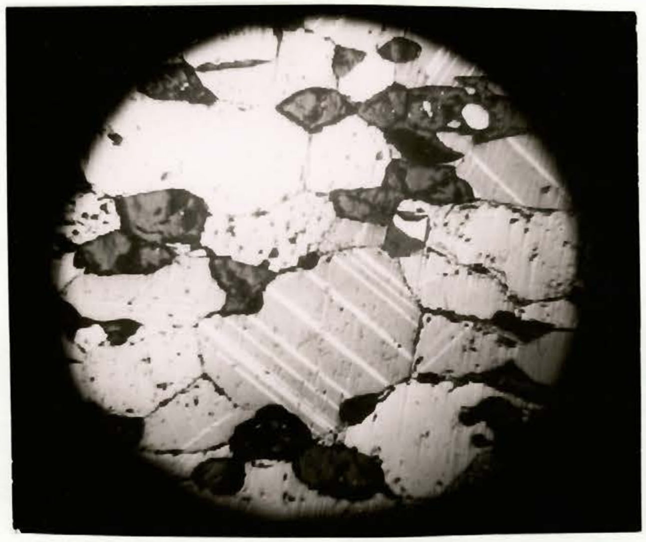


Figure 23. - Photomicrograph (X15) shows hematite twinning inclined 45° to bedding. (X nicol).

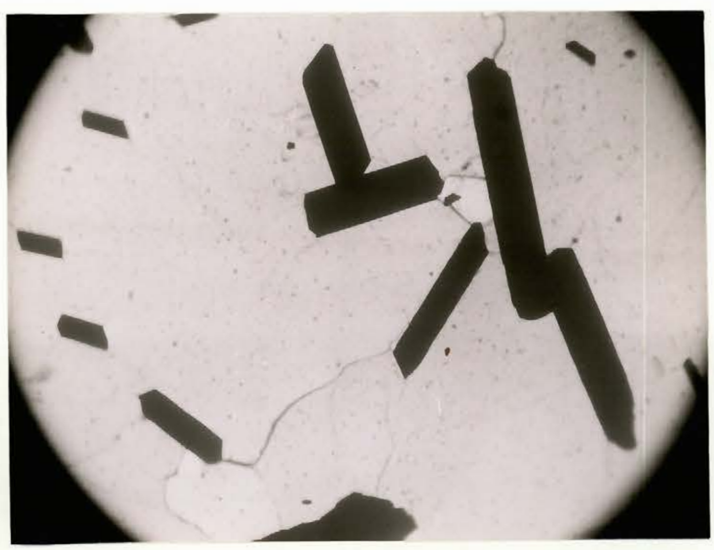


Figure 24. - Photomicrograph (X20) shows euhedral hematite grains in a quartz groundmass.

ment. Biotite gneiss, east of Mount Reed, has been intruded lit-par-lit by pegmatites causing the gneiss to approach a migmatite gneiss. Metasomatic replacement by pink potash feldspar is found along the felsic-rich foliations. With increased metasomatic replacement the amount of garnets and biotite decrease as the potash feldspar increases.

Little to no disturbance is associated with the intrusion and metasomatic replacement by pegmatites. A biotite gneiss exposure, one mile north of Mount Reed, shows the mafic-rich foliations of the biotite gneiss, faintly outlined in the pegmatite, continuing across the 10 foot wide zone without disturbance.

Well developed quartz rodding in the quartzofeldspathic pegmatites indicates slight movement forming b-lineations parallel to the axes of the drag folds.

Macroscopic Description

Both fine and very coarse grained pegmatitic phases are present in the intrusive and replacement zones. The texture throughout is granular; graphic texture is not common except in two small localities within larger quartzofeldspathic zones. In fine-grained zones, the texture becomes granitic.

Microscopic Description

Microcline

The most important mineral associated with the quartzofeldspathic intrusions and metasomatic replacement is pink potash feldspar. Microcline is identified by the fresh unaltered grains, pericline-polysynthetically twinned, replacing the plagioclase (Fig. 13, p.38). The plagioclase crystals are highly altered by saussuritization in areas that have been intruded and replaced by quartzofeldspathic pegmatites.

Amphibolites

Structural and Field Relations

Apart from the minor hornblende-rich lenses associated with the mafic-rich foliations of the biotite gneiss, there are two amphibolite exposures; the most important of which is located 6000 feet west of the northern end of the Big Three Lake deposit. The contact is obscured by overburden.

Fractures in the massive amphibolite have the same strike as the foliations of the surrounding gneisses, but dip more steeply to the west.

Macroscopic Description

The weathered surface of the amphibolite, dark brownish green in color, is friable and coarsely crystalline. Fresh surface is difficult to obtain because of deep weathering. A fresh surface is medium to coarse grained, granular and has a mottled green color. Light greenish fibrous amphiboles, light pink garnets and grey pyroxene crystals in a dark green matrix impart a mottled appearance to the rock.

Microscopic Description

The dominant minerals present are pyroxene and amphibole, both averaging about 45 percent. Amphiboles replace the pyroxenes possibly due to retrogressive metamorphism. Biotite crystals are scattered across the amphibole crystals indicating a later origin than the aligned amphiboles.

Pyroxene

The pyroxenes are medium grained (1-3 mm.), crystalline, granular textured and porphyroblastic. The poikilitic texture of the porphyroblasts consist of abundant fine-grained amphibole inclusions. Hypersthene pyroxene is the composition suggested from the following properties:

Optical Properties:

Biaxial negative
$2V == 70^o$ (estimated)

length slow
extinction: parallel
pleochroism: clear pink to light green.

Amphibole

The amphiboles are medium grained, crystalline and granular textured. Porphyroblastic crystals are poorly aligned in the pyroxenes which they replace. Biotite is seen to be irregularly desseminated in the amphibole grains. The optical properties indicate calcic hornblende composition:

Optical properties:

Biaxial negative
$2V = 70^o$ (estimated)
extinction: $z\text{-}c = 18^o$
pleochroism: yellow-green to dark green
color: dark green
$nZ = 1.64$

Biotite

In hand specimens the color of the biotite is shiny brown, similar to phlogopite. In thin sections the biotite is seen to be holocrystalline and euhedral, however, some crystals are poorly developed with indistinct boundaries, which together with lack of orientation imply an alteration product. The crystals, light brown in color, constitute about 3 percent of the rock. Minor zircon inclusions with pleochroic haloes are associated with the biotite.

Apatite

Desseminated, fine-grained, euhedral crystals of apatite occur as inclusions in the amphibole. They have a light blue-green color.

PETROGENESIS AND METAMORPHISM

GNEISS

The uniform, thick, widely continuous banding and the lack of intrusive evidence both suggest to the writer that the gneisses are metamorphosed sediments. They have been metamorphosed to such a high degree that all former sedimentary features have been obliterated. They are similar lithologically to the biotite and garnetiferous biotite gneisses described in the Grenville-type area by Logan (1863). Also, because they are located within the boundaries of the Grenville subprovince (Robinson, 1957), the Mount Reed gneisses are here classified as Grenville type. There are no quartzite and marble formations within the gneisses.

In the Grenville-type area the gneissic foliations are considered to represent former bedding planes because they are conformable with the highly contorted metasediments. Engel and Engel (1952a, p. 1029), from studies of Grenville-type paragneisses in the Adirondacks, mention that:

> "the bulk of the major rock motions and the most dominant planes of secondary shear appear to have followed the sedimentary fabric".

resulting in a "quasi bedding foliation". The gneissic or secondary foliations which result from stresses acting on essentially solid rocks during metamorphism may be controlled by former sedimentary bedding or by pressure banding formed by the high degree of metamorphism and folding to which the gneisses have been subjected.

The metasediment formations conformably overlie the gneisses but there is no other evidence supporting similar age. Indeed, the analogous but low metamorphic grade of metasediments at Knob Lake disconformably overlie the gneisses at a low angle (Dufresne, 1952). Therefore, the gneisses and metasediments at Mount Reed are conformable as a result of the movements and metamorphism during the Grenville orogeny.

The origin of the gneiss, i.e. paragneiss, is not clear. Adams (1896) working on the Grenville-type paragneisses north of Montreal postulated from the chemical analysis that the original sediments varied from shaly sandstones to sandy shales in composition. The resulting metamorphic paragneisses are potash rich. Work done on the Grenville-type paragneisses of Morris County, New Jersey, by Sims (1958, p. 11) indicates the metamorphosed sedimentary rocks were aluminous-rich. Buddington (1939, p. 11) also states that the biotitic, garnetiferous, and locally sillimantic Grenville-type paragneisses in the Adirondacks are metamorphosed alumina-rich sediments.

The mineral assemblage of the gneisses in the Mount Reed quadrangle (biotite, graphite, and garnets in quartz-oligoclase groundmass) indicates that the metamorphosed sediments were soda-rich. There is no alumina excess similar to that reported by Dufell (1959) northeast of Mount Reed. Potash has been introduced by the intrusion of and metasomatic replacement by pegmatites. The pegmatites probably were introduced at the end of the orogeny. Engel and Engel (1953a, 1953b, 1958) have identified the paragneisses in the Adirondacks as soda-rich and potash-poor in chemical composition. This study is based upon detailed trace element and chemical analysis. Engel and Engel (1953b, p. 1078) suggest the:

> "nearest analogue to the gneiss in terms of composition are graywackes and tuffaceous sediments which must be derived with a minimum of chemical weathering, hastily transported and deposited...reflecting a highly unstable crustal environment".

It is interesting to note that Pettijohn and Baston (1959, p. 596) have recognized a high-soda and low-potash content in the Precambrian metamorphic graywacke sediments of the Cobalt series, near Cobalt, Ontario. It is possible that soda-rich and potash-poor content is characteristic of the Precambrian graywacke sediments. The Precambrian graywacke sediments of the Missi series, Flin Flon, Manitoba (Ambrose, 1936) represents a series of metamorphic facies up to and including the upper amphibolite facies which is similar to mineral composition and lithologic description to the gneisses of Mount Reed. It is suggested from the above discussion that the Mount Reed gneisses were formally graywacke sediments.

Graphite is associated with the gneisses characteristic of the quadrangle's southwest corner. Graphite has been explained on the basis of atmospheric changes during the Precambrian. Rankama points out (1948, p. 403) that carbon and pyrite together are traces of living matter of Precambrian age.

The metamorphism of the gneisses is best described by the principle of metamorphic facies first proposed by Eskola (1915, p. 14, and again in 1920) that:

> "in a rock of metamorphic formations which has arrived at a chemical equilibrium through metamorphism at constant temperature and pressure conditions, the mineral composition is controlled by the chemical composition".

Subsequent development of the mineral facies concept is discussed in Turner and others, (1958); Turner and Verhoogen, (1951); Barth (1952); and Ramberg (1952). Tilley (1924) introduced the concept of metamorphic grades, in which successive metamorphic stages are represented by characteristic index minerals. Thus rocks having the same mineral facies are of the same metamorphic grade. According to Turner and others (1958, p. 13) progressive regional metamorphism gives rise to a series of belts in which the sequence of facies from low to high metamorphic grade are: greenschist; albite-epidote amphibolite; and amphibolite, with granite migmatites prominent in the zone of amphibolite facies.

Applying Eskola's metamorphic facies concept to the Mount Reed quadrangle, the mineral assemblage as a function of bulk chemical composition is graphically represented on an ACF diagram, which is a three component diagram representing $(Al,Fe)_2O_3$; CaO; (Mg,Fe)O with an excess of SiO_2 (Fig. 25 a & b). The diagram is subdivided by lines joining minerals associated in the various assemblages.

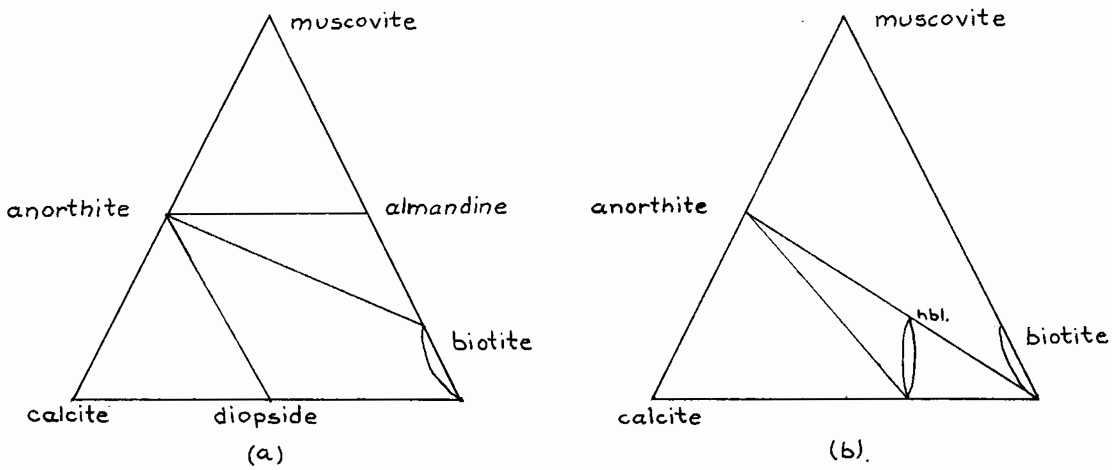


Figure 25. - ACF diagram of the almandine amphibolite facies.
a) Represents a higher degree of metamorphism within the almandine-amphibolite facies, characteristic of the garnetiferous biotite-gneiss.
b) Represents the almandine amphibolite facies, characteristic of biotite and graphitic biotite gneiss.

From the mineral assemblage studied, it is possible to deduce the grade of metamorphism of the gneiss based on the metamorphic facies concept. The Mount Reed gneisses, regionally metamorphosed under conditions of high temperature and pressure, are classified as almandine-amphibolite subfacies of the amphibolite facies (Turner and others, 1958, p. 228). The northeast area represents a slightly higher degree of the almandine-amphibolite facies than the southwest and central areas. The prevalence of hydrous minerals such as micas and amphiboles indicates a high water content. Exact temperature and pressure ranges are unknown, but the pressures that formed the Mount Reed gneisses were high and the temperatures less than 500°C.

The minerals characteristic of the almandine-amphibolite subfacies in the Mount Reed quadrangle are:

Pyroxene

The diopside pyroxenes are minor in amount and located in the gneisses of the northeast area. They indicate here temperature-pressure conditions of the upper amphibolite facies. The content of water controls the formation of amphibole and pyroxenes. The latter are characteristic of higher temperature-pressure conditions or lower water content than that of amphiboles.

Garnet

Garnets are dominant in the northeast corner area and found in minor quantities in the remainder of the quadrangle. They are thought to be spessartite-almandine type. The composition of garnet depends upon the degree of metamorphism at which the garnets formed. Manganese is absorbed to form spessartite-rich garnets which are stable at lower temperatures. Chlorite, which is present as inclusions within the garnet porphyroblasts, results from retrogressive metamorphism.

Plagioclase

The composition of the plagioclase is oligoclase-andesine which is indicative of high rank metamorphism. The oligoclase-andesine grains in the northeast corner area have a characteristic antiperthite texture; that is, the potash member (usually orthoclase feldspar) forms thin films and lamellae within the soda member. Ramberg (1952, p. 160) suggests that this is an indication of a high grade of metamorphism approaching that of a granulite facies. Oligoclase and epidote found in the gneisses of the central and southwest areas indicate that the facies is below the granulite facies but above the albite-epidote amphibolite subfacies.

Biotite

Biotite, which is stable from the greenschist to the granulite facies, is the most important mafic mineral present within the gneisses of Mount Reed. Biotite reacts with muscovite to form potash feldspar and garnet at temperature and pressure conditions of the low granulite facies. Biotite decreases in amount with the increase in the proportion of potash-rich pegmatites.

The Green and Brown Biotite

Only five of the twenty-four thin sections of gneisses studied contained green biotite and these were located in the central and southwest corner areas. The remainder of the thin sections contained biotite varying from light to dark brown with a few having a deep reddish brown color. Only one thin section from the central area had a green biotite being replaced by or changing to a brown biotite (Fig. 14, p. 43). The occurrence of green and brown biotite is related to the degree of metamorphism; the green biotite representing a lower degree than the brown.

Ambrose (1936, p. 264) studied a series of metamorphosed graywacke sediments called the Missi series at Flin Flon, Manitoba, which clearly show the effects of progressive metamorphism from the greenschist facies of low grade metamorphism to the higher metamorphic grade amphibolite facies. Ambrose noted that the green biotite is associated with the greenschist facies and changes gradually through light brown to dark brown and deep reddish brown in the amphibolite facies. He concluded that the change in color occurs as metamorphism increased. Engel and Engel (1953a, p. 1069) and Flinn (1954, p. 182) have come to the same conclusion.

Barth (1936, p. 782) noted that in Dutchess County, New York, the brown biotite is associated with Paleozoic rocks of low and high grade metamorphism. He suggested that, in addition to the increasing grade of metamorphism, the color is controlled by the FeO content: the higher the FeO content the darker the brown color. Hall (1941) supported this conclusion and added that the titanium content predetermines the reddish hue in the brown biotites.

The following observations were made in the highly metamorphosed gneisses of the Mount Reed quadrangle:

1) Dark brown biotite grains have abundant iron oxide inclusions.

2) No sphene, which would indicate presence of titanium, was recognized.

3) Green biotite was not observed in the gneisses from the northeast corner area. This area has a slightly higher degree of metamorphism than the remainder of the quadrangle.

4) Deep reddish brown biotite occurs in the metasediment iron oxide formations.

METASEDIMENTS

The thick regular bedding with minimal crossbedding and intraformational breccia as well as orthoquartzite-carbonate-iron oxide comprising the metasediments are typical of a marine environment. Deposition probably was in a large basin or possibly in part of the Labrador Trough extending south to Mount Reed. Folding, faulting, and erosion have separated the metasediments into numerous isolated units.

The metasediments within the quadrangle are classified as the Mount Reed-type and the Jeannine Lake-type deposits on the basis of stratigraphic sequence and mineral composition. The latter type deposit is represented only at Big Three Lake. Kranck (1959) classified the Mount Reed-type deposit as an "offshore" sedimentary facies and the Jeannine Lake-type as "onshore" facies. Much detailed mapping and structural interpretation must be done before these facies can be correlated.

The lowermost dolomite, quartzite, and quartz mica schist formations are similar to the orthoquartzite-carbonate sedimentary associations which Pettijohn (1957, p. 613) thought to be the product of sedimentation marginal to a low lying stable land surface. Either dolomite or quartzite may be deposited first, and in this region dolomite has been deposited first.

The dolomite was laid down as a thick deposit in the "offshore" facies and as a thin deposit in the "onshore" facies. No indication as to the genetic origin of the carbonates has survived the metamorphism. Sandy interbeds and lenses and cherty lenses were deposited contemporaneously with the dolomite. No differentiation between metamorphosed sandy lenses and cherty lenses could be made. This is mainly because the quartz-rich lenses are not well represented in the thin sections studied.

With changing tectonic conditions such as the rise of the borderland, erosion increased bringing lime deposition to an end. The contact between the dolomite and quartzite formation in the "offshore" facies is represented by a zone several feet to tens of feet thick in which quartzite and dolomite are interbedded. In the "onshore" facies the contact zone is relatively sharp.

The quartzite formation is quartz with minor mineral associations. The question exists whether the quartz was chemically precipitated or of detrital origin. Gross (1955) on the basis of a heavy-mineral residue study of the quartzites at Mount Wright states that the quartz was partly of detrital origin. Zircons, tourmaline, and other accessory minerals suggest a detrital origin of the quartz in the Mount Reed quartzites. The clean quartzite, if mechanical in origin, is probably an orthoquartzite which Pettijohn (1957, p. 299) attributes to a product of "protracted and profound weathering, sorting, and abrasion". The source area or site of deposition must be tectonically stable or the sand must go through several cycles of sedimentation to acquire orthoquartzitic characteristics. Orthoquartzite formations are characteristic of young Precambrian formations.

The quartz mica schist formation is a pure quartzite containing thin foliations of mica. The mica foliations represent clay or mud interbeds deposited near shore. One reason why clay should be deposited in the "onshore" facies and not in the "offshore" facies is that the clay (later mica foliations) is possibly analogous to the quartz silicate iron formation of the offshore facies but was deposited under oxidizing conditions.

At the end of the orthoquartzite-carbonate deposition, environmental conditions changed resulting in the deposition of the three iron formations: quartz silicate iron, quartz magnetite iron, and quartz specularite iron. James (1954) proposes that an iron formation should constitute at least 15 percent iron, but because this report is general, the quartz silicate iron formation, whether it contains 15 percent iron or not, is here included as an iron formation.

There is a strong similarity in the lithologic descriptions, mineral associations, and structural relations, of the Precambrian iron formations of Africa, Brazil, Australia, and India, (Bruce, 1945; Pulfrey, 1952, p. 127; Tyndale-Biscoe, 1952, p. 171; Wilson, 1952, p. 175; and Way, 1952, p. 191). From this literature it is evident that the same confusion regarding the origin of silica and iron, the problems of disposition, and the diagenetic changes exist as in the case of the Lake Superior iron region. Gruner (1956, p. 208) notes that the iron formations of the Lake Superior type, which are high in silica, have no counterpart in any setting younger than the Precambrian.

The iron formations of Mount Reed are similar to those of the Labrador Trough and the Lake Superior range. Most research has applied to the Lake Superior range, but the problems are similar in two aspects: the source of the iron and silica, and the environment and form of deposition.

1) Source of iron and silica. Van Hise and Leith (1911, p. 516) thought that the deposition of iron was related to volcanism, but James (1954, p. 276) points out that:

> "volcanism, though not uncommon during deposition of the major iron-formations, does not have a close enough corelation in space and time with iron-rich sediments to be genetically related to those sediments".

Gill (1927), Gruner (1922), and James (1954), among others, favor deep chemical weathering of a landmass, probably under tropical and subtropical conditions, as the source of iron and silica. Moore and Maynard (1929) studied the behavior of silica and iron in aqueous solutions in relation to transportation and deposition, and concluded that iron is transported as ferric oxide hydrosol stabilized by organic colloids, and that the form in which the iron is precipitated is a function of environment. Recent work by Krauskopf (1956) indicates that silica is much more soluble than that suggested by Moore and Maynard and that iron and silica would not be precipitated until saturation was reached.

Huber (1959) discusses the results of Krauskopf's work and mentions that though the increased solubility of silica in water solves the problem of silica transportation it introduces the problem of the high concentrations needed before precipitation takes place. Organisms are suggested by Huber (1959) and others to cause precipitation of silica and iron possibly in a finely banded form.

2) Environment and form. Each of the iron formations of the quadrangle, like those of the Labrador Trough and Lake Superior regions, has a characteristic chemical and mineralogical environment that reflects the differences in the sedimentary environment. James (1954), divided the sedimentary iron formations into four facies, on the basis of the dominant iron mineral present: sulphide, carbonate, silicate, and oxide.

a) Sulphide facies. It is composed of pyrite and pyrrhotite characteristic of a reducing environment. The iron in solution in sea water is precipitated as sulphide by hydrogen sulphide generated by bacteria acting on organic material. This facies is not recognized in the Mount Reed region.

b) Carbonate facies. Composed of siderite and ferrodolomite, the carbonate facies is characteristic of alternating reducing and oxidizing conditions. The iron is precipitated in the ferrous state as a carbonate. Though this facies is not recognized in the Mount Reed quadrangle, the carbonate type formation has been thought to be the original rock from which all the other iron formations were derived through metamorphism, such a view was held by Van Hise and Leith (1911).

c) Silicate facies. The silicate facies is composed of cummingtonite, grunerite, and hypersthene in the Mount Reed region and of minnesotaite, greenalite, and chlorite in the less metamorphosed silicate rocks in Labrador and Lake Superior region, and is associated with the carbonate facies near the boundary zone between the oxidizing and reducing environment. It is difficult to differentiate between minerals of primary and secondary origin in this facies member.

d) Oxide facies. The oxide facies composed of specularite and magnetite is the most common in the Mount Reed region. James (1954) considers the oxide facies to indicate deposition in shallow, wave-and current-swept regions where oxygen is abundant. Difficulty arises when deciding whether hematite (later specularite by metamorphism) and magnetite minerals are of primary or secondary origin.

The primary minerals constituting the above facies are controlled by the oxidation-reduction potential which is a measure of the environmental conditions. Krumbein and Garrels (1952) have proposed that:

> "the depositional environments of the iron-rich rocks clearly belong to their restricted environments, in which physiographic, tectonic, or biologic features impose controls on circulation, oxygenation, or concentration of dissolved salts".

The oxidation-reduction potential Eh may range from positive (oxidizing) at the surface to strongly negative (reducing) at depth; the hydrogen-ion concentration (pH) may range from mildly alkaline at the surface to slightly acid at depth, thus the restricted marine environment proposed by Krumbein and Garrels could control the various pH and Eh values needed for iron and silica precipitation.

The regression and transgression of the sea at the time of deposition resulted in the interbedding and change in composition along the strike of the iron formations. White (1954) and Gruner (1956) point out that the iron silicate-rich foliations are only associated with the magnetite-rich and never with the specularite-rich foliations.

The metasediments which have retained their sedimentary bedding, marked by characteristic mineral assemblages and by bedding planes, clearly shows the metamorphic isograde to follow parallel to the strike of the metasediment formations. The differences in the partial pressure and quantity of carbon dioxide and water, which are as important as increasing the temperature and pressure (Yoder, 1955, p. 509), can account for the different metamorphic facies present in the metasediment formations. Water and other volatile components facilitate metamorphism and permit most metamorphic reactions to take place at lower temperatures. Turner and others

(1958, p. 180) summarized the physical conditions which might lead to a facies change:

> "(1) increase in temperature at constant pressure; (2) reduction inwater pressure at constant load pressure and constant temperature; (3) increase of load pressure at constant temperature and water pressure; (4) increase in stress at constant load and water pressure and constant temperature; (5) a combination of all these effects".

The dolomite formation is completely recrystallized and contains little or no quartz in the groundmass. Sandy or cherty lenses have been tightly folded within the massive-appearing dolomite formation with little metamorphic reaction between the quartz and dolomite. Regular quartz-rich interbeds have a high percentage of calcium magnesium silicates such as tremolite and diopside. The more abundant tremolite crystalline aggregates are contorted suggesting drag folding. It is difficult to explain why the tightly folded quartz lenses have little or no metamorphic reaction with the dolomite whereas the regular quartz interbeds have been so highly altered to tremolite and diopside. The drag folded tremolite, in zones parallel to the apparent bedding plane, suggests thrust faulting along the planar quartz interbeds. Water is more abundant in fault zones than in the massive dolomite, and heat, though minor, would be generated by the fault movement providing ideal conditions for the crystallizing of tremolite. The diopside crystals require less water than the tremolite to remain stable.

The quartz silicate iron has a high percentage of carbonate. The original mineral composition is not known because of the susceptibility of this formation to metamorphic change.

The low grade metamorphic silicate iron formations at Knob Lake consist of minnesotaite and stilpnomelane silicates. The minnesotaite and stilpnomelane silicates are altered to cummingtonite, grunerite and hypersthene with increased metamorphism. Such is the case at Mount Reed. Kranck (1959) has suggested the following reactions:

Ferrodolomite + siderite --- Hypersthene (1)

Minnesotaite + siderite --- Cummingtonite (2)

Cummingtonite --- Hypersthene (3)

Reaction (3) suggested by Kranck (1959, p. 63) depends upon the partial water vapor pressure being high.

The quartzite, quartz mica schist, and quartz iron oxide formations have a very high percentage of quartz. Metamorphosed chert could not be differentiated from quartzite. The common silicates are iron magnesium pyroxenes. Magnetite may either be primary or secondary in origin. Specularite is formed from the hematite by increased metamorphism.

The metasediments here have been metamorphosed to the same degree, but because of the different mineral composition and varying water anc carbon dioxide content, the reactions have been different. The epidote-amphibolite facies is the most representative of the metasediment formations.

The cause of the increased temperature is not clearly understood. If the temperature of metamorphism is to be explained by having the metasediments downbuckled, hence buried to great depth, then it is indeed fortuitous that erosion of the overlying material has been so consistant as to leave the metasediments presently at the surface.

STRUCTURE

GENERAL STATEMENT

The structural interpretation depends upon the stratagraphic sequence of the metasediments accepted by the reader. In this thesis, the quartz iron-formations are considered to be uppermost in the metasediment stratigraphic sequence; however, Kranck (1959) and Spat (1959) favor the presence of an "upper" gneiss overlying the metasediments. The "upper" gneiss is considered by them to be generally graphitic. Nowhere in this area could the distinction be made between "upper" and "lower" gneiss.

The Cartier series was deposited as sediments in a marine basin probably an extension of the Labrador Trough with the gneisses forming the basement. The possibility exists that the gneisses and metasediments are contemporaneous. After deposition, these sediments were metamorphosed to a low grade similar to the Kaniapiskau series in Knob Lake (Dufresne, 1952). Later, intense deformation associated with the Grenville orogeny folded and metamorphosed the low rank metasediments to their present regional trend and composition. The northwest-trending regional structure is due to the first phase of folding. A second phase of folding, with its axis of deformation aligned to the northeast, is poorly developed. "First" and "second" cannot be interpreted as an actual time sequence, but rather represents the folding in order of importance, Possibly other orogenies have affected the region, but evidence supporting this contention is absent. Folded Ordovician limestone intruded by andesine volcanics at Lake Manicouagan (Rose, 1955), 30 miles south southwest of Mount Reed, indicate post Ordovician movement.

Folding

Due to lack of outcrop major fold structures are difficult to recognize. The gneissic foliations average 30 degrees dip to the northeast or to the southwest. The gneissic foliations in juxtaposition with the metasediments are steeply dipping. Flat dipping gneissic foliations, characteristic of the Grenville subprovince, are referred to by Osborne (1956, p. 11) as "broad domical structures".

Isoclinal recumbant folding is common in the gneisnes. Minor drag folding with uniform axes are localized in zones interbanded with evenly foliated gneisses. Such zones suggest movement along incompetent beds. Similar structures were recognized within the metasediments. Flowage is associated with some major and most minor folding, particularly within the felsic foliations which show much thinning of the limbs and thickening at the crests and troughs of the folds.

The plunge of the major and minor first phase fold

Figure 26. - Air photo (A12494-350) shows the complex structure of Mount Reed which is interpreted to be a syncline overturned to the southwest. Note sharp north-south trending feature to the west of Mount Reed marking the contact between metasediments on the east and gneiss to the west. Scale 1" - 3000'.

axes from 10 to 15 degrees to the northwest or southeast indicates cross-folding of the second phase. In some localities the fold axes plunge up to 80 degrees to the northwest or southeast.

The metasediments overlying the gneisses have been tightly folded into synclines and anticlines which plunge gently to the northwest or southeast. The Big Three Lake, Black Dan Lake, and Mount Reed metasediments in the southern part of the quadrangle occur in synclines overturned to the southwest. At Mount Reed the synclinal structure is recumbant to the southwest. The air photo (Fig. 26) illustrates the complex structure of Mount Reed area. Minor folds within the metasediments are isoclinal and recumbant.

Faulting

No direct evidence of faulting was observed in the field. However, the following evidence is offered to support longitudinal faulting. In the massive recrystallized dolomite at the base of the metasediment stratigraphic sequence, there are several tabular zones composed of crystalline aggregates of tremolite and diopside. Some of the crystalline aggregates within these zones have a contorted structure indicative of movement. Former quartz-rich interbeds act as competent members within the dolomite and would act as planes along which the dolomite moved at time of deformation. A strong linear feature (Fig. 26) along the western boundary of the Mount

Reed deposit is produced by the metasediments in contact with a gneissic ridge to the west. On the east side of the contact within the dolomite there is a coarsely crystalline diopside zone, 10 inches thick, dipping 20 degrees to the west as if to pass under the gneiss. The contact is obscured by a stream.

The northwest-trending Big Three synclinal deposit is sharply drag folded to the southwest at its southern end. Two other metasediment formations to the northwest have similar structure. All three formations terminate on a line parallel to the trend of gneissic foliations.

Lineations

Lineations within the quadrangle are due to mineral rodding and small folds and crenulations. Most lineations in this region were recognized as b-lineations, because they are parallel to the axis of drag folds. According to Cloos (1946) this recognition of b-lineations is not infallible and lineations may be due to and parallel to movement; therefore, classified as a-lineations.

Tightly folded sandy or cherty lenses within massive dolomite form rods which were measured as b-lineations. The quartz rods here have a uniform plunge.

Quartz grains in the felsic foliations are uniformly aligned parallel to the axes of drag folds and are measured as b-lineations.

Within recrystallized quartzite containing specularite iron oxides, the euhedral specularite grains are aligned parallel to the axis of the folding.

Stereographic projections of foliations and lineations on a Schmidt equal-area net were attempted for several metasediment deposits. The gneissic and metasediment foliations were plotted and where adjacent foliations intersected provided Beta lineations which were plotted with b-lineations of mineral rodding and fold axes. The readings, being too scattered and too few, did not produce any pattern.

Fractures and Joints

Macrofractures are not well developed in the metasediments or gneisses; however, microfractures, analogous to the Boehm lines recognized in the microscopic study, are seen aligned perpendicular to the bedding.

Jointing is poorly developed in both the gneisses and metasediments. One set of joints identified as tension joints and filled with quartz were recognized in dolomite along the Riviere Themine. They are perpendicular to the apparent bedding and parallel to the bedding strike. In the gneiss, two joint sets varying in dip between 60 and 90 degrees trend northeast and northwest.

ECONOMIC GEOLOGY

The specularite and magnetite of Mount Reed and several smaller deposits in the quadrangle as well as the Jeannine Lake and Mount Wright deposits have made it economically feasible for Quebec Cartier Mining Company to build a seaport on the Gulf of Saint Lawrence and a road and railroad from it to the deposits. Production will begin in the latter part of 1960.

The Jeannine Lake deposit, south of Mount Reed, will be developed first. It is about 800 feet deep, 500 feet wide, and 6000 feet long and will be mined by open pitmethods. The iron ore with a grade of 30 percent will be concentrated at Jeannine Lake before shipping. Twenty million tons of crude ore will be processed annually to eight million tons of shipping ore. The Mount Reed deposit will be developed after Jeannine Lake.

The iron ore has a low titanium, phosphorous, and sulphur content. Silica content is high, and manganese is a major constituent in the iron silicates. No opaque manganese oxides were identified. A rhodonite band two inches wide was identified in the specularite iron.

Sand and gravel, particularly glacial outwash, are being used for construction.

SUMMARY AND CONCLUSIONS

The Mount Reed quadrangle, located 140 miles north northwest of Sept-Iles, Quebec, is an area of 183 square miles bounded by latitudes 52°00'N and 52°15'N and longitudes 68°00'W and 68°15'W. The quadrangle was mapped on a reconnaissance scale, using two inches to one mile, during the summer of 1958. The Jeannine Lake quadrangle, south of Mount Reed, was mapped by the writer during the summer of 1959 and provided an opportunity to restudy the similar petrological and structural relations.

The area, with its rolling topography, is located in the southern part of the uplifted Quebec-Labrador plateau and north of the highly dissected plateau edge. All the physiographic features have been modified by continental glaciation which retreated to the north leaving extensive glacial deposits. Depositional features are common below the 2250 foot contour and erosional features above. Present drainage follows the post glaciation drainage system flowing south into Lake Manicouagan. The vegetation boundary between the close forest type and the open lichen woodland is located in the region. Here the lichen woodland is characteristic of those regions below the 2250 feet. An extensive flat area in the northern part of the quadrangle is covered by muskeg.

Biotite gneiss plus graphitic and garnetiferous varieties collectively form the ubiquitous soda-rich gneiss in whick oligoclase-andesine feldspar is the dominant mineral. Potash feldspar was introduced at the end of the orogenic movements. The gneisses, originally graywackes, were metamorphosed to the almandine-amphibolite facies. Within this facies there is a slight increase in degree of metamorphic grade toward the northeast corner where garnetiferous biotite gneiss is found. The gneiss exposed in the northeast corner are petrologically similar to the garnetiferous biotite gneisses exposed along the western and southwestern boundaries, of the quadrangle to the south. The latter are associated with intrusive anorthositic gabbros.

The metasediment formations, classified as the Mount Reed-type and Jeannine-type, are referred to as typical of "offshore" and "onshore" sedimentary facies respectively. The "offshore" facies differs from the "onshore" sedimentary facies by having, in general, thicker formations, and quartz silicate iron and quartz magnetite iron formations. However, the stratigraphic sequence is essentially the same; each ranging from carbonates through quartzites to iron formations.

The metasediments represent sediments deposited in a marine environment on the gneiss. The dolomite and quartzite formations at the base are typical orthoquartzite-carbonate associations. The iron deposition represents special environmental conditions. The origin of the silica and iron is not clearly understood nor the form in which the iron minerals were first deposited.

The gneisses and metasediments appear to be conformable. The high degree of metamorphism and folding caused the dolomite to act as an incompetent formation and the remaining metasediments to be tightly folded and, in some cases, overturned to the southwest. The metamorphic grade of the metasediments is of the epidote amphibolite facies.

Associated with the high degree of folding is a strong possibility of thrust faulting parallel to the bedding. The contorted tremolite silicates within the quartz interbands suggest thrust movement of the surrounding dolomite.

The gneisses and metasediments have been deformed and metamorphosed by the Grenville orogeny. The metasediments are analogous to the Labrador-Trough metasediments. Later orogenies may have affected the area giving rise to the intensely folded Ordovician limestones to the south southwest of the region.

The amphibolite intrusives in the area are massive and have not been folded.

The region is economically important for its deposits of low-grade iron ore. The Big Three Lake deposit was found while mapping the quadrangle. Apparently the deposit did not produce an appreciable anomaly in electro-magnetic and gravity surveys. The writer notes, in closing, that Black (1958) observed boulders of iron oxide at mile 122 on the road from Shelter Bay to Jeannine Lake. He concluded that glaciation had carried the boulder 60 miles south from its probable source at Jeannine Lake.

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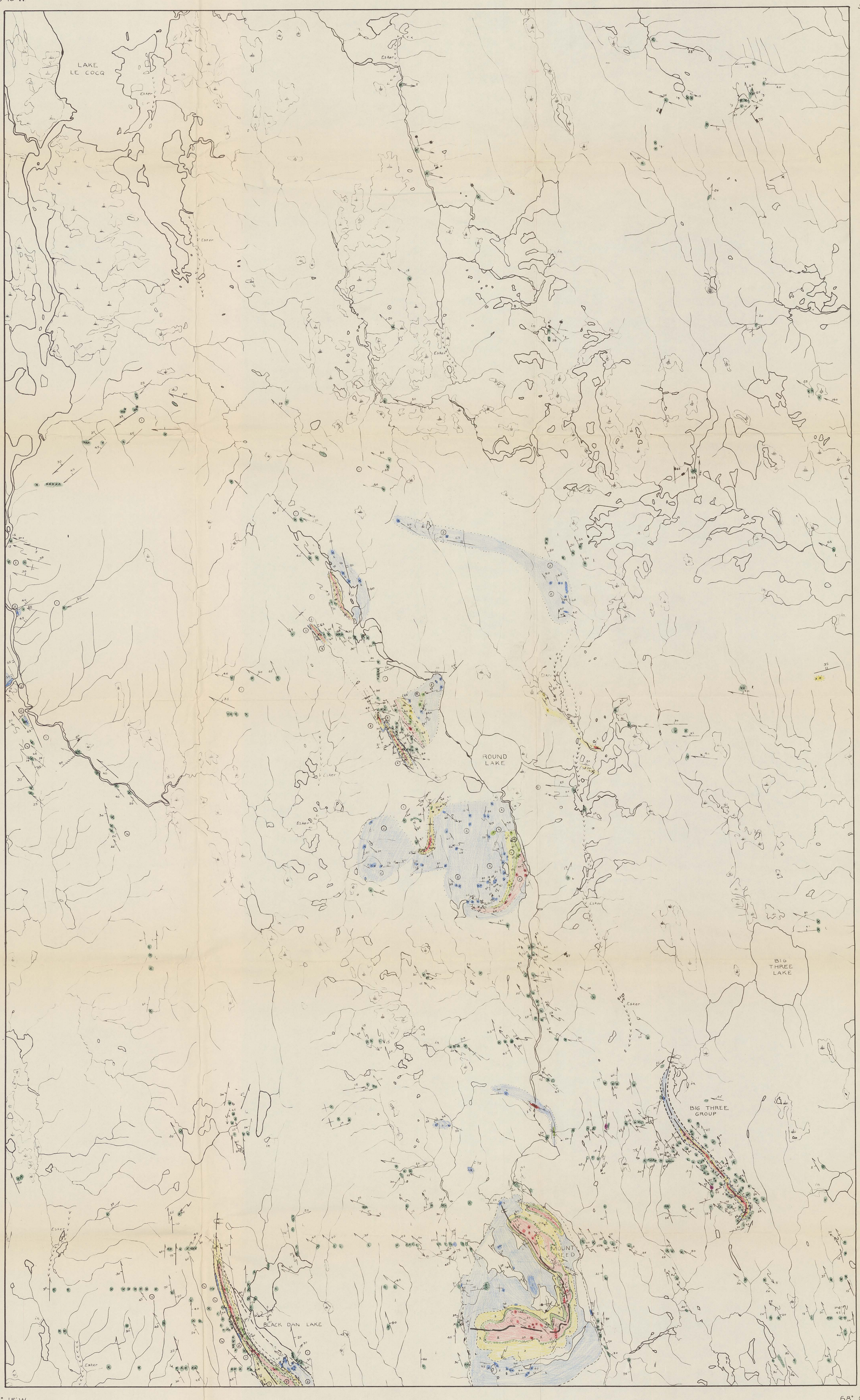
68° 15' W
52° 15' N
68° 00' W
52° 15' N



52° 00' N
68° 15' W
52° 00' N
68° 00' W

LEGEND

QUATERNARY

UNCONSOLIDATED DEPOSITS SAND & GRAVEL MATERIAL.

PRECAMBRIAN

7. AMPHIBOLITE

6. QUARTZ FELDSPATHIC MATERIAL
PEGMATITE DYKES ; LIT-PAR-LIT INJECTION ;
METASOMATIC REPLACEMENT.

METASEDIMENTS :- "TROUGH-TYPE"

5. QUARTZ IRON OXIDES
HEMATITE ; MAGNETITE ; QUARTZITE MATRIX

4. QUARTZ SILICATE IRON
DIOPSIDE - HEDENBERGITE PYROXENES
CUMMINGTONITE - GRUNERITE AMPHIBOLES

3. QUARTZITE AND QUARTZ MICA SCHIST

2. DOLOMITE
CALC MAGNESIUM SILICATES

PARAGNEISS :- "GRENVILLE-TYPE"

1. BIOTITE PLAGIOCLASE QUARTZ GNEISS.
1_x - GRAPHITIC BIOTITE PLAGIOCLASE QUARTZ GNEISS
1_g - GARNETIFEROUS BIOTITE PLAGIOCLASE QUARTZ GNEISS

SYMBOLS

OUTCROP : 1) SMALL 2) LARGE

GEOLOGICAL BOUNDARY : DEFINED, APPROXIMATE, ASSUMED.

STRIKE AND DIP OF BEDDING
1: INCLINED 2: HORIZONTAL.

STRIKE AND DIP OF GNEISSOSITY (FOLIATION)
1: INCLINED ; 2: VERTICAL ; 3: DIP NOT KNOWN.

TREND AND PLUNGE OF LINEATION

STRIKE AND DIP OF JOINTS 1: INCLINED 2: VERTICAL

STRIKE AND DIP OF SHEAR ZONE

ANTICLINAL FOLD AXIS AND PLUNGE.
1. KNOWN 2. ASSUMED 3. OVERTURNED

SYNCLINAL FOLD AXIS AND PLUNGE
1: KNOWN 2. ASSUMED 3. OVERTURNED

DIRECTION AND ANGLE OF PLUNGE OF MINOR DRAG FOLDS.

FOLDS : DIRECTION AND ANGLE OF PLUNGE
DIP AND STRIKE OF AXIAL PLANE

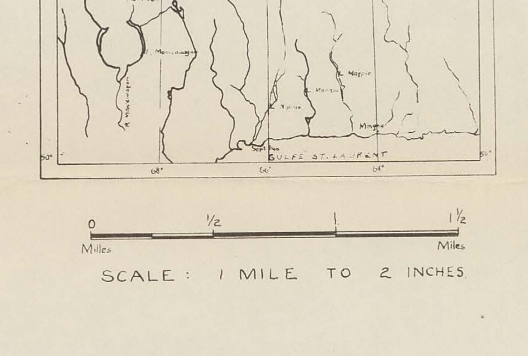
GLACIAL STRIAE : DIRECTION OF MOVEMENT

ESKER.

SWAMP

APPROXIMATE MAGNETIC DECLINATION 28° W

INDEX MAP



0 ½ 1 1½
Milles Miles
SCALE : 1 MILE TO 2 INCHES.

MOUNT REED AREA

DISTRICT ÉLECTORAL DU ELECTORAL DISTRICT OF
SAGUENAY

B. E. MACKEAN, 1955