GEOLOGY OF THE JOHAN BEETZ AREA

SAGUENAY COUNTY

BY

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GEOLOGY OF THE JOHAN BEETZ AREA

Saguenay County

INTRODUCTION

Location of Area

The Johan Beetz Area is situated on the north shore of the Gulf of St. Lawrence and is bounded by latitudes 50°15'N and 50°30'N, and by longtitudes 62°30'W and 63°00'W. It measures about 22 miles east-west and 17 miles north-south and is approximately 350 square miles in area.

Johan Beetz, after which this area has been named, is a small settlement on the shore about midway between the east and west boundaries of the area. It is 440 miles downstream from Quebec City and 34 miles east of Havre St. Pierre, one of the principal settlements on the Gulf. The location of the area is shown by Figure 1.

Means of Access

In summer, boats of the Clarke Steamship Company Limited, sailing from Montreal and Quebec, make regular stops at Johan Beetz.

There are numerous large lakes in the area suitable for landing by seaplanes. The nearest seaplane base is at Sept Isles, 165 miles west of Johan Beetz. From Havre St. Pierre, which has an airplane landing strip, a motor-driven fishing barge can be rented to reach the area.

Travel Within The Area

Travel within the area is best accomplished by seaplane or by motor-equipped canoe. There are numerous lakes suitable for landing, so that all parts of the area can be reached by air. The largest

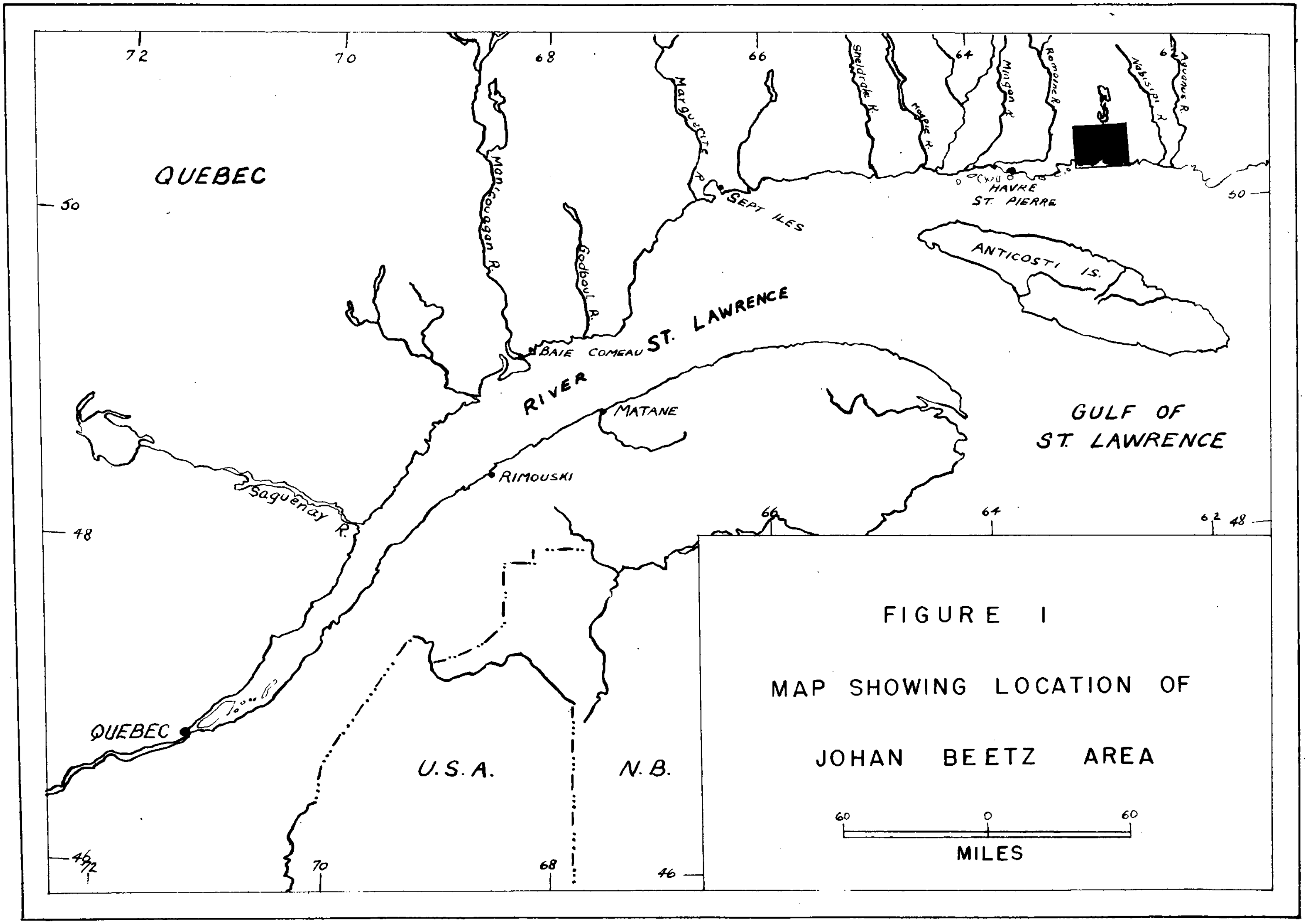

FIGURE I

MAP SHOWING LOCATION OF

JOHAN BEETZ AREA

rivers in the area are, from east to west, Watshishou river, Piashtibaie river, Little Piashti river and Corneille river. These are the most suitable canoe routes inasmuch as they, together, give access to nearly all parts of the map-area. Little Piashti river is the most important of the above routes because it is connected by several short portages with both the Corneille river route and the Piashtibaie river route.

The rivers in the area contain many rapids and chutes, but they can be bypassed by well-worn portages. All the portages are short except the one leading from Cabane-Neuve lake to Prudent lake and the second portage north of Turgeon lake. Several portages have been cut at different places along these main routes to provide access to smaller lakes and rivers.

Table 1 lists the number and the total distance of the portages between the major lakes along each of the four routes.

TABLE 1.

Route	From	To	Portages	Total Length
Corneille	Sea	Tanguay L.	4	2800 ft.
	Tanguay L.	Turgeon L.	5	7800 ft.
	Turgeon L.	Ferland L.	4	7500 ft.
	Ferland L.	Traverse L.	1	900 ft.
Little Piashti	Johan Beetz	Salé L.	0	
	Salé L.	L. Piashti L.	2	2700 ft.
	L. Piashti L.	Turgeon L.	2	2300 ft.
	L. Piashti L.	Cabane-Brulée L.	4	2700 ft.
	L. Piashti L.	Big Piashti L.	4	2800 ft.
Piashtibaie	Sea	Cabane-Brulée L. (outlet)	6	4000 ft.
	River (outlet Brulée L.)	Villeneuve L.	3	6500 ft.
	Outlet Cabane-Brulée L.	Bellanger L.	5	6000 ft.
	Bellanger L.	Napoleon L.	3	2100 ft.
Watshishou	Sea	Veronique L.	10	5300 ft.
	Veronique L.	L. Veronique L.	1	1600 ft.
	Veronique L.	Fork in W. River	1	600 ft.
	Fork in W. River	Cabane-Neuve L.	7	5300 ft.
	Cabane-Neuve L.	Prudent L.	1	5100 ft.
	Cabane-Neuve L.	Theodule L.	3	1100 ft.

Figure 2 illustrates the various canoe routes in the area.

A motor-driven fishing barge was used to travel along the coast.

Field Work

Mapping of the area was done at a scale of one-half mile to one inch by systematic pace-and-compass traverses spaced at intervals of approximately one-half mile. As far as possible, the traverses were arranged to cross the trend of the formations. Shore exposures of the more accessible lakes were examined in detail.

The coastal section of the eastern half of the area was mapped at a scale of approximately one-quarter mile to one inch, corresponding to the scale of the aerial photographs of that section. The western part of the coast was mapped at the scale of one-half mile to one inch.

Vertical aerial photographs were used continually in the field. They were useful in determining the structure of the area and acted as a guide in following the contacts between different rock types.

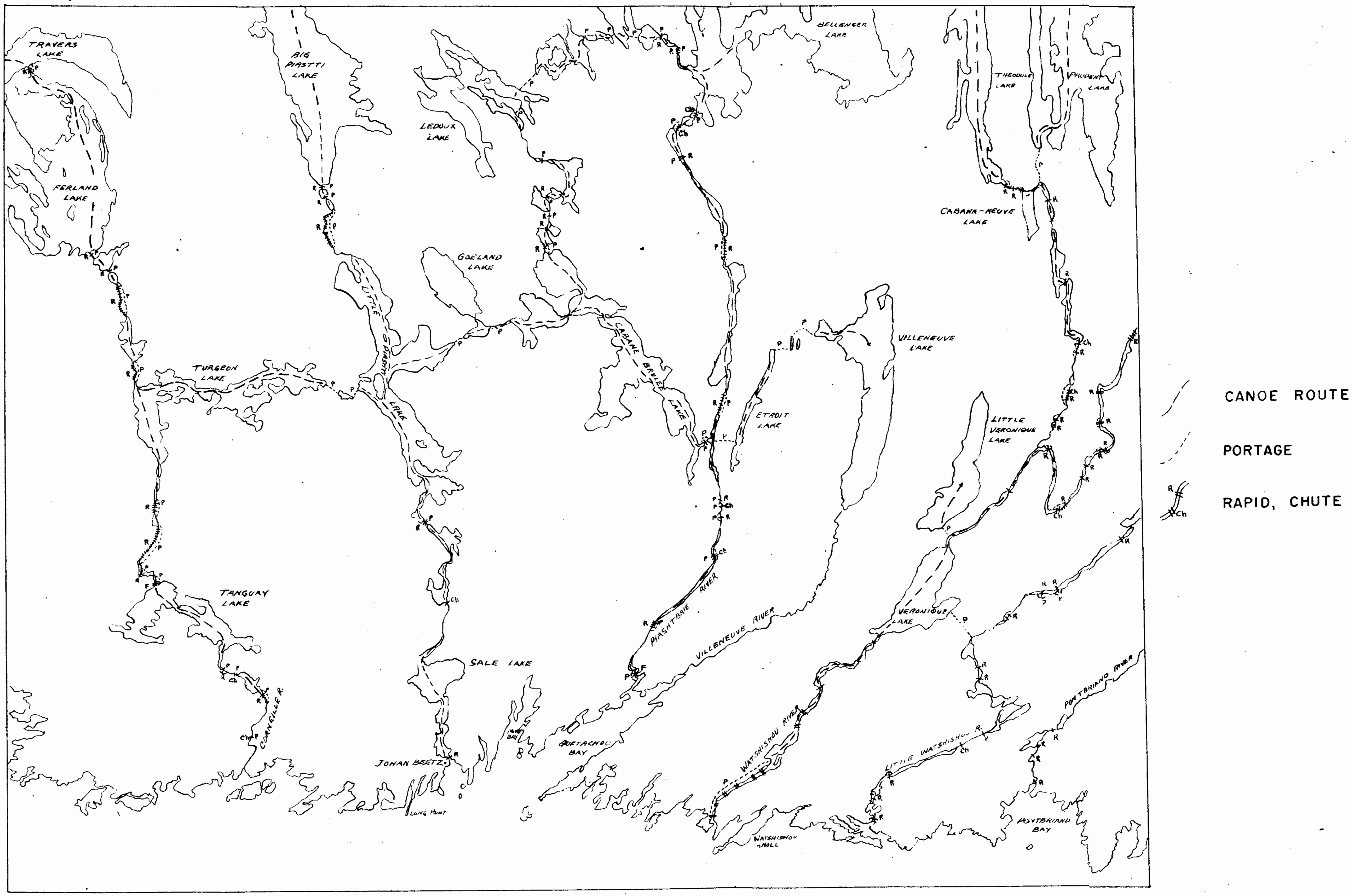

FIGURE 2. CANOE ROUTES IN THE JOHAN BEETZ AREA.

Previous Work

Reports of mineral occurrences within the map-area, and in areas not far removed from it, are contained in publications by De Puyjalon (1899) and Walker (1911). A more recent investigation was made by Elenborn (1925) of the feldspar quarry which is located on the east side of Quetachou bay.

In 1943 Longley (1950) carried out a geological reconnaissance survey of the north shore of the Gulf of St. Lawrence between Mingan and Aguanish. The geology of the shoreline of the Johan Beetz Area is included in his report.

Claveau (1945) made a brief examination of the quartz deposits of Watshishou Knoll. These deposits were studied in detail by Owens in 1949 (Owens 1951).

The area immediately to the north was mapped by Grenier (1950, 1951).

Acknowledgements

The field work was done during the summers of 1951 and 1952 as part of the mapping programme of the Province of Quebec, Department of Mines. The writer is grateful to Dr. A. O. Dufresne, Deputy Minister of the Department, and to Dr. I. W. Jones, Chief of the Geological Surveys Branch, for permission to use the information collected as thesis material.

Thesis research work was made possible by scholarships awarded to the writer by the Quebec Department of Mines for the school terms 1951-52 and 1952-53.

The base-map, thin-sections and many of the photographs used in this thesis were supplied by the Quebec Department of Mines.

Valuable information used in this thesis was collected by Pierre Sauve, senior assistant in 1951, and Erwin Hamilton, senior assistant in 1952. Their unfailing help is gratefully acknowledged.

The writer wishes to acknowledge his indebtedness to Dr. E. H. Kranck, of McGill University, under whose direction this thesis was written. Dr. Kranck offered many valuable suggestions and he has read the manuscript critically.

NATURAL RESOURCES

Vegetation

Vegetation consists of black spruce, balsam, poplar and a small amount of white birch. The best stands of timber in the area are in the valleys bordering the rivers and lakes. For the most part, however, these are limited in area and are of such quality suitable only for pulp. Only scrub spruce grows on the higher hills because of their steepness. Due to the strong wind which blows inland from the Gulf, very little vegetation is able to grow along the shore. The soil, which is present locally, within the area is too lean and thin to be used for agricultural purposes.

Fish and Game

Marine fish are plentiful in the coastal waters and provide the chief means of livelihood of the inhabitants of Johan Beetz. Salmon are netted along the shore, chiefly at the mouth of Watshishou river. Lobsters are trapped in this vicinity and in Appititatte bay.

Trout and salmon are abundant in Watshishou, Little Watshishou, and Corneille rivers. There are few trout in Piashtibaie river and, owing to the height of the falls at its mouth, salmon are not known to mount the river.

Whales and porpoise are plentiful in the offshore waters and a few seals live among the islands east of Pontbriande bay.

There are no moose or deer in the area and few caribou. Furbearing animals, chiefly muskrat and mink, are trapped during the winter months. Spruce partridge, rabbit and porcupine are fairly numerous.

Wild duck are abundant, particularly eider duck, which next in large numbers along the coast.

A small fishing village has been established at the mouth of the Watshishou river by the inhabitants of Johan Beetz.

PHYSIOGRAPHY

General Considerations

The Johan Beetz Area is located in the eastern part of the Pre-cambrian Shield. The general slope of this part of the shield is south at approximately 30 feet per mile. However, east and west of the area, this slope becomes much steeper and elevations of up to 2000 feet are reported within a few miles of the coast.

To understand properly the local topography, it is necessary to review briefly the general physiographic history of the Canadian Shield. This history has been traced by numerous workers, in particular by Cooke (1929, 1930, 1931) and by Wilson (1939).

Studies of those areas of the shield where post-Archean rocks are found have established beyond doubt that the surface of the Canadian Shield is an ancient, partly dissected peneplain. Further, unconform-ities exposed through erosion show that the shield has undergone not one, but many cycles of erosion, some of which have produced peneplains. One such peneplain is found beneath the lower Paleozoic sedimentary rocks that fringe the shield and occur locally within it.

The even skyline observed in most areas is generally regarded as marking the position in the present topography of the last fairly com-plete peneplain. This remained close to sea-level until about mid-Tertiary, at which time uplift, in relation to the sea, resulted in re-newed down-cutting and rapid erosion of the weak rocks. Extensive straths were developed and were incised before the onset of glaciation. Uplift and westward tilting of the eastern part of the Shield bordering the Gulf of St. Lawrence and Atlantic Ocean took place in Late Tertiary.

This rising of the Shield must have been slow, because some of the major streams were able to continue cutting across the rising mountains, carving deep gorges: Hamilton and Lower Saguenay rivers. At the same time, dissection of the marginal parts of the peneplain proceeded rapidly, giving rise to the young mountainous topography of the Laurentian and Torngats. The cycle was interrupted in its early stages by the Pleistocene glaciation.

Local Topography

The land rises from a low, flat irregular shore (Plate 1) to an average height of less than 600 feet. In the eastern part of the area there is a ridge and valley topography inland, but in the western part, the inland surface has the form of a gentle sloping plateau. Therefore, the area may be divided into three topographic units, the characteristics of each dependent upon the underlying rocks and their structure.

Coastline

The coastline is very irregular and is indented by numerous bays. The structure of the underlying rocks is the most important factor in determining the shapes of the bays. From Johan Beetz to Watshishou Knoll, the bays are long and narrow, their long direction trends north-east parallel to the strike of the bedding of the quartzite. They are extensions of valleys of the interior. The peninsulas, which are underlain by pegmatite or gabbro intruded into quartzite, rise to a height up to 50 feet above the water.

East of Watshishou Knoll the bays are more open, owing to variations in the trend of the underlying rocks. The irregularities of the shore of the bays, such as Pontbriand bay, are due partly to the strike of the

PLATE 1

Fig. 1 Low irregular shoreline east of Watshishou Knoll.

Fig. 2 Low irregular shoreline west of Watshishou Knoll.

gneiss in that area and partly to a prominent system of joints which strike N10°E and S80°E.

West of Johan Beetz the shore is more regular. Jointing and foliation in the granite east of Corneille river cause minor irregularities, but west of the river the granite is massive and the coast is, therefore, smooth.

There are a large number of low, barren islands along the coast, particularly east of Watshishou Knoll. Their shape and orientation is due to the underlying rock structure.

The low coast, with its numerous bays and islands, is a typical "skärgård" coast and is similar to the coasts of the Baltic Sea, particularly the southern coast of Finland.

Ridge and Valley Topography

Long narrow ridges alternating with narrow valleys are characteristic of that part of the area underlain by metasedimentary rocks and gabbro (Plate 2). The ridges outline the structural trend of the area. Because the gabbro is more resistant to erosion than are the metasedimentary rocks, the ridges are underlain by gabbro or gabbro injected quartzite. They are highest in the north, sloping gently toward the sea.

The valleys, which are underlain by metasedimentary rocks, are occupied by lakes and small streams. East and west of Villeneuve lake, however, where there are relatively few intrusions of gabbro, resistant beds of quartzite form low ridges. This area has considerably less relief than the remainder of the map-area.

Plateau

That part of the area northwest of Johan Beetz, which is underlain

PLATE 2

Fig. 1 High ridges of gabbro northwest of Bellanger lake.

Fig. 2 Gabbro ridges southeast of Ledoux lake.

by granite, is a gentle undulating surface, sloping southward. Many of the irregularities which would be expected in a region underlain by well-jointed granite of this type have been smoothed out through glacial action. The deeper depressions are occupied by lakes. The shape of these lakes is controlled, to a large degree, by jointing in the granite.

At corresponding distances from the sea, the plateau is at a lower elevation than the gabbro ridges.

The area, taken as a whole, slopes gently to the south. The highest points are along the gabbro ridge which follows the east side of Big Piashti lake. Here there are heights over 600 feet above sea-level. The southern part of the area, particularly the southeast corner, has very little relief, its elevation being close to sea-level.

The shores of most of the lakes where they are bordered by quartzite are low, of the order of twenty feet above lake-level. In contrast, those lakes bordered by gabbro have steep shores. In many places cliffs, over 100 feet high, extend down to the water's edge.

All the lakes in the country underlain by the sedimentary rocks and gabbro, with the exception of Bellanger lake and Cabane-Brulée lake, have striking shapes. They are long and narrow, paralleling the trend of the rock formations. They occupy low portions of persistent depressions, formed by selective erosion, along the line of contact between quartzite and gabbro. Bellanger lake consists of two parts joined by a narrow passage. The large east bay occupies a low area in a wide band of quartzite; the west bay fills depressions between high gabbro ridges. Cabane-Brulée lake fills several shallow depressions underlain by sedimentary rocks and surrounded by gabbro. Passage between these depressions has been made possible by erosion in areas where the gabbro is highly jointed.

Besides the major lakes of the area, which occupy low portions of the main valleys or broad basins in the granite plateau, there are many small lakes filling low areas in the gabbro ridges or quartzite hills.

Drainage

There is no well-developed drainage system in the area. In most cases, a lake overflows into the one below by a short series of rapids and cascades. This is particularly true of Little Piashti river. All the rivers are shallow, but contain sufficient water for travel by canoe, even in dry seasons.

The drainage of the area is directed to the Gulf of St. Lawrence through four main drainage basins:

(1) Corneille river; draining lakes Traverse, Ferland, Turgeon and Tanguay and several small lakes which flow into these.

(2) Little Piashti river; Large Piashti, Little Piashti and Salé lakes are drained by this river, which empties into the Gulf at Johan Beetz.

(3) Napoleon and Bellanger lakes, as well as Cabane-Brulée lake and numerous small lakes draining into it, belong to Piashti-baie river which discharges into Quetachou bay.

(4) Watshishou river and its west tributary, draining lakes Theodule and Cabane-Neuve, which empties into the Gulf five miles east of Johan Beetz.

Besides these main rivers, numerous smaller streams, such as

Villeneuve, Little Watshishou and Pontbriand rivers discharge independently into the Gulf.

Physiographic History of the Area

The physiographic history of the area may be summerized briefly as follows:

1) Erosion of the Precambrian rocks and development of a peneplain by at least early Paleozoic time.

2) Submergeance of this peneplain and deposition of Paleozoic rocks. Evidence for this submergeance can be round across Appititatte bay where Paleozoic (Ordovician) rocks rest unconformably upon Precambrian rocks, similar to those observed along the western part of the coast of this area. Many sandstone dykes were observed filling fractures in granitic rocks between Appititatte bay and Quetachou bay. These resemble the basal sandstone of the Paleozoic sedimentary rocks.

3) Summit Peneplain. It is probable that several cycles of erosion affected the area between the beginning of the Paleozoic and the end of the Mesozoic. No details can be worked out in this area, but it seems conceivable, from studies in other parts of the shield, that the summit peneplain had been formed and partially dissected before the onset of glaciation. The age of this peneplain is not known definitely, but it has been correlated with the summit peneplain of the Appalachian system, which is variously dated as late Cretaceous to Middle Tertiary or even later. D. W. Johnson, after extensive studies, has advocated a Tertiary age for it (Johnson 1931).

4) Rejuvenation, through differential uplift. A new cycle was developed during which extensive straths were developed in valleys

adjusted to structure.

5) Differential Uplift during which time the rivers were encised. This movement was slow, allowing rivers to maintain their courses across the structure (e.g. Hamilton and Lower Saguenay rivers).

6) Pleistocene Glaciation, during which the topography was modified and the drainage disturbed.

7) Post Glacial-Cycle: Following the retreat of the glaciers, a modern cycle was developed which is now in the stage of youth. Evidence of recent uplift of the area has been observed at several localities along the Gulf. Claveau (1950) reports recent terraces at the mouth of the Natasquan river 35 miles east of the east boundary. Post-glacial terraces have been reported on Anticosti Island 30 miles south of the area (Twenhofel 1921) and on the Mingan Islands.

GLACIAL GEOLOGY

There is abundant evidence throughout the region of continental glaciation. Glacial striae, erratic boulders and morainic debris are found on practically every high hill, as well as in the valleys. The intensity of the glacial action cannot be calculated fully until more detailed work has been done in the area. It is certain that the greater part of the erosion pattern is of pre-glacial age and that the work of the glaciers consisted of scouring the valleys and smoothing the hilltops. Many of the gabbro hills and the valleys between them have smooth rounded profiles, undoubtedly caused by the effects of glaciation.

The general direction of movement of the glacier was south-southwest. Glacial striae were observed along the shores of many lakes. These strike between S8°W and S20°W. Glacial grooves are abundant in the amphibolite. They are particularly well-developed along the coast. The grooves range from six to twelve inches wide and are up to twenty feet long. They have smooth sides and strike between S10°W and S20°W. On the relatively low shores of many lakes friction cracks were frequently seen in quartzite. It was not possible to determine the direction of ice movement using this feature.

At many localities large grooves, thirty to forty feet long, were observed in the walls of the larger valleys. This indicates that the movement of the glacier was controlled, in part at least, by the topography.

Further effects of glaciation can be seen along the coast in the character of the topography. The outcrops are very smooth, well-rounded and polished. Several have the appearance of small "roches moutonées".

Deposits left by the retreat of the glacier are few. In most places the bedrock has been left clean, or is covered by a thin mantle of sand, gravel and clay. Glacial deposits consist mainly of erratic boulders, unsorted till and clay. Erratic boulders are common on many of the high hills (Plate 3, Fig. 1), but are more numerous in the valleys (Plate 3, Fig. 2). A few valleys are covered by unsorted and unstratified till, but their aerial extent is small. A band of sandy clay is exposed along Villeneuve river. The clay is massive, light buff in colour, very fine-grained and up to thirty feet thick.

In many places the glacial deposits have been reworked by the present streams. The resulting post-glacial deposits are numerous, but of limited aerial extent. In the upper reaches of Watshishou river there are numerous gravel bars. Many sand and gravel deposits are present along Little Piashti river.

PLATE 3

Fig. 1 Erratic boulders on long portage south of Ferland lake.

Fig. 2 Erratic boulders in a wide valley three miles east of Corneille river.

GENERAL GEOLOGY

Introduction

All the consolidated rocks of the area are of Precambrian age. The oldest formations consist of metamorphosed sedimentary rocks, grading from pure quartzite through to biotite schist. At three localities in the southern part of the area and at Ferland lake, the metasedimentary rocks have been transformed into migmatite. Intrusive into the metasedimentary rocks is a series of long, tabular sill-like bodies of altered gabbro. East of Corneille river, a coarse-grained gneissic granite cuts the metasedimentary rocks and contains inclusions of quartzite and gabbro. This granite is cut by a younger medium-grained generally massive granite. A small stock of coarse-grained granite is exposed at Ferland lake. The youngest rocks of the area are also intrusive and consist of a series of pegmatite dykes and sills which cut the granite, gabbro and quartzite.

Metasedimentary rocks occupy slightly more than one-third of the area, gabbro slightly less than one-third and granite and migmatite about one-quarter.

Table of Formations

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Metasedimentary Rocks

Introduction

Metamorphosed sedimentary rocks occupy slightly less than one-half of the area. Fine-grained light to dark grey impure quartzites are most abundant. Interbedded with these are small amounts of carbonate-bearing quartzite, and hematite- and rutile-bearing quartzite. These rocks are exposed throughout the entire northern part of the map-area east of Big Piashti lake. The best exposures are found on each side of Villeneuve lake, where the sediments form a wide band extending from Quetachou bay to Bellanger lake. Elsewhere they occur in bands of irregular thickness between sills and dykes of altered gabbro.

Micaceous quartzite, quartz-biotite schist and gneiss, and biotite schist constitute a second, minor, group of sedimentary rocks. They are exposed throughout the southern part of the area between Quetachou bay and Appititatte bay. They are commonly interbedded with varying amounts of dark grey quartzite. A few bands are present in the northern part of the area, but the number is small relative to the more pure quartzite.

This subdivision of the sedimentary rocks into two groups, based on mineralogical composition, does not, of course, mean that there was a break in sedimentation, or that one group is older than the other. Actually, all gradations between the two groups were observed in the field in such a manner as to suggest a change in the type of sedimentation in the southern area.

Besides the two groups noted above, a minor amount of coarsely crystalline limestone and a small lense of conglomerate were observed.

Primary bedding (Plate 4, Fig. 1), ripple marks and cross-bedding were observed in the quartzites. The last two features are well enough preserved to indicate the tops of some of the beds.

Grey Quartzite

Grey quartzite is the principal metasedimentary rock of the area. It is hard, tough and fine-grained. Single beds range from a fraction of an inch to three feet in thickness. The colour varies from almost pure white to dark grey. The quartzite has a rough conchoidal fracture, the perfection of which is controlled by the degree of recrystallization of the rock. Usually its weathered surface is light grey. In many places, however, the surface and the rock for a few millimeters beneath it is pure white. This colour has been produced by the leaching of the iron oxide impurities which have been carried away in solution and redeposited lower down as limonite, forming an iron-rich band some distance below the surface.

The pure quartzite is exposed in narrow bands between sills and dykes of amphibolite east of Little Watshishou river. The rock is sugar-grained. Its mineralogical composition, as determined with the petrographic microscope, is as follows:

Quartz	75 - 90 percent
Feldspar	5 - 15 percent
Muscovite	3 - 15 percent
Epidote	0 - 3 percent
Chlorite	0 - 5 percent
Accessories	Apatite, tourmaline, sphene, biotite, carbonate

The average grain size of this rock is larger than that of the impure types. The quartzite has been recrystallized to such an extent that none of the original outlines of quartz grains can be observed.

PLATE 4

Fig. 1 Primary bedding in grey quartzite, Quetachou bay.

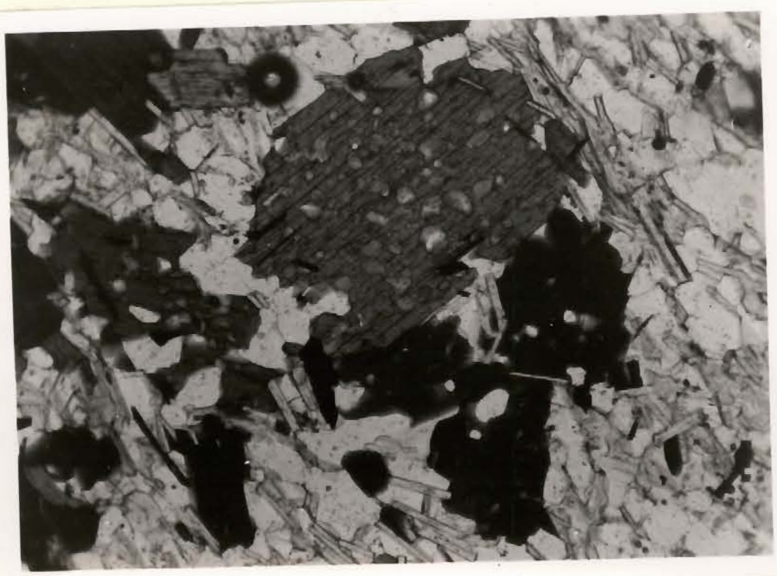


Fig. 2 Photomicrograph of impure grey quartzite showing poikilitic texture in biotite. Natural light. (X64).

Pore spaces and sandy textures are absent. The quartz grains are highly strained. Both orthoclase and microcline are present. The latter is clear, but orthoclase has been altered. This alteration has formed sericite. Muscovite occurs as small, tabular crystals between grains of quartz or included near the outer edges of quartz grains, which suggests that silica has been added to the original quartz of the rock. Chlorite was observed in one thin-section, as an alteration product of biotite. Another thin-section showed irregularly scattered epidote.

The type locality for the grey quartzite is east of Villeneuve lake where it forms a continuous band extending from Bellanger lake to the sea. The mineralogical composition of this rock is:

Quartz	60 - 75 percent
Feldspar	4 - 20 percent
Biotite	2 - 10 percent
Muscovite	8 - 13 percent
Amphibole	accessory - 20 percent
Magnetite	accessory - 8 percent
Accessories	carbonate, apatite, tourmaline, sphene, epidote, garnet, rutile, pyrite, scapolite

The average grain size of the grey quartzite is 0.2 mm. in diameter.

Quartz, the major constituent of the quartzite, occurs as irregularly shaped inequigranular crystals whose boundaries are frequently sutured. Under the microscope, it is difficult, if not impossible, to distinguish individual grains in plain light, except where quartz abuts against calcite, mica or feldspar. In such cases, the quartz has a well-rounded outline. Many grains display undulatory extinction, particularly in the southern part of the area, where some of the rocks have been granulated. Inclusions of other minerals are common about the edges of quartz.

In six thin-sections of this rock, examined by the writer, a small amount of fine-grained (0.01 mm. in diameter) quartz in clusters 0.2 mm. in diameter was observed interstitial to the larger grains. The quartzite of these thin-sections is considerably less deformed than that of the other thin-sections.

Three feldspars are present in the quartzite - orthoclase, microcline and albite. One or more may be lacking from place to place, but often all three are found together. The orthoclase is optically negative with $2V = 70^{\circ}$. The bisetrix X makes an angle of from $4^{\circ} - 6^{\circ}$ with 010. Invariably it is altered and, in many grains, the alteration has been intense, producing a fibrous matte of kaolin and sericite. Because of this alteration and its well-rounded grain outline, orthoclase is considered to be primary. Microcline on the other hand, is always fresh and shows microcline twinning. As it is present interstitial to and partly enclosing quartz, biotite and orthoclase, it is considered to be a secondary mineral. Very little albite is present. It generally occurs as irregularly shaped, clear grains or intergrown with microcline as microperthite.

A small amount of biotite is present in the quartzite. The optical properties of this mineral are :

Pleochroic formula - Z = dark brown to opaque
Y = yellow brown
X = pale yellow

Absorption - $Z > Y > X$; (-) $2V = 0^{\circ}$ to very small.

The biotite is lath-shaped and 0.4 mm. or less long. The larger grains contain numerous small inclusions of quartz in poikilitic fashion (Plate 4, Fig. 2). Other inclusions are magnetite, apatite and zircon.

Where the rock has been granulated the biotite is altered to chlorite.

Muscovite forms tabular crystals 0.3 mm. long and 0.1 mm. wide, interstitial to and partly surrounding quartz grains. The mineral is colourless. In four thin-sections clots of fine-grained fibrous white mica (possibly primary) forms the matrix of the rock. In this case large crystals of muscovite are rare, if not absent.

The amphibole most commonly present in the quartzite is hornblende. Its optical properties are:

Pleochroic formula: Z = dark bluish green
Y = pale olive green
X = straw yellow

Absorption - $Z>Y>X$; $Z \wedge C = 18^\circ - 19^\circ$; (-) $2V = 75^\circ - 80^\circ$

In three thin-sections a much paler less pleochroic amphibole was observed. The optical properties of this mineral are:

Pleochroic formula: Z = light bluish green
Y = very pale olive green
X = colourless

Absorption - $Z>Y>X$; $Z \wedge C = 16^\circ$; (-) $2V = 85^\circ$

These properties correspond closely to tremolite. Hornblende usually exists in elongated crystals between grains of quartz. Some crystals are poikilitic, enclosing numerous quartz grains. This suggests that the hornblende is secondary.

Scattered grains of magnetite are distributed throughout nearly all the thin-sections of the quartzite. They have a sub-angular outline. In two thin-sections, magnetite is concentrated in narrow bands, suggesting that it is detrital. A few grains of rutile were observed associated with the magnetite, but this mineral is more abundant in the hematite- and rutile-bearing quartzite described below.

Of the accessory minerals, carbonate, apatite, tourmaline and sphene are the most widespread. Carbonate is present in clusters or single grains. The carbonate is assumed to be calcite because any magnesium present would be utilized in the formation of amphibole during recrystallization. Sphene occurs in two modifications - as excellent wedge-shaped crystals included in biotite and as well-rounded grains often associated with magnetite. This latter occurrence of sphene suggests that these grains are detrital. Apatite and tourmaline are common constituents scattered irregularly throughout the rock. They form subhedral to euhedral crystals included in quartz or between these minerals.

Epidote is a common associate of many quartzites. It has the following optical properties:

Pleochroic formula - Z = yellow green
Y = pale greenish yellow
X = colourless

Absorption - $Z>Y>X$; $Z \wedge 001$ cleavage = 26°; (-) $2V = 80^{\circ}$

These properties indicate an iron content of approximately 15 molecular percent.

In one thin-section, epidote and garnet are intricately intergrown. Because of this close association between the two minerals, which would have rendered the results inaccurate, a determination of the specific gravity of the garnet was not attempted. The mean refractive index is 1.795^{+} and a borax bead test indicated the presence of manganese. These properties correspond closely to those of spessartite.

Small crystals of zircon were observed included in biotite. They are surrounded by pleochroic halos.

Pyrite was observed in three thin-sections.

Two thin-sections cut from samples taken from close to the gabbro-quartzite contact contain scapolite. It forms anhedral crystals partly surrounding quartz grains and contains numerous inclusions of quartz grains around the outer edge of the crystal.

A variety of the grey quartzite, hematite- and rutile-bearing quartzite, outcrops locally throughout the map-area. The best exposures are east of Little Piashti lake, north of Cabane-Brulée lake, and on the west side of Quetachou bay. The rock is characterized by black bands, averaging 1/32 of an inch thick, alternating with bands of grey quartzite that are 1/4 inch to six inches thick (Plate 5, Fig. 1). Frequently the black bands exhibit excellent cross-bedding. Several zones of hematite- and rutile-bearing quartzite, up to three feet thick, are present in about twenty feet of grey quartzite. The zones are lenticular. They are seldom exposed for more than twenty feet along strike, but one zone, three feet wide and 100 feet long, was observed two miles north of Cabane-Brulée lake.

In thin-section the black bands contain high percentages of magnetite and hematite. Sphene and rutile are also present. The magnetite, hematite and some sphene form well-rounded grains. Most of the sphene, however, has an irregular crystal outline. Rutile forms accicular crystals.

The occurrence of magnetite in sedimentary rocks is not uncommon and its primary sedimentary origin is well established. The origin of rutile is more difficult to explain. Rutile in occurrences of economic interest are found mainly in gabbro pegmatites, but the mineral

PLATE 5

Fig. 1 Hand specimen of hematite- and rutile-bearing quartzite. Upper scale in inches.

Fig. 2 Photomicrograph of calcareous quartzite. Crossed nicols. (X45).

is quite common as an accessory in granite and other rocks. No gabbro pegmatites are known in the area. The presence of rutile in sedimentary rocks has led to the belief that it may form authigenically at the expense of ilmenite and biotite (Derby 1891; Greenwood 1917; Thomas 1909). Possibly some of the rutile has formed in this manner. The sphene may also have formed authigenically at the expense of ilmenite.

Calcareous Quartzite

Beds of calcareous quartzite, three feet or less thick, were observed interbedded with grey quartzite. Good exposures are found south of Bellanger lake, east of Little Piashti lake and on the west side of Quetachou bay. The weathered surface of the rock resembles the dark grey quartzite with the exception that its surface is pitted, due to the solution of the carbonate.

The average mineralogical composition of the rock is as follows:

Quartz	30 - 60 percent
Carbonate	12 - 25 percent
Feldspar	5 - 30 percent
Biotite	10 - 20 percent
Muscovite	5 - 8 percent
Magnetite	accessory - 4 percent
Accessories	epidote, sphene, apatite, zircon and tourmaline

The rock is fine-grained - 0.1 mm. average grain diameter. It is difficult to distinguish the grain boundaries of quartz except where they are in contact with carbonate or feldspar. Here the quzrtz has a subrounded outline. Of the feldspar, secondary microcline is most abundant, but orthoclase and some secondary albite were observed. Biotite is always more abundant than muscovite. Clusters of minute flaky crystals of white mica frequently occur interstitial to the quartz grains.

Calcite forms in clusters or single grains scattered irregularly throughout the rock (Plate 5, Fig. 2).

Of the accessory minerals, epidote and apatite are most abundant. Sphene, tourmaline and zircon are frequently included in biotite, but also occur interstitial to the grains of quartz and feldspar.

Crystalline Limestone

Lenses of coarsely crystalline limestone, intercalated with grey quartzite, outcrop on the northwest side of Quetachou bay. These lenses are from six to eight inches thick and up to twenty feet long. They are distributed in rows along the bedding of the quartzite and are clearly the remnants of originally continuous beds which have been squeezed and drawn out under pressure between thick quartzite beds to the point of being severed into discontinuous lenticular segments.

The mineralogical composition of the rock, as determined with the microscope, is as follows:

Calcite	55 - 70 percent
Diopside	20 - 35 percent
Quartz	5 - 8 percent
Feldspar	3 - 5 percent
Accessories	sphene, apatite

Calcite, as irregularly-shaped grains ranging from 0.2 mm. to 2 mm. in diameter, is the principal mineral. It is light grey in colour, uniaxial negative and has high birefringence.

Diopside is colourless and forms anhedral to subhedral crystals. Its optical properties are: (+) $2V = 60^{o}$; $Z \wedge C = 40^{o} - 42^{o}$; dispersion $r > v$, weak. These properties indicate that the diopside contains eighteen percent of hedenbergite.

Quartz and feldspar are present in almost equal amounts. The feldspar (orthoclase) is biaxial negative and has a 2V equal to 85°. The extinction angle $X \wedge 010$ is 6°. It forms somewhat rounded grains and is generally altered to sericite. The presence of quartz in the limestone, in round grains which were obviously present in the original sediment, is found recrystallized side by side with calcite. This indicates that the conditions of metamorphism did not always allow the combination of quartz with lime, a reaction which requires the dissociation of the carbonate and the escape of carbon dioxide.

A small amount of apatite and sphene is scattered irregularly throughout the rock.

<u>Thin Conglomerate Lense</u>

An exposure of conglomerate was observed on the northwest side of a small island in the Gulf one mile and three-quarters west of the mouth of Watshishou river. This exposure is a large inclusion in amphibolite and measures 85 feet in length and 40 feet across at its widest point. Well-rounded pebbles and boulders, up to one foot in diameter, were observed. These have been elongated slightly in the direction of strike and considerably so in the direction of dip. They are composed of medium- to fine-grained quartzite, some of which are bedded. A few cobbles of fine-grained granite were observed, but no fragments of dark rock.

At the south end of Croche lake, two discontinuous bands of "pebbly" quartzite, two to twenty feet wide, were observed in a mica-rich quartzite (Plate 6, Fig. 1). The bands strike N40°E, parallel to the schistosity of the quartzite. This shear zone, which is 400 to 600 feet wide, was traced 1500 feet south of the lake. The "pebbles" range

PLATE 6

Fig. 1 Pseudoconglomerate south of Croche lake.

Fig. 2 Photomicrograph of micaceous quartzite.

Crossed nicols. (X50).

in size from one-half to three inches in diameter. They are flattened slightly in the plane of the bedding. The "pebbles" are composed of very fine mylonitized quartz, a few grains of magnetite and a small amount of fibrous white-mica. The matrix of the rock is sheared quartzite, containing a high percentage of biotite and muscovite.

These bands of pseudoconglomerate represent two beds of pure quartzite which were ruptured during movement. Continued deformation rolled the fragments into their present form, whereas the adjacent quartzite, being rich in mica, was able to form minute S-surfaces.

Micaceous Quartzite

This quartzite is essentially the same as that of the first group, but contains more impurities and is darker in colour. Narrow beds of mica schist, quartz-biotite gneiss and quartz-biotite schist are interbedded with the quartzite. All gradations from micaceous quartzite to schist were observed. The mineralogical composition of the micaceous quartzite is variable as shown in the table below:

Quartz	20 - 60 percent
Biotite	25 - 30 percent
Feldspar	10 - 20 percent
Muscovite	0 - 40 percent
Magnetite	accessory - 10 percent
Accessories	apatite, carbonate, zircon, epidote, sphene, tourmaline, chlorite, garnet and pyrite

In thin-section the rock is fine-grained (0.02 mm. to 0.05 mm. in diameter) and inequigranular (Plate 6, Fig. 2). Although the micas have a strong preferred orientation in thin-section, hand specimens of the rock show no schistose or gneissic structure.

Quartz is usually strained, particularly where the rock has been granulated. The contacts between quartz crystals in the non-granulated rock are sutured. Grain boundaries cannot be distinguished in plain light. Orthoclase is altered to sericite, but microcline and albite are fresh. The last two minerals are interstitial to quartz and mica. Pleochroic brown biotite, as lath-shaped grains 0.05 mm. long and 0.01 mm. wide, is the most common mafic mineral. It is generally orientated parallel or nearly parallel to the bedding.

One thin-section contains porphyroblasts of biotite up to 0.3 mm. long. These have an irregular outline and are poikilitic, enclosing numerous small grains of quartz. Zircon, surrounded by pleochroic halos, forms inclusions in biotite. The biotite is altered to chlorite in two thin-sections. This mineral is light green, has low birefringence and is optically negative. Muscovite may form crystals equal in size to biotite, but these are seldom poikilitic. Small rounded grains of magnetite are enclosed by the muscovite. Elsewhere, magnetite is scattered throughout the rock.

Apatite, sphene and tourmaline occur as subhedral crystals. A few grains of carbonate and epidote are present. In three thin-sections garnet was observed, but it is not pure, containing minute flakes of mica and grains of magnetite.

Quartz-biotite Schist

These sediments are intercalated with micaceous quartzite and grade into this rock. The thickness of a bed is variable, but is always less than one foot. The rock is fine-grained (less than 0.1 mm. in diameter). The mineral composition of the rock, as determined by a study of thin-sections, is as follows:

Quartz	10 - 40 percent
Biotite	20 - 60 percent
Muscovite	20 - 40 percent
Feldspar	5 - 20 percent
Accessories	magnetite, epidote, sphene, hornblende, carbonate, apatite, zircon, tourmaline, chlorite, garnet

Quartz is clear and inequigranular. In three thin-sections, abundant mica is concentrated in narrow bands separated by quartz-rich bands, producing a microscopic gneissic structure. The quartz grains in the lamella rich in mica are larger than the grains in the mica-poor layers.

Biotite and muscovite are present together, but never in equal amount. Invariably, the mica minerals are larger than the remaining constituents. One thin-section shows small slender crystals of hornblende up to 0.5 mm. long randomly scattered throughout the rock. The accessory minerals were observed in all the thin-sections of this rock, but magnetite and epidote are most abundant. In one thin-section epidote forms three percent of the rock composition and is associated with biotite and hornblende.

Biotite schist was observed at two localities in the area. On the west shore of Mine Bay an exposure of biotite schist 600 feet long and varying in width from twenty to forty feet outcrops between grey quartzite and a large pegmatite dyke. The deformation of the rock has produced an undulating schistosity. Large curved crystals of biotite and a small amount of mylonitized quartz are the main constituents. Several small lenses and stringers of quartz have intruded the rock along the foliate planes. Wine coloured garnets ranging in size up to one-half inch in diameter may form as much as twenty percent of the volume of the rock. The garnet contains flakes of biotite, as well as small grains of magnetite and epidote.

For a distance of a mile and one-half east of Appititatte Bay, biotite schist outcrops interbedded with micaceous quartzite, quartz-biotite schist and quartz-biotite gneiss. This schist is similar to that described above, but contains only a few crystals of garnet.

Veinlets, lenses and irregular stringers of pegmatite, which pinch and swell along strike, have been injected along the schistosity of the rock.

Quartz-biotite Gneiss

This rock, associated with schist and micaceous quartzite, outcrops throughout the southwest part of the map-area. The rock possesses a pronounced gneissic structure. Individual layers average four millimeters wide, but their width may exceed one centimeter. They are alternately rich in quartz and mica. The table below gives the average mineral composition of the rock:

Quartz	10 - 50 percent
Biotite	15 - 55 percent
Muscovite	accessory - 40 percent
Feldspar	accessory - 20 percent
Magnetite	accessory - 5 percent
Carbonate	accessory - 3 percent
Amphibole	accessory - 3 percent
Accessories	apatite, zircon, sphene, epidote, tourmaline, garnet

There is considerable variation in the grain size of the gneiss. Quartz grains are generally small, 0.2 mm. or less in diameter. Mica varies from 0.1 mm. up to 0.5 mm. in length.

The rock may be considered as a combination of thin beds of biotite schist and micaceous quartzite. The association and occurrence of the minerals in the mica-rich bands is similar to that of the quartz-biotite schist. The mica minerals are generally aligned parallel or nearly parallel to the bedding.

Metamorphism

One of the most successful classifications of metamorphic rocks is the facies classification advocated by Eskola (1920), which has been adopted by numerous geologists. This classification of rocks is based on certain mineral associations which are stable under a particular set of physical chemical conditions. The principle is valid regardless of whether chemical reconstitution of the rock took place in response to rising or falling temperature; whether the reaction has taken place through the medium of pore solutions or interstitial gas, or without the intervention of any liquid phase.

In choosing a particular set of minerals to define a metamorphic facies, it is important to select those which are stable within relatively narrow limits of temperature and pressure. Because quartz is the major constituent of the metasedimentary rocks of the Johan Beetz area, it is necessary to use small quantities of mafic minerals to determine the metamorphic facies to which these rocks belong. The association of these minerals is listed below:

1. biotite - hornblende - epidote - albite
2. biotite - muscovite - epidote - albite
3. calcite - epidote - hornblende - albite

Microcline is an additional mineral in the above assemblages.

For rocks in which microcline is not present, the mineral assemblages are:

1. biotite - hornblende - epidote - albite
2. biotite - hornblende - chlorite - albite
3. biotite - chlorite
4. epidote - garnet - albite

The hornblende which appears continually throughout the metasedimentary rocks is a deep bluish green variety. According to Turner (1948, p. 98) this amphibole is characteristic of the albite-epidote amphibolite facies. The mineral associations listed above are characteristic of this facies.

The relationship between epidote and plagioclase is shown in the equilibrium diagram of Ramberg (1949) in Figure 3.

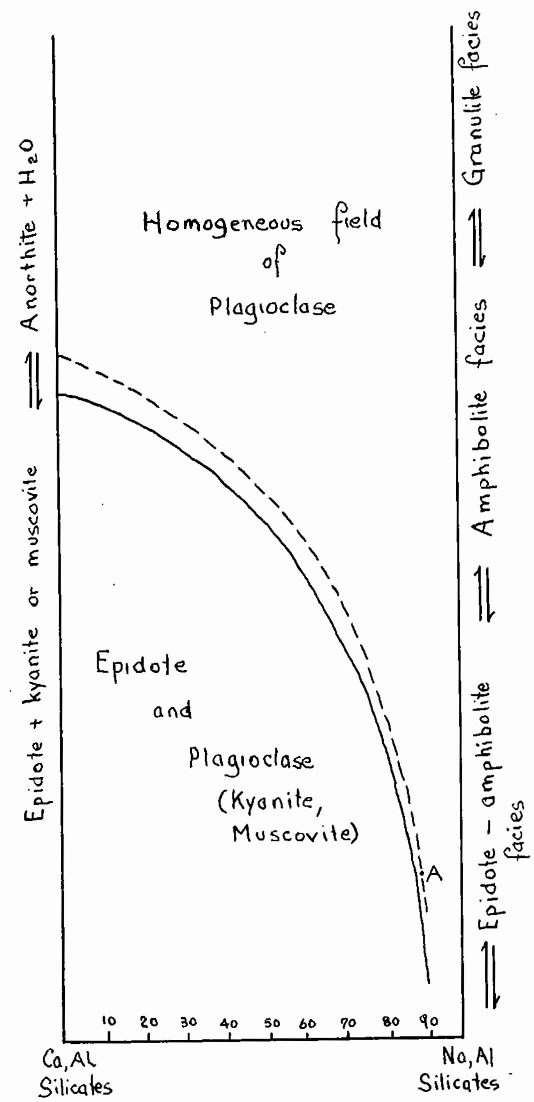


Figure 3. Subsolidus curve of the plagioclase $\rightleftharpoons$ epidote equilibrium. (After H. Ramberg, 1949)

The transition temperature between anorthite and epidote is between 400° and 500° centigrade. The solid curve gives the approximate composition of the plagioclase feldspar which may exist in equilibrium with epidote in potassium-free rocks. The stippled curve represents plagioclase in equilibrium with epidote in rocks containing muscovite and, or potash feldspar.

The composition of the plagioclase associated with epidote in the metasedimentary rocks of this area varies between An8 and An12. Using An12, the highest anorthite content, the association between plagioclase and epidote is represented by point A on the stippled curve in Figure 3. This temperature corresponds to the lower part of the albite-epidote amphibolite facies. The effect of pressure on this equilibrium diagram is, as yet, not fully known. However, the curve at least gives an approximation. Even if the transition temperature between epidote and plagioclase were 600° (corresponding to a depth of 20 km.), the association albite-epidote would still lie within the albite-epidote amphibolite facies, although at the upper limit of the facies.

Stratigraphy

The distribution of the sedimentary rocks in the area has already been discussed, but it may be restated at this point. The purer sediments, that is, the light to dark grey quartzites, the hematite- and rutile-bearing quartzite, and the calcareous quartzite, are found predominantly in the north and east parts of the map-area. Progressing south and west, micaceous quartzite becomes more abundant. In the southeast part of the area, underlain by metasedimentary rocks, mica schist and quartz-biotite gneiss, as well as micaceous quartzite, increase relative to the amount of light grey quartzite. This change in the mineralogical composition of the sediments is gradual and inconsistent throughout the width of the area, indicating that the conditions of sedimentation were undergoing continuous changes.

The grain size of the sediments is extremely variable. The smallest grains are 0.01 mm. in diameter, while the largest grains, excluding the porphyroblasts, are 0.5 mm. in diameter. As an average condition, the least recrystallized quartzites, that is, those containing fine interstitial sandy material, average 0.2 mm. in diameter, while the grain size of the recrystallized types ranges between 0.1 mm. and 0.3 mm. in diameter. The grain size of the former is, in all probability, close to the original grain size before compaction and recrystallization, whereas that of the latter is undoubtedly greater. However, because the degree of recrystallization is not high, the grain size of these rocks is probably close to its original size before recrystallization.

The northern sediments, consisting predominantly of quartz with a small amount of feldspar, locally, calcite and other minor impurities, represent a series of well-sorted fine-grained rocks and presupposes a long period of erosion of a predominant granite type landmass. The universal fine grain of the Johan Beetz sediments indicates further, that the landmass was one of relatively low relief or that the sediments travelled a considerable distance before deposition.

The sedimentary rocks form a series of folds, which, in the northern half of the area, plunge south at an angle between 25° and 40°. Near the axis of the folds, the oldest sediments would outcrop at the north boundary and the rocks would be progressively younger to the south. The northern sediments are relatively pure quartzites, whereas those in the south are impure. Furthermore, the grain size decreases southward. From these facts it may be postulated that the relief of the landmass was being lowered, or that the basin receiving the sediments was gradually sinking. The interbedded character of mica schist, quartz-biotite schist, quartz-biotite gneiss and micaceous quartzite with grey quartzite, however, suggests the basin floor receiving the sediment was close to sea level, at times being deep enough to allow the micaceous impurities to settle. A rise of the bottom of the basin would allow the currents to transport the finer grains of quartz and mica to deeper water. Thus, in the shallow part of the basin, purer sediment would be deposited. The presence of cross-bedding and ripple marks preserved in the quartzites supports the hypothesis that they were deposited in a shallow basin.

The thickness of the metasedimentary rocks of the Johan Beetz area, as measured across the west limb of the Bellanger lake anticline, is between 15,000 and 20,000 feet. It is the opinion of the writer that the true thickness of this sedimentary series is much less than this figure. This leads to the conclusion that certain parts of the series have been repeated by faulting. Although no evidence of faulting was observed within the area, this does not preclude the possibility that such faults do exist. Strike faults, particularly, would be difficult to observe in an area such as this, in which the sedimentary series contains no marker horizons and at the scale the area was mapped.

Correlation and Age

Very little is known about the geology of the north shore of the

Gulf of St. Lawrence. Except for a few reconnaissance surveys, which have been made along the coast and some of the large rivers in the interior, detailed geological investigations have been confined to that part of the north shore north of Havre St. Pierre and Johan Beetz.

The total area covered by metasedimentary rocks of mineralogical composition similar to those found in the Johan Beetz area is not known. They have been mapped for a distance of 53 miles north from the coast, but their northern limit lies in unmapped territory. The Romaine river is the approximate east boundary of this trough. The sediments here can be correlated with those mapped by Longley (1948) and, hence, with the sediments of the north end of the trough. The east limit of the sediments is not known, but it can be appraised from a study of topographic maps, because the north trending sediments are reflected in the drainage pattern. On the basis of such observations and from information given the author by prospectors who have worked in that area, the east limit of these sediments lies east of the Nabisipi river. This river discharges into the Gulf twelve miles east of the east boundary of the map-area. Thus, the minimum dimensions of the sedimentary belt are 53 miles in a north - south direction and 35 miles in an east - west direction. No other basins are known to exist along the north shore.

It is not advisable to attempt any correlation between the rocks of this trough with those of better known regions. The following discussion, however, has been included to illustrate the difficulties of correlation and to present the available information.

The Johan Beetz sediments are located on the eastern extension of the Grenville Province (Gill, 1949). Retty has mapped the sediments along the Romaine river as Grenville in age (Retty, 1944). The characteristics of the Grenville Province have been described by numerous writers (in particular Adams and Barlow, 1910; Wilson, 1925; Osborne, 1936a, 1936b; Dresser and Denis, 1944). These characteristics may be summarized as follows:-

(1) Generally high degree of metamorphism to which the rocks have been subjected.

(2) Fold axes of Grenville rocks, although complicated in detail, have a general northeast trend.

(3) In the tightly folded belts of Grenville rocks, the intrusions have been emplaced parallel to the bedding and schistosity of the sediments and paragneisses respectively. In the more open folded belts, the Grenville rocks are associated with large anorthosite intrusions.

The Johan Beetz sediments are not highly metamorphosed. The fold axes of these rocks strike north and are, therefore, at a high angle to the general trend of the Grenville rocks. The possibility arises that they may be a relatively unmetamorphosed series of Grenville rocks in a cross-fold of the Grenville. They may, therefore, represent a case similar to that of the Bristol series of Bristol township in southwestern Quebec (Wilson, 1924). These rocks are less altered and less strongly folded than the average Grenville rocks. However, the Bristol series is clearly folded with the neighbouring Grenville rocks. The sediments in the southwest part of this area and those near the mouth of the Romaine river are more highly deformed and have a northeast trend. Additional mapping is required in the areas to the north and east in order to test these relationships and to establish the overall general trend of the fold axes on the north shore.

Béland (1950) has tentatively put forward the hypothesis that the rocks of the Wakeham lake area north of Johan Beetz were formed at the same time as a similar suite in the Gabbro lake area at the south end of the Labrador trough. Béland has worked in both areas and was impressed by the petrographic similarities between them. He believes the Gabbro lake suite is Lower Huronian, which would make the Johan Beetz sediments the same age, should his hypothesis be correct. However, correlations over such long distances are of little value, particularly in the light of present knowledge concerning the distribution and age relationships between the sediments of this area and the remaining rock types exposed in the north shore region.

Considering the third characteristic tabled above, the Johan Beetz sediments have been intruded by a series of sheet-like bodies of gabbro, which are generally parallel or nearly parallel to the bedding. This complex is located close to a large body of anorthosite exposed north of Havre St. Pierre. The anorthosite is considered to be younger than the sediments and paragneisses, but older than the gabbro (Retty, 1944; Claveau, 1949). There is no known intrusion separating the emplacement of the anorthosite and the gabbro. These conditions are similar to the belts of open folded Grenville rocks.

Thus, there is a similarity between the Grenville rocks and the rocks of this area, but the structural trends and the low degree of metamorphism are not characteristic of the Grenville.

Migmatite

Introduction

The term "migmatite" was proposed by Sederholm (1907) for gneisses which contain two elements of different genetic value, one, a schistose sediment or foliated eruptive, the other, either formed by resolution of material like the first or by injection from without.

Later Turner (1948, p. 11) defined migmatites as -

> "Composite rocks in which the effects of metamorphism have been complicated by soaking of rocks in magmatic fluids, or by the development of lenticles and sheets of liquid magma, either injected from external sources (lit-par-lit injection) or segregated as products of differential fusion of the host rock itself (anatexis)."

Migmatites were observed at four localities within the map-area: east of Watshishou Knoll; on Puyjalon Island and on the mainland east of the island; one and three-quarter miles west of the mouth of Watshishou river; and in the vicinity of Ferland lake.

At the first two localities, the migmatite possesses a pronounced gneissose structure, but at the last two, the rock is devoid of any foliate structures.

In view of the fact that the migmatite exposed at each locality differs from that exposed at any of the other areas, the migmatite at each locality will be described separately.

Migmatite East of Watshishou Knoll

The bedrock along the coast east of Watshishou Knoll is composed of gneissic rocks of granitic composition. They extend beyond the east boundary of the map-area.

Within this area, long narrow bands of amphibolite, which parallel the gneissose structure, outline the general trend of the gneissic rocks. Close to the sea, the amphibolite bodies are smaller and appear on the surface as long, discontinuous lenses and streaks. A few have the form of irregular blocks.

Dykes of granite and dykes and sills of pegmatite were observed to cut the gneiss. Many small zones of pegmatite and much infiltrated pegmatitic material is associated with the gneiss near the coast.

In the field, two distinct types of gneiss were distinguished - banded gneiss and augen gneiss.

Banded Gneiss

This rock is exposed between Watshishou Knoll and Pontbriande bay and north of the group of peninsulas which form the east side of the bay.

The characteristics of the banded gneiss are excellently displayed on the islands at the mouth of Little Watshishou river. The gneiss is pink, medium-grained, and has a granular texture. Thin, discontinuous seams of mica 1/16 to 1/8 inch wide, which alternate with narrow bands of felsic material 1/8 to 1/4 inch wide, give the rock a pronounced gneissic structure.

The average mineral composition of the banded gneiss, as determined with the petrographic microscope, is as follows:

Quartz	30 percent
Microcline	30 percent
Plagioclase	20 percent
Biotite	15 percent
Accessories	magnetite, sphene, apatite, and garnet

The average grain size of the rock is 1.00 mm. Quartz forms irregular masses interstitial to the remaining grains, partly surrounding biotite and feldspar and projecting into these minerals in irregularly-shaped tongues and apophyses. Some quartz is intergrown with feldspar in typical myrmekitic fashion. Microcline tends to form equidimensional grains, but their outlines are, in detail, very irregular. They are usually fresh and contain irregularly-shaped patches of altered plagioclase. Plagioclase (oligoclase) forms stubby lath-shaped grains, but more commonly the crystals are anhedral. Albite and Carlsbad twinning were observed in many grains. Secondary albite forms a mantle surrounding the inclusions of plagioclase in microcline. Elsewhere, it forms small clear patches, interstitial to several plagioclase crystals and replaces this mineral. Biotite is pleochroic in light yellow and golden brown. Clusters or single grains in parallel orientation form narrow discontinuous seams which give the rock a distinct gneissose structure. The outlines of some grains, however, are controlled by the crystal boundaries of quartz and feldspar.

Plagioclase has been altered to secondary mica, some epidote and zoisite, but the alteration is slight. Biotite has been altered to chlorite (penninite), which has been developed along the cleavages of the biotite. A few crystals of green hornblende and several crystals of garnet are present in some of the thin-sections.

The mineralogical composition of the gneiss changes gradually in a northerly direction. The amount of quartz increases, whereas the content of feldspar and biotite diminishes. The rock retains its gneissic structure, although it is not as pronounced as at the sea. Furthermore, the rock develops a compositional banding due to the concentration of biotite in certain bands and quartz and feldspar in others. The width of each band or layer ranges from one to three feet. The contacts between adjacent bands are sharp, close to the contact with the quartzite, but become gradational toward the sea, where the gneiss shows its best development.

Augen Gneiss

That part of the coast between Pontbriande bay and the east boundary is underlain by augen gneiss. Bands of augen gneiss, which vary in thickness from a few inches to several feet, were observed on the islands at the mouth of Little Watshishou river and on the mainland at that place (Plate 7, Fig. 1). The typical gneiss outcrops on the east shore of Pontbriande bay. Lenses of augen of pink felsic material are enclosed in a grey banded matrix. The size of the augen is variable. The largest augen are two inches long and one inch in diameter (Plate 7, Fig. 2). They are composed of clusters of small microcline crystals and a small amount of quartz. At several localities, however, augen composed of a single crystal of feldspar were observed. The matrix enclosing the augen is composed of well-banded gneiss, similar to the banded gneiss described above. The biotite bands of this matrix are arched around the augen. Augen comprise between 50 and 80 percent of the volume of the rock.

Exposures of the gneiss at the mouth of Little Watshishou river exhibit all gradations between augen gneiss and banded gneiss. Augen gneiss forms long tabular bodies in banded gneiss. The contact between the two rock types is well-defined. When the augen gneiss is traced along strike, however, the augen gradually merge into long narrow

PLATE 7

Fig. 1 Bands of augen gneiss in banded gneiss, one-half mile east of the mouth of Little Watshishou river.

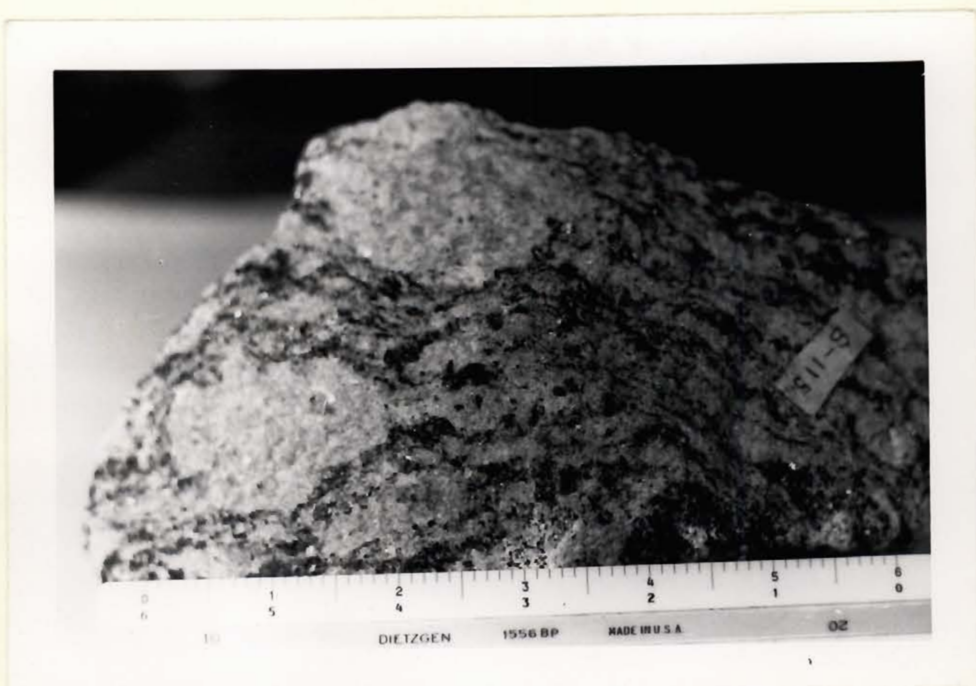


Fig. 2 Hand specimen of augen gneiss. (Scale is 6 inches long.

lenses and streaks of pegmatite. The characteristic shape of the augen is lost and the rock becomes essentially a banded gneiss containing innumerable small concordant lenses and stringers of pegmatite. Where the augen are well developed in these masses, the rock is devoid of pegmatitic material, yet the banded gneiss on each side of it contains numerous pegmatitic stringers. Similarly, the augen gneiss on the east side of Pontbriande bay is devoid of pegmatitic material, except for a few well defined pegmatite dykes.

Gneiss West of Watshishou River

One and one-quarter miles west of the mouth of Watshishou river, several discontinuous and irregularly-shaped bodies of mixed rocks, separated by bands of impure grey quartzite and amphibolite are exposed over an area approximately one mile wide and extending from the sea to the north end of Foin lake.

The rock is composed of lenticles of pink felsic material embedded in a pink or grey fine-grained matrix. These lenticles vary from a fraction of an inch to one inch long, and are up to one-half inch wide. At a few places, the matrix of the rock exhibits a distinct foliation. The majority of the exposures of this rock, however, show very little structure, except for the characteristic shape of the pink felsic lenticles.

Examination of the rock in thin-section reveals that the lenticles are composed of an aggregate of fine-grained equidimensional crystals of microcline and a small amount of quartz. The mineralogical composition of the matrix of the rock is strikingly similar to that of the impure grey quartzite. Indeed, all gradations from quartzite through to gneiss were observed. Where the rock is foliated, its mineralogy and texture are essentially the same as the quartz-biotite gneiss described in the section on metasedimentary rocks. The pink colour, which was observed at many localities, is due to two factors. First, a widespread distribution of numerous small, irregularly-shaped aggregates of microcline crystals and second, the introduction of microcline to the matrix of the rock as veinlets and interstitial material.

The number of augen varies from place to place and they may form between 20 to 80 percent of the volume of the rock.

These rocks differ from the augen gneiss described above in mineralogy, grain size and composition of the matrix.

Gneiss at Puyjalon Island

This rock may be described most accurately as being a biotite-rich banded gneiss with augen facies. In hand specimen, the rock exhibits a pronounced gneissic structure resulting from the parallel orientation of biotite flakes along closely spaced layers. These alternate with seams rich in quartz and feldspar. Occassionally, small augen, about one-quarter inch wide and one-half inch long, are distributed along the light coloured bands. These augen are composed of an aggregate of coarse feldspar crystals. Besides having the gneissic structure, the rock is banded. Each band, which may be one or two feet wide, has a slightly different mineralogical composition from the bands on either side of it. The dark bands contain abundant biotite and quartz and only a small amount of feldspar, wheras the light coloured bands contain abundant feldspar and quartz and less biotite.

Dykes and sills of pegmatite and dykes of granite are abundant in this area.

In thin-section, the estimated mineralogical composition of the dark bands is biotite: 35 percent; quartz: 45 percent; and feldspar: 20 percent. The biotite forms long, tabular crystals which are orientated parallel to the gneissic structure. Quartz is severely strained and the contacts between the grains are highly sutured. Many quartz crystals completely enclose crystals of biotite. Both potash and plagioclase feldspar form anhedral crystals, generally interstitial to quartz. Plagioclase (An24) has been altered to sericite, epidote and zoisite, whereas the potash feldspar (microcline) is fresh. A few microscopic grains of feldspar are included in quartz. Magnetite, sphene, apatite and a few crystals of epidote are the accessory minerals.

The light-coloured layers are composed of quartz: 30 percent; microcline: 30 percent; plagioclase: 20 percent; and biotite: 20 percent. Magnetite, apatite, zircon and sphene are the accessory minerals. The rock is inequigranular, individual grains measuring between 0.1 mm. and 2 cms. in diameter.

The quartz grains are clear, highly strained and have very irregular shapes, often surrounding and projecting into feldspar. Irregular patches and globules of quartz are included in plagioclase. In places, microcline forms equidimensional crystals, but more commonly, irregularly-shaped grains of microcline fill the interstices between the other minerals. Anhedral crystals of plagioclase (intermediate oligoclase), some of which are lath-shaped, have been altered to sericite. A few are coated with clear albite. Plagioclase is also intergrown with microcline, forming microperthite. Pleochroic brown biotite in clusters or single crystals form thin discontinuous seams. Magnetite, sphene and zircon are included in biotite. Zircon is surrounded by pleochroic halos. Sphene and magnetite are also present as inclusions in quartz and as small crystals interstitial to the other minerals. Sphene frequently forms a mantle about magnetite.

Ferland Lake Migmatite

At several places on the shore of Ferland lake, a rock composed essentially of quartz and mica was observed to contain large crystals of feldspar. Good exposures of this rock were observed in two bands which traverse the point at the southwest corner of the lake. Elsewhere, inclusions of this rock were observed in the granite exposed in that area.

Where the amount of feldspar is relatively small, the rock breaks into discontinuous parallel layers one-half to two inches thick. This layering or parting dips toward the lake at from 5° to 10°. The parting is very pronounced and obscures the poorly-developed schistosity in the rock, to which it is parallel.

The proportion of minerals in the rock is not constant over a large area and is dependant upon the number of porphyroblasts of feldspar in the rock.

Four thin-sections of this rock were examined. Potash, as well as plagioclase feldspar, constitutes the large grains, whereas the fine-grained matrix is composed of quartz, biotite, some potash feldspar and accessory minerals apatite, sphene, magnetite, zircon, hornblende and pyrite. The composition of the plagioclase varies between An12 and An26. Alteration of many crystals has produced abundant sericite, epidote and zoisite. Microcline forms lath-shaped grains which contain patches of altered plagioclase. The twinning and cleavage of these patches are perfectly aligned, which indicates that the microcline is the product of the replacement of original crystals of plagioclase. Orthoclase, in the form of small rounded grains, is altered to sericite.

The biotite is in random orientation and is present as clusters between the large feldspar crystals or as narrow seams which arch around the feldspar. In many places, the biotite exhibits curved cleavages. In one thin-section, the biotite has been altered to chlorite (penninite).

Origin of Migmatites

Scope of the Problem

The origin of granitic rocks, and particularly of granitic gneisses, has long been the subject of controversy. The idea that granite can be formed from sedimentary rocks, as well as by crystallization from a granitic magma, has been attractive to even the earliest students in geology. The present diverging opinions may be summarized briefly as follows: one group of geologists holds the view that granites are formed through the consolidation of a magma. Another group, however, favours the opinion that granites are formed by the replacement or alteration of pre-existing rocks, which may or may not be connected with magma. Most geologists agree that both processes operate, but there is no agreement concerning the amount of granite formed by either method.

Although the problem under consideration at present concerns the origin of the various migmatites of the area, the information contained in the following pages will be of value in the discussion of the source of the granitizing material. As an introduction to the discussion of the origin of the migmatites, the various ideas of each school will be reviewed briefly.

Origin of Granites

Since Hulton first proposed the magmatic theory (Bradley 1928, p. 362-364), evidence of the intrusive nature of granite masses has been collected by many geologists. The following lists some of the most important of these observations: cross-cutting relations; contact metamorphism without gradation; chilled borders; angular and non-orientated fragments of older rock included in granite; consistent patterns of internal structures, such as cross-joints, diagonal joints, lineation and foliation; uniformity of texture; euhedral phenocrysts developed in a subhedral matrix; presence of high temperature minerals; presence of unusual accessory minerals in diverse types of igneous rocks in any area.

Certain characteristics of bodies of granite rocks, however, are difficult to explain with this hypothesis. Most notable is the presence of gradational boundaries between granite and sediments or schists; the conformity of strike and dip of foliate structures, bedding and other features of inclusions with these structures in the host rock; the uniformity of composition between phenocrysts in the granite and metacrysts in the neighbouring schist wall, as for instance, along the border of the Rapakivi granite.

In order to explain satisfactorily the existance of granitic gneisses, several hypotheses of granitization have been advanced. A brief summary of the main theories is given below.

Hypothesis of Granite Infiltration

According to this theory, migmatites are produced by the injection of layers and streaks of magma along S-surfaces in the invaded rocks. The success of this hypothesis requires that the S-surfaces be closely spaced and is dependent upon the fluidity of the magma. A well known illustration of this phenomenon is the observations made by Fenner (1914) in the Highlands of New Jersey. Here numerous gradational transitions from granite to inclusions that lie parallel to the regional schistosity were observed. Most of the strata show some evidence of crumpling and twisting. Vertical exposures illustrate, in addition, that thin tabular sheets were given support by the magma. From this data, Fenner concludes (1) that the intrusion was affected among the layers of a previously schistose or foliated rock without causing great disturbances in position; (2) that the magma was thin, but not as fluid as water.

<u>Hypothesis of Magmatic Soaking</u>

French geologists, impressed by the transitional features along granite contacts, developed the idea of granitization. While still maintaining that a granite magma was involved in granitization, they believed that its intrusion was preceded by a cortège of emanations that transformed the wall rock into granite, or so made possible its assimilation by the advancing granite. Sederholm considerably extended this hypothesis to explain the formation of migmatites on a regional scale in Finland (Sederholm 1923, 1926, 1934).

Following the lead of these geologists, many workers have adopted and developed, in widely separated regions, the concept of mobile fluids accompanying the main intrusion (Barth, 1936; Billings, 1938; McGregor, 1938; Stark, 1935). Many students of this school consider that the resulting granitic rocks are due to metasomatic changes of the host rock by these emanations, rather than by a mechanical intrusion as was considered by the first hypothesis.

Hypothesis of Differential Fusion

The hypothesis of differential fusion has been put forth by Sederholm, following his extensive studies of the Precambrian rocks of Finland. He has observed areas which he claims represent regions where erosion has reached a depth to which a granite magma was formed through fusion of the deeper parts of the earth's crust. The process of subsurface melting, Sederholm calls "anatexis". Where movement has followed the birth of a new magma, the resurrection is called "palingenesis".

Whether or not the product of anatexis should be called a primary magma is still unsettled. Buddington (1943) would use the term "primary magma" only if part of that part of the sial subjected to anatexis was primordial.

The product of consolidation of fused sediments, however, is considered by most geologists to be granite, providing the composition is appropriate.

Hypothesis of Granitization Without Magma

This hypothesis is supported by geologists (the transformists) who reject the necessity of a magma and who consider the production of granite rocks to take place by "emanations" without defining any source. One proponent of this theory, Backlund (1946), considers granitization of a series of sediments can be brought about as a result of activation of the original liquid contained in the pore spaces by elevation of the temperature of the rock.

According to Reynolds (1947), the process involved in this hypothesis consists of the addition of certain substances, notably soda and lime, with concomitant expulsion of material unnecessary for the formation of granite. This "excess" material, such as Fe, Mg, etc., becomes fixed in the basic front of granitization. This process requires a great transfer of material, which may take place as solid diffusion (Reynolds, 1947) or with the help of water.

There is much disagreement among geologists concerning the validity of this theory. Among the questions yet to be answered are the absence of basic fronts in many granitic areas; the source for these emanations; the means by which the transformation of material is accomplished; and the difficulties of explaining zoned plagioclase crystals in an otherwise homogeneous granite.

Formation of the Migmatites of Johan Beetz Area

The writer believes that the migmatites of the Johan Beetz area were formed by recrystallization and introduction of pegmatitic and granitic solutions to pre-existing sedimentary rocks, and, to a lesser degree, to the amphibolite. In view of the distance between the areas of migmatite, the formation of the migmatite in each area will be described separately.

The contact between the gneiss east of Watshishou Knoll and the sedimentary rocks was observed at two localities, east of Watshishou Knoll and east of Pontbriande river. At both these places no definite line can be drawn between the two rock types, the change from quartzite to gneiss being gradual. Actually, the transition zone from quartzite to typical banded gneiss, such as the gneiss exposed at the sea, is almost a mile wide in some places. However, it is possible to separate the rocks into quartzite and gneiss on the bases of mineralogical composition, texture and structure. Hence, the transition zone can be narrowed down to within several hundred feet.

At Watshishou Knoll the mineralogical composition of each type shows a tendency to be segregated into definite layers which are easily recognized by their colour. For example, in the sedimentary rocks, certain bands, rich in mica, are dark coloured, while others, containing less mica and more quartz and feldspar, are light coloured. The adjacent gneiss can be separated into similar layers of equal thickness. They parallel the bedding of the quartzite. Where the rock was observed from a distance and where the granoblastic texture of the gneiss was not discernable, the banding in the gneiss is very similar to that of the quartzite. On closer examination, however, slight differences in composition were noted, which enabled the rocks to be classified as quartzite or gneiss. In the dark bands, quartz and biotite are the essential constituents, whereas the gneiss contains abundant feldspar. Similarly, the light coloured bands of quartzite contain a high percentage of quartz relative to feldspar and mica, whereas in the gneiss, quartz and feldspar are the essential constituents. Furthermore, the texture of the gneiss is typically granoblastic, coarser grained and the mica minerals have a definite preferred orientation.

The contact between quartzite and gneiss was observed a mile east of Pontbriande river and one and three-quarter miles north of Pontbriande bay. The quartzite in this area is the pure type of quartzite described on page 25 in this thesis. Several beds of impure quartzite containing mica are intercalated with the quartzite. The white colour of this assemblage changes to pink southward along the strike and across the strike. At the same time, white mica gives way to biotite, which is orientated parallel to the bedding of the neighbouring quartzite. This pink coloured rock is the first representative of the gneiss in this area. The transition from quartzite to gneiss takes place across a zone 500 feet wide.

This transition gneiss was observed in thin-section. The rock is composed of porphyroblasts of quartz 0.4 mm. wide and 0.8 mm. long, enclosed in a matrix of quartz, biotite and feldspar. The porphyroblasts have developed at the expense of the original quartz and biotite, and shows helicitic structure. Other porphyroblasts contain inclusions of quartz, but not biotite. The biotite is arched around the porphyroblast, indicating that it has forced this mineral aside. The matrix has been recrystallized and is considerably more coarse-grained than the neighbouring quartzite. Furthermore, the presence of microcline and, farther away from the quartzite, of plagioclase, even to the bands which can be traced to pure quartzite, indicates that these minerals have been introduced. The gneiss in this area is layered, each layer reflects the composition of the original quartzite.

The mineralogical change in the gneiss continues southward to the sea. The change is affected by an increase in the amount of microcline and plagioclase. Corresponding to this change, the amount of pegmatitic and granitic material increases. At the contact between the quartzite and the gneiss, there is no pegmatite. Southward, occasional pegmatite stringers, lenses and dykes increase in abundance and, at the sea, they are very numerous (Plate 8). Pegmatite dykes which cut the gneiss do not have a sharp contact, but at their edges they"feather" along the gneissose structure. This "feathering" is most pronounced in those bands containing abundant biotite, because these bands offer easier channels for the solutions than the massive bands poor in biotite. The mobility of the granitic solutions is shown by dykes of granite which cut the rocks without obliterating the gneissose structure (Plate 9, Fig. 1).

These dykes and sills of pegmatite and granite are considered to represent excess material which was intruded into the rocks during and following the recrystallization and the transformation of the sedimentary rocks to gneiss.

The compositional banding in the gneiss is visible even where the typical granite gneiss is exposed, although in these areas it is much less distinct.

The gneiss contains sills of amphibolite which range in thickness from a few feet to over 2,000 feet. These amphibolites do not represent "basic fronts", but are intrusive bodies. They can be traced to large amphibolite bodies (metamorphic derivatives of the gabbro) which cut the sedimentary rocks north of the area of migmatite. Furthermore, the amphibolites have been deformed and intruded by pegmatite and granite. The formation of the gneiss, therefore, took place following the intrusion of the gabbro sills and dykes. The alteration of the amphibolite has been most intense where the gneiss shows its best development. Near the contact between the quartzite and gneiss, the amphibolite has

PLATE 8

Fig. 1 Irregular dykes and stringers of pegmatite in banded gneiss at the mouth of Little Watshishou river.

Fig. 2 Small irregular lenses of pegmatite in banded gneiss at the mouth of Little Watshishou river.

PLATE 9

Fig. 1 Dykes of granite cutting banded gneiss at the mouth of Little Watshishou river. Note gneissic structure is not obliterated.

Fig. 2 Interbedded schist and micaceous quartzite injected by stringers of pegmatite. Note well-defined banding.

suffered no alteration other than intense shearing. Where the typical gneiss is exposed, the narrow sills have been drawn out into long lense-shaped bodies and streaks, whereas the larger sills were ruptured and the gneiss flowed into the intervening spaces. Much of the hornblende and biotite of the small masses has been altered to chlorite. In addition, the plagioclase has been intensely saussuritized and replaced by secondary albite. Potash feldspar and quartz have been added.

Nowhere in the area is there any evidence that the rocks reached a molten state. The compositional banding, a relic structure of the original bedding, has been preserved even at the sea where the effects of the solutions have been most intense. Further, the amphibolites, although ruptured and deformed, have not become molten. No areas of homogeneous granite grading to gneiss were observed.

The discussion in the preceding pages shows that the effects of granitization increase toward the southeast and east. A brief examination of the region east of the map-area showed that the gneiss grades into gneissic granite and hence to massive granite.

Eskola (1933) in discussing granitization, emphasizes the importance of differential fusion in the formation of migmatites. In this connection he recognizes three indefinitely defined depth zones, subject to local upward displacement in orogenic belts or to local inversions in regions where there has been intense lateral migration of magma. These zones are - (a) an uppermost zone of regional metamorphism and hydrothermal activity; (b) a middle zone of potash metasomatism and injection; (c) deep zone of differential anatexis. The character of the rocks of this area fits into the middle zone as defined by Eskola. The increasing amount of granitic and pegmatitic material south and eastward from the quartzite gneiss contact indicates these directions are toward the deeper zone. It is suggested, therefore, that this area represents the outer limit of a large area of migmatites which were formed by recrystallization, metasomatism and injection of pre-existing sedimentary rocks and gabbro during a period of extensive granitization of the bedrock, either by means of anatexis and palingenesis, or magmatic activity.

On Puyjalon Island, a similar gradation from sedimentary rocks to gneiss was observed. The sedimentary rocks of this locality are mica schists and quartz-biotite gneisses, interbedded with a minor amount of micaceous quartzite, which have been intruded by narrow amphibolite sills. This assemblage has been injected by pegmatitic material and, with increasing amounts of pegmatite, grades into granite gneisses. Where the amount of pegmatitic material is small, the original compositional banding of the sedimentary rock is easily visible on the surface (Plate 9, Fig. 2). As the amount of pegmatite increases, the banding is more difficult to recognize (Plate 10, Fig. 1) and, where the sediments have been completely saturated with the pegmatite, the resulting rock is a banded gneiss containing numerous small pegmatite lenses and stringers (Plate 10, Fig. 2). At certain places, quartz and feldspar have crystallized together as small blebs which, during their growth, forced aside the lamella of the schist which now arches around these augen.

The amphibolite sills in this area have been deformed in a manner similar to that described previously, but the deformation was not so

PLATE 10

Fig. 1 Interbedded schist and micaceous quartzite partly migmatized. Compositional banding difficult to recognize.

Fig. 2 Banded gneiss cut by irregular stringers of pegmatite.

intense.

The migmatization increases toward the granite and gneissic granite masses in the area. This suggests, therefore, that the gneiss is related, genetically, to one of these granites.

The medium-grained biotite granite contains inclusions of migmatite and gneissic granite. The contact between the inclusions and the granite is sharp. Other bodies of medium-grained massive granite in the area are not associated with migmatites, their contacts being well-defined. Furthermore, dykes of medium-grained granite cut the migmatites with sharp contacts. These facts are evidence that this granite was not the source of the migmatizing solutions.

In the case of the gneissic granite, there are two possibilities - the granite is the result of granitization or the granite supplied the solutions which transformed the sedimentary rocks to gneiss. All the available evidence in the field indicates that the granite is intrusive. This evidence will be discussed in a later section. The sediments north and east of this body consist predominantly of fairly pure quartzite. They have been intruded by many pegmatite sills and dykes, but have not formed migmatites. Inclusions of sedimentary rocks and gabbro in the granite are highly digested and granitized. Moreover, the gneissic granite is not cut by as many pegmatites as the surrounding rocks and the pegmatites which cut the granite have sharp contacts. The writer concludes from the above facts that the sedimentary schists, which offer an easy passage to solutions in comparison with the massive quartzites, were transformed to migmatite during the emplacement of the gneissic granite. Possibly the migmatite is a large roof pendant in the granite.

The description of the migmatite of Ferland lake shows that the porphyroblasts developed in the mica schist are composed of feldspar crystals similar in composition the the granite in the area. These zones of migmatites are enclosed in granite and are, therefore, large inclusions. Inclusions of quartzite and gabbro in the granite have not been altered extensively. The schists, however, allowed easy passage of the granitic material and porphyroblasts of feldspar were developed in them. The original porphyroblasts were plagioclase, but these have been partially replaced by microcline. The growth of the porphyroblasts was accomplished by forcing the adjacent lamella of biotite to one side so that, in the final product, the foliation arches around the porphyroblasts.

The migmatite west of the mouth of Watshishou river is composed of lenticles of microcline and quartz enclosed by a matrix of micaceous quartzite. These lenticles have been developed only in quartzites containing a relatively large proportion of mica. In the initial stage, where there are relatively few augen or lenticles, the rock has all the characteristics of a sediment. As the number of augen increases, all semblance to the quartzite is lost and the rock has an igneous-looking texture and composition. The resulting rocks contain approximately the same proportion of biotite and muscovite as the micaceous quartzites in the area. The quartzites of this area are relatively poor in feldspar. Thus, the transformation to migmatite requires the introduction of sodium and potassium to form microcline. This material was introduced in two ways - (1) as small veinlets of microcline which were observed to traverse the width of several thin-sections, (2) through the interstitial spaces of the rock. Some veinlets pinch out within the area covered by the thin-section and others act as feeders to the lenticles. These have developed by replacement of the original quartz of the rock. There is no evidence that the growth of the lenticles was controlled by a nucleous. It is possible, however, that the nucleous was an original feldspar grain in the sediment about which the lenticles grew. The source of the solutions which formed these rocks is unknown. They are cut by large pegmatite dykes and sills believed to be related to the intrusion of the medium-grained granite. It is possible that these rocks were transformed at the same time as the formation of the older granites. The reason this particular area was affected by the process is still unknown and will require special study, which the writer was not able to undertake.

In summary, migmatites have been formed at four localities within the map-area by recrystallization and addition of pegmatitic and granitic material to pre-existing sedimentary rocks and, to a lesser extent, to the amphibolite. The migmatite at Puyjalon Island and Ferland lake seems to be related to the granite in each of these areas. It is suggested that the migmatites west of Watshishou Knoll represent the outer edge of a large region of migmatites formed during granitization of the bedrock, either by anatexis and palingenesis, or magmatic intrusion. No origin for the solutions which transformed the rocks west of Watshishou Knoll could be given.

Uralite Gabbro and Derivatives

Introduction

The oldest intrusive rocks in the area consist of a series of altered gabbro sheets. Individual sheets vary from one-quarter of a mile to over a mile wide. Some pinch out within the map-area, but the majority extend beyond its boundaries. These have been mapped north of the area for a distance of more than 35 miles.

The thickness of any individual sheet is not uniform, but they pinch and swell along strike. In the southeast part of the area, the gabbro is highly interfingered with the quartzite. Many of the gabbro sheets are concordant with the intruded metasedimentary rocks. Many bodies, however, cut the bedding of the sediments at a small angle. At several localities, such as south of Cabane-Brulée lake and northwest of Croche lake, the gabbro masses are irregular in shape. However, even in these masses, the long direction is parallel to the bedding of the sedimentary rocks, but the gabbro is discordant in detail.

This system of multiple sills and dykes is an unusual occurrence. The writer knows of no other such assemblage in the Canadian Precambrian Shield. Gabbro is not an uncommon rock in the shield, but it occurs in irregularly-shaped masses of varying thickness, as stocks and as thick sheets which are of limited areal extent. The diabase sills of the Purcell District of British Columbia, mapped by Daly (1912), are similar in some respects to the gabbro in this area. Numerous large sills and dykes of gabbro intrude the bedrock in the Pectoria Area, South Africa, but these are considered to be related to norite (Hall, 1928). The gabbro of the Johan Beetz area is near a large body of anorthosite which is exposed north of Havre St. Pierre, and the two rocks are probably related.

In the northern masses, the rock has the appearance of a gabbro. Examination in thin-section shows that, in many cases, it possesses an ophitic texture. Where the rock is coarse-grained, the ophitic texture can be seen in hand specimen. However, the rock has been altered to such an extent that it is no longer a normal gabbro petrographically. The petrographic dividing line between gabbro and diorite, based on the composition of plagioclase, would classify most of it as diorite (Johannsen, 1937, Pt. 111, p. 146).

Some of the sills are the southern extensions of olivine gabbro-diabase, mapped by Claveau (1949a), in which the composition of the plagioclase is labradorite. The term "uralite gabbro" is, therefore, applied indicating that the composition of the rock is due to the alteration of the mafic minerals and the plagioclase. Throughout the discussion, however, the term "uralite" is often omitted and the rock is referred to as gabbro.

Four types of this rock have been distinguished on the basis of their degree of alteration. Nowhere does the rock contain pyroxene, the mafic mineral present being amphibole. The gabbro, showing an ophitic texture, is confined to the northeast part of the area. Southward, this rock passes into amphibolite. In the vicinity of the granite masses, the alteration is more intense and, south of Tnaguay lake, the rock becomes hybridized. The types distinguished in the description that follows, and on the accompanying map, are:

(1) Uralite gabbro
(2) Amphibolite
(3) Amphibole gneiss
(4) Hybrid rocks

No line of demarcation can be drawn between types 1 and 2 or, for that matter, between any two adjacent types in the above list. The change from uralite gabbro to amphibolite and from this to gneiss and finally to hybrid rock is gradual. All stages of the alteration can be followed in the field. Each rock type was examined in thin-section.

The age relationship between the gabbro and the granites is well established. Gabbro sheets are truncated by the younger granite, which, in addition, projects into the gabbro in tongues, dykes and small stringers. Numerous altered and partly digested inclusions of gabbro were observed in the granite.

Uralite Gabbro

The least altered representatives of gabbro are exposed west of Large Piashti lake, northwest of Cabane-Brulée lake and between lakes Theodule and Prudent.

The rock is massive, extremely hard, dark grey to black and medium- to coarse-grained. The distribution of grain size in any individual body is extremely irregular, except in the narrow sills and dykes. In these, the outside edges are finer grained.

Petrography

In thin-section, the rock shows an ophitic texture (Plate 11, Fig. 1). The plagioclase is relatively fresh and lath-shaped. Amphibole occurs as single crystals or aggregates of crystals between the feldspar (Plate 11, Fig. 2). The variation in the composition of the gabbro is shown in the following table:

PLATE 11

Fig. 1 Photomicrograph of uralite gabbro.
Crossed nicols. (X26).

Fig. 2 Photomicrograph of uralite gabbro.
Note cluster of amphibole crystals in upper right hand corner. Crossed nicols. (X16).

Amphibole	45 - 60 percent
Plagioclase	40 - 55 percent
Biotite	0 - 7 percent
Magnetite	accessory - 3 percent
Ilmenite	accessory - 1 percent
Accessories	apatite, tourmaline, sphene, epidote and carbonate

Very few large crystals of amphibole were observed. The majority form clusters of accicular or stubby prismatic crystals which have random orientation. In many cases, they form a confused mass, but fibrous and compact needle-shaped crystals of amphibole, in parallel orientation, were observed in thin-section (Plate 12, Fig. 1). In some thin-sections, the large amphibole crystals grade into needle-shaped fibrous amphibole which have diverse orientations, or into a complex mass of fibrous amphibole in parallel orientation, or into a combination of both. One thin-section shows fibrous amphibole in parallel orientation replacing larger amphibole crystals.

Except for a few colourless amphiboles and those which have a distinct bluish tinge, the optical properties of the remaining crystals are similar. They are slightly pleochroic; X = pale yellow, Y = pale yellow green, Z = pale green. The absorption formula is $Z>Y>X$. The mineral is optically negative, with $2V = 75^{\circ}-80^{\circ}$. The extinction angle varies between $14^{\circ}-17^{\circ}$ for the needle-shaped and short prismatic crystals to $19^{\circ}-24^{\circ}$ for the larger amphiboles. The colourless amphibole is optically negative with $2V = 75^{\circ}$. The extinction angle $Z \wedge C = 14^{\circ}-17^{\circ}$. Because of the larger extinction angle, the large crystals of amphibole are classed as hornblende, whereas the optical properties of the fibrous and stubby prismatic crystals correspond to those of members of the actinolite-tremolite series. According to Winchell

PLATE 12

Fig. 1 Photomicrograph of uralite gabbro showing fibrous amphibole in parallel orientation. Note amphibole replacing plagioclase. Crossed nicols. (X18).

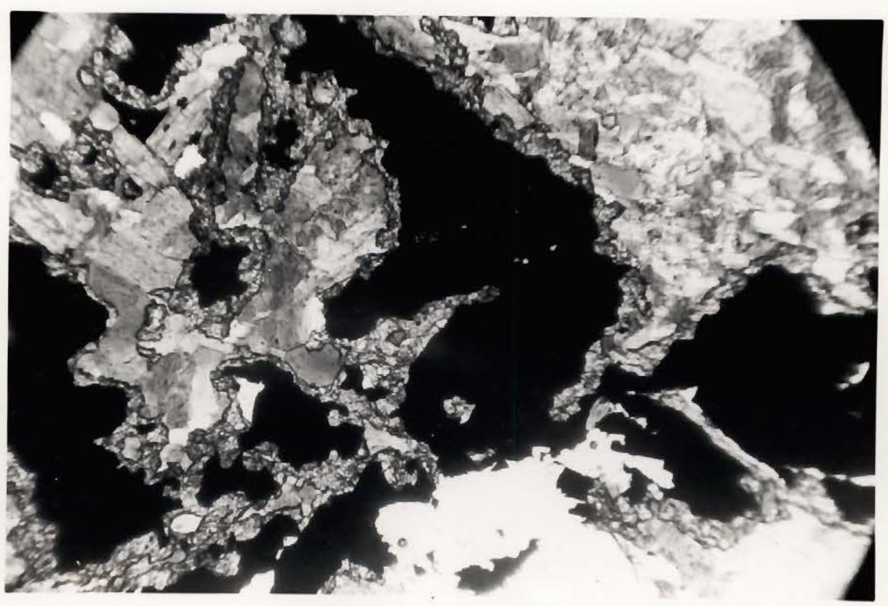


Fig. 2 Photomicrograph of uralite gabbro showing sphene forming a mantle around crystals of ilmenite. Natural light. (X50).

(1951, Pt. 2, p. 436) the colour of hornblende depends upon its iron content, but Eskola (1914, p. 103) has shown that the content of alumina determines the colour.

Many thin-sections contain crystals of green amphibole which have a distinct bluish tinge. The fibrous amphibole grade into this bluish green amphibole where they are in contact with plagioclase. The optical properties of this mineral are:

Pleochroic formula X = pale yellow green
Y = light green
Z = bluish green

Absorption - Z>Y>X; (-) $2V = 80^{\circ}$; $Z \wedge c = 17^{\circ}$

This amphibole (hornblende) is considered to be soda-bearing (Iddings, 1906, p. 364).

Plagioclase is invariably lath-shaped. Albite, pericline and Carlsbad twinning were observed in thin-section. Normal zoning was observed in many crystals, the composition of the core is An47 and that of the outer edge An34. The unzoned plagioclase has the composition An37. The cores of the zoned crystals are altered, whereas their outer edges and the unzoned crystals are fresh. The alteration has produced epidote, zoisite and a small amount of sericite. Where the alteration of the gabbro has been intense, the plagioclase contains numerous inclusions of amphibole. Small veinlets of amphibole were also observed cutting across several plagioclase crystals. The feldspar has been attacked by secondary albite. This mineral forms a growth around the original crystal or replaces it in homogeneous patches and veinlets.

Biotite is present in the highly altered gabbro. Some biotite is associated with magnetite, which assumes a striking pattern of skelital crystals, consisting of criss-crossing blades between which the biotite is present. The optical properties of the biotite are:

Pleochroic formula X = straw yellow to colourless
Y = light brown to slight greenish brown
Z = golden brown to opaque

Absorption - Z>Y>X; (-) 2V = 0° to very small

Besides occurring in the above-described form, magnetite is also associated with large hornblende crystals forming blade-like inclusions along the cleavage planes of that mineral. Elsewhere, it is present as irregular grains or clusters of small crystals associated with biotite. Ilmenite is present in amounts up to one percent. In some places, it is coated with a mantle of small crystals of sphene (Plate 12, Fig. 2). Chlorite occurs as the alteration product of biotite and amphibole. Generally, it forms along the cleavages of these minerals. The chlorite (penninite) is uniaxial positive and has a high birefringence.

Other minerals present include small crystals of carbonate, epidote, tourmaline, and apatite. Carbonate and sphene were nowhere observed together. Epidote is present in one thin-section only. Apatite and tourmaline increase in abundance towards the granite masses.

Amphibolite

Amphibolite outcrops throughout the southern part of the map-area, but the best exposures were observed southeast of Veronique lake. Northward, they grade into the massive uralite gabbro. They first make their appearance where the regional trend of the formation changes from south to southwest. A few outcrops of amphibolite were observed east of Ferland lake. Long narrow sills of amphibolite, many of which are sheared and ruptured, were observed in the area underlain by migmatite.

Southward, these bodies grade into hybrid types.

The amphibolite is black, tough and fine- to medium-grained. At many places, the rock possesses a distinct foliation, owing to the parallel arrangement of biotite.

<u>Petrography</u>

In thin-section, the texture of the amphibolite is hypidiomorphic inequigranular. Abundant amphibole, biotite and plagioclase are the essential constituents. Apatite, sphene, carbonate and magnetite are the accessory minerals.

The most common amphibole is a pleochroic green hornblende which has the following optical properties:

Pleochroic formula X = pale yellow green
Y = pale green
Z = deep green

Absorption - $Z>Y>X$; (-) $2V = 75^{\circ}-80^{\circ}$; $Z \wedge C = 16^{\circ}-19^{\circ}$
dispersion - $r<v$ weak

In two thin-sections, several stubby prismatic crystals of colourless amphibole were observed. Some crystals of this mineral are twinned. Its optical properties are:

(+) $2V = 85^{\circ}$; $Z \wedge C = 16^{\circ}$; dispersion $r<v$ weak

These optical properties correspond to those of cummingtonite.

Feldspar forms stubby, lath-shaped crystals, which invariably are altered. This alteration has produced a dark grey opaque fibrous mass, some epidote and zoisite. Determination of the less-altered plagioclase gave the composition An34.

Biotite in amounts up to 20 percent is pleochroic as follows:

X = light buff
Y = light brown
Z = golden brown

Absorption - $Z>Y>X$; (-) $2V = 0^\circ$ to very small

The biotite contains inclusions of magnetite.

Inclusions of sphene were observed in amphibole and magnetite. Sphene also forms small anhedral crystals interstitial to amphibole. Where the amount of sphene is high, magnetite is present in relatively large amounts.

Amphibole Gneiss

Representatives of this group are few and occur principally close to the Turgeon lake granite. Other exposures were observed along the coast between Quetachou bay and Watshishou Knoll. The typical gneiss contains compact aggregates of elongate crystals of amphibole, separated by aggregates of plagioclase crystals. The rock shows a strong preferred orientation. This structure is attributed to deformation of parts of the sills, particularly near their contacts with the sedimentary rocks, during the intrusion of the granite. The gneiss contains abundant amphibole (60 percent), plagioclase (30 percent) and biotite (10 percent). Elongate prismatic crystals of hornblende are concentrated along well-defined layers, separated by layers rich in plagioclase. The optical properties of the hornblende are:

Pleochroic formula X = pale yellow brown
Y = green with brownish tinge
Z = dark green

Absorption - $Z>Y>X$; (-) $2V = 75^\circ$; $Z \wedge C = 19^\circ$

Several crystals contain numerous small quartz crystals in poikilitic fashion.

The plagioclase is lath-shaped and is relatively fresh. The composition was determined to be oligoclase (Ab79 An21).

Biotite is everywhere associated with hornblende. It is strongly pleochroic as follows:

X = straw yellow
Y = yellow brown
Z = dark brown to opaque

The absorption is : $Z>Y>X$. The mineral is optically negative with $2V = 0^{o}$ to very small.

In one thin-section, biotite is present in an amount equal to that of amphibole. These two minerals compose 60 percent of the volume of this rock. They are present together, forming poorly-defined bands separated by plagioclase-rich layers. The plagioclase is considerably more altered in this gneiss, the alteration having produced sericite with some patches of zoisite, epidote and calcite. Chlorite (penninite) has formed along the cleavages of some biotite crystals.

Hybrid Rocks

Many exposures of gabbro close to the contact of the granite masses show various degrees of alteration. New constituents were added and, in many exposures, there appears to have been a complete redistribution of the original material.

Exposures of hybrid rocks were found between the Ferland lake granite and the Turgeon lake granite, and between the Turgeon lake granite and the granites exposed along the coast. Other exposures were mapped in the area underlain by the migmatites and within the granites.

The alteration of the gabbro in these areas has not been uniform in any one body or, for that matter, between one body and the next. Indeed, many of the large gabbro inclusions in the Turgeon lake granite show relatively few effects of the intrusion of the granite. The contact between the granite and the gabbro is sharp and an ophitic texture is clearly visible on the weathered surface of the gabbro inclusions. Inclusions of gabbro in the Ferland lake granite and the gneissic granite, however, show varying degrees of digestion by the granite. As a result, the rock has little resemblance to the original gabbro.

One type of hybrid rock, observed between lakes Ferland and Turgeon, is black and very heavy. Ferromagnesian minerals are the essential constituents, but small clots of felsic minerals, up to one-half inch in diameter, are present in all the exposures. Common green hornblende is the most abundant mafic mineral. It forms short prismatic crystals in compact clusters and at random orientation. Abundant magnetite and small amounts of biotite and ilmenite are present. The felsic clots are composed of aggregates of small crystals of plagioclase and quartz.

A second type of hybrid rock, exposed south of Tanguay lake, has the composition of quartz diorite. It is composed of hornblende, plagioclase, biotite and quartz. Apatite, tourmaline and magnetite are the accessory minerals. The hornblende is anhedral, needle-shaped and is dispersed irregularly throughout the rock. The plagioclase (sodic andesine) and quartz are present in almost equal amounts. Biotite and hornblende occur together.

The most highly altered varieties of the gabbro are found in the areas underlain by the migmatites, and, in particular, where the migmatite is best developed. They form discontinuous, elongated masses which parallel the strike of the gneiss and represent formerly continuous sheets which were drawn out and ruptured during the formation of the granite gneiss. A few bodies are highly sheared.

In thin-section, the rock consists of pleochroic green hornblende, chlorite, magnetite, epidote and plagioclase. Much of the chlorite has formed as an alteration product of hornblende. A few crystals, however, have the outline of biotite and are probably the alteration product of that mineral. The alteration of the feldspars has been intense and these crystals are coated with a grey, opaque, fibrous matte of kaolin and sericite. Additional minerals include quartz, apatite and sphene.

Alteration of the Gabbro

The writer believes that the gabbro intruded the sedimentary rocks as a series of multiple sills and dykes during the late stages of the initial folding, but that, in the southern part of the area, tectonic movements further deformed the rock. In the northern parts of the sills and dykes, there is no evidence that the rocks were involved in large-scale tectonic movement. The only sills which are sheared are those bordering the granite as, for example, east of Ferland lake. Elsewhere the rock is massive and is not ruptured or faulted. Examination of the gabbro in thin-section failed to show any physical deformation other than the chemical redistribution of the original constituents and the addition of new material. The gabbro has an ophitic texture and the minerals are randomly orientated. In the adjacent metasedimentary rocks, however, biotite has a pronounced preferred orientation. In addition, a schistosity has been produced in the mica-rich beds.

In the southern part of the area, the gabbro has been recrystallized to such a degree that the ophitic texture has been completely obliterated. Furthermore, the rock has a pronounced foliation, due to the parallel arrangement of platy minerals, such as biotite. Many sills are highly sheared and, in the area underlain by the gneiss, the amphibolite derivatives of the gabbro are frequently drawn out and ruptured.

In the introduction to the description of the gabbro bodies, the term "uralite" was proposed to describe the less altered masses. This term was first applied by Rose (1842) to a mineral with the crystal form of pyroxene and the structure of amphibole. Dana (1947) states that the change begins at the outer edge of the pyroxene, transforming it into an aggregate of slender amphibole crystals parallel in position to each other and to the parent pyroxene. Uralite gabbro is the name given to gabbros whose original pyroxene has been transformed to amphibole (Johannsen, 1937, Pt. 111, p. 228).

Although no pyroxene was observed in any of the thin-sections examined by the writer, the former presence of that mineral is indicated by the excellent ophitic texture of the least-altered representatives of the gabbro and the secondary origin of the amphiboles just mentioned. All the large hornblende crystals contain minute blades of magnetite along the cleavages, indicating that the magnetite is a released product of the transformation from pyroxene to amphibole. Furthermore, several of the sills in the eastern part of the area can be traced north of the area, and here they have the composition of olivine gabbro. The present mineral composition of the gabbro is, therefore, considered to be due to the uralitization of pyroxene formerly present in the gabbro. In view of the variation and complexity of the chemical composition of the amphiboles, the alteration of the rock cannot be represented by simple chemical equations. It was probably complex, involving a continual redistribution of the original constituents, as well as the addition of new material. In some places, a single amphibole crystal occupies the former position of the pyroxene, whereas elsewhere, compact fibrous and slender prismatic crystals of amphibole, in both parallel and random orientation, are present between the plagioclase laths. Some of the fibrous amphibole has formed by the replacement of the large hornblende crystals. This phenomenon was observed in thin-section. In plain light, a large prismatic crystal has all the appearance of a single crystal. However, when examined with crossed nicols, what appeared to be a single crystal, is seen to consist of unreplaced relics of large hornblende surrounded and penetrated by compact fibrous tremolite and actinolite.

As a result of the alteration, the amount of amphibole increased and the amount of plagioclase decreased. This is shown by the replacement of plagioclase by amphibole and the greater amount of amphibole in the more highly altered types. At the same time, the amphiboles reacted with the plagioclase to produce the soda-rich hornblende which forms a mantle around both the large hornblende crystals and the fibrous masses. A further effect of the alteration was the formation of abundant sphene in the more highly altered gabbro. This mineral is associated with ilmenite, with which it is intergrown, and around which it forms a mantle. The association of these two minerals indicates that the sphene is derived from the ilmenite. Tilley (1921, p. 108) represents the reaction by the following equation:

$$Ca(OH)_2 + TiO_2 + SiO_4 = Ca\ Ti\ SiO_5 + H_2O.$$

The $Ca(OH)_2$ and the SiO_2 are considered to be released products of the uralization of pyroxene. That new material has been introduced, is shown by the presence of biotite in the more highly altered varieties. Biotite does not occur in the less altered gabbro and its presence, therefore, indicates that potassium and water have been introduced. Apatite and tourmaline are additional minerals which, although present in the least altered varieties, are more abundant in the highly altered gabbro near the granite.

The causes of uralitization have been described only briefly in the literature. Duparc and Hornung (1904) suggest that after the pyroxene has crystallized in the magma, it is acted upon by the residual magma, transforming the pyroxene into patches of amphibole. Later, Duparc (1908) stated that the phenomenon of uralitization is confined chiefly to feldspathic rocks and he attributed it to a later injection of feldspathic magma. Colony (1923) concluded that uralitization can be a deuteric change and that the resulting uralite shows great penetrating powers by invading the feldspar in every direction. Schwartz (1939) states that uralitization is a frequent product of hydrothermal alteration, but that it may take place during metamorphism of various types. Oliver (1951) concludes that the uralitization of the Sudbury norite took place without any important change in the chemical composition of the rock. He believes that the process was caused by a residual liquid carrying small amounts of silica and alumina.

The prevailing medium- to fine-grained texture and the presence of fine-grained chilled borders of the gabbro sills, indicates that they cooled quickly. Very coarse-grained facies only occur in the central part of the large bodies, but these are relatively rare. The effect of the intrusion on the sedimentary rocks is moderate. Epidotization and amphibolitization are confined to within a few inches of the contact. Scapolite has been formed over a greater distance, but the amount is small. No high temperature minerals, such as diopside and wollastonite, were observed in the calcareous quartzite. It appears highly improbable, therefore, that the alteration of the gabbro was produced as a late magmatic or deuteric stage.

The distribution of the altered gabbro masses in the area is such that the most altered types are found close to, or between granite masses. The presence of minerals such as apatite and tourmaline in increasing amounts toward the granites, the formation of biotite and, finally, the introduction of quartz close to the granite bodies indicates that the granite was responsible for the alteration of the gabbro. The above minerals, particularly biotite and quartz, are too abundant to be explained entirely as a rearrangement of the constituents of the rock, and it is concluded, therefore, that the material to form them has been introduced.

Origin of the Gabbro

This area, and indeed a large section of the north shore of the Gulf of St. Lawrence, is characterized by multiple sills and dykes of gabbro. They range in composition from fresh olivine gabbro-diabase to various metamorphic derivatives which have an extremely diverse mineralogical composition. These gabbro bodies are in close proximity to a number of large anorthosite masses. Their exact number and their dimensions are still unknown, but they have been observed for a considerable distance north of Havre St. Pierre. The age relationship between the gabbro and the anorthosite has not been proven conclusively.

The available evidence, collected by Retty (1944) and Claveau (1949), along the Romaine river indicates that the gabbro is the younger rock. The association of these two rocks indicates that they may be related genetically.

Buddington (1939), who studied the anorthosite and the related gabbros in the Adirondacks, discusses the possible methods by which gabbro may be derived from the parent anorthosite. According to one hypothesis, the gabbros may be of the nature of residual liquid from crystallization differentiation during cooling. In this case, the composition of the plagioclase should be less calcic than that of the anorthosite. On the other hand, if the gabbro were the product of partial melting of primordial gabbroic or noritic anorthositic horizons of primordial layers, then the plagioclase of the gabbro should be more calcic than that of the anorthosite. The composition of the plagioclase in the anorthosite northwest of the area varies between An50 and An56. In the present map-area, the least altered gabbro contains plagioclase of the composition An47. However, these crystals are probably less calcic than the plagioclase of the original rock, in view of the fact that, in the transformation from pyroxene to amphibole, calcium is taken up by the newly formed amphibole at the expense of plagioclase. It is conceivable, therefore, that the plagioclase, prior to the uralitization of the gabbro, was considerably more calcic. The origin of the gabbro, therefore, can be explained by the second hypothesis.

Considering the derivation of the mafic magma, Buddington

(1939, p. 220) states

> "... the deepseated anorthosite horizon might perhaps be banded with layers of noritic, troctolitic, or gabbroic anorthosite. Such more mafic bands might be completely molten at the same temperature at which the anorthosite was only partly melted to yield the magma of assumed composition. Such more mafic minerals would, however, be of higher density than the less mafic magma and would tend to settle out as units from it and not necessarily appear as contemporaneous facies. Daly (1914) observes that, in general, 'the femic pole which would settle at the bottom would remain there invisible until a later eruptive effort forces it up through the anorthosite or country rock'."

The above explanation for the origin of the gabbro, as suggested by Buddington and Daly, is considered by the writer to be quite plausible. The gabbro is closely related in time to the anorthosite for, as far as is known at present, there is no intrusive event in the time scale between the emplacement of the anorthosite and the intrusion of the sills and dykes of gabbro.

Gneissic Granite and Pegmatite

Introduction

Gneissic granite is exposed west of Johan Beetz, between Corneille river and Long Point. West of Corneille river, a band of gneissic granite, one-quarter to one-half mile wide, extends eastward to Appititatte bay.

The lithology of the gneissic granite is fairly uniform. In general, the rock is coarse-grained, pink or light grey and strongly gneissic. The gneissose structure is clearly visible in hand specimen - thin discontinuous seams of biotite alternate with narrow bands composed of elongated crystals of feldspar and quartz.

Petrography

In thin-section, the rock is coarse-grained, allotriomorphic and inequigranular. The essential mineral constituents are quartz, 35 percent; potash feldspar, 35 percent; plagioclase, 17 percent and biotite, 13 percent. The average grain size of the minerals is 0.9 mm. in diameter.

Quartz is xenomorphic. Invariably it is strained and some grains are fractured. Lines of inclusions and bubbles were observed to cut indiscriminately across several crystals, but these have no preferred orientation. Equidimensional crystals of microcline and small, irregular patches of microcline were observed filling the interstices between plagioclase and quartz. Microcline is altered, but only slightly, to sericite. Plagioclase forms stubby lath-shaped crystals which have been altered to sericite. Where the alteration has been intense, secondary albite forms a clear mantle around the crystals. The composition of the plagioclase is An17. Irregular long narrow stringers and patches of plagioclase are intergrown with microcline, forming microperthite. Clusters of biotite crystals in parallel orientation form long, narrow seams, giving the rock a distinct foliation. Rarely does it occur as single crystals. Biotite is pleochroic as follows:

X = yellow brown
Y = golden brown
Z = very dark green to opaque

The absorption is: $Z>Y>X$. The mineral is optically negative with 2V = very small.

Alteration of the biotite has been intense, producing chlorite along the cleavages. The optical properties of this mineral are: The chlorite is pleochroic with X = colourless to yellow green, Y = green, Z = green. The absorption is: X<Y = Z. The mineral is uniaxial negative. These properties and the "ultra blue" interference colour are characteristic of penninite.

Small wedge-shaped crystals of sphene and subhedral crystals of apatite are included in biotite.

<u>Field Relationships and Age</u>

All the available evidence in the field indicates that the granite is younger than the sedimentary rocks and gabbro, but older than the medium-grained massive biotite granite.

The contact between the sedimentary rocks and the north and east edge of the granite is abrupt and sharp. The granite contains inclusions of quartzite, schist and gabbro which have been partly digested by the granite. Dykes of medium-grained massive granite cut sharply across the gneissic granite at a high angle to the foliation. Further proof that the granite is older than the medium-grained massive granite, is shown by two stocks of the younger granite which are intrusive into the older rock. These younger granites also contain blocks of gneissic granite as inclusions.

The foliation of the granite is parallel to the schistosity and bedding of the surrounding metasedimentary rocks, and this indicates that the emplacement of the granite took place before the completion of regional metamorphism. The pattern produced by the foliation is remarkably consistent with the attitude of the intruded sedimentary rocks. The term "mantled dome" (Eskola, 1949) could be applied to this feature.

Exkola has studied the problem of mantled domes in the Karelidic zone of Finland and later the domes in Maryland. He believes that the domes have been produced by a process of granitization, whereby pre-existing intrusive granites were made mobile during tectonic movements and were forced upward, lifting the overlying country rock and injecting into it. The granitization, which accompanied the doming, caused the uprising of fresh granitic material and this granite magma collected into separate intrusions, which forced their way through either the domes or the country rock.

The mantled dome of this area is similar to those described by Eskola. However, the younger granite masses of the area are far too large to be considered as the result of palingenesis of an older granite intrusive. Moreover, they have the characteristics of late kinematic intrusions.

Although the gneissic granite appears to be injected into the country rocks, it does not follow that the writer postulates an igneous source for the rock. Whether the granite is a differentiation product of a magma or the result of fusion of older rocks at depth is not known. There is an absence of granite dykes in the surrounding country rock of appropriate composition other than the massive fine-grained dykes which cut all the rocks and are probably related to the younger granite. The gradation from the metasedimentary rocks on Puyjalon Island to migmatite and hence to gneissic granite, suggests that the two rocks are related genetically.

The migmatites in the eastern part of the area also seem to be related to gneissic granite exposed east of the present map-area. This leads to the possibility that the granite may be the result of palingenesis and that the "new born" magma intruded the overlying rocks, partly by the process of doming, as suggested by Eskola, and comparable to the manner suggested by MacGregor and Wilson (1939, p. 201) whereby mobile migmatites are injected into the non-mobile migmatites or host rock and have sharply defined contacts.

There is ample evidence in the area of two ages of pegmatites. The older group generally forms narrow sills and dykes which cut the metasedimentary rocks and migmatite. These pegmatites feather-out along the foliation of the migmatites and the schistosity of the schist members of the metasedimentary rocks. The younger group cuts indiscriminately across the older pegmatites and has well defined sharp contacts with the enclosing rocks. They are usually coarser-grained and larger than the older group. Furthermore, the old pegmatites have been deformed (Plate 13, Fig. 1), whereas the younger pegmatites are undeformed. The first group of pegmatites were intruded before the emplacement of the young granite. Dykes of medium- to fine-grained granite were observed cutting pegmatite and, in turn, both these rock types are cut by the later pegmatites. The medium-grained granite contains inclusions of quartzite and schist injected by pegmatites (Plate 13, Fig. 2). These inclusions have sharp contacts with the enclosing granite. The granite has been intruded by later large coarse-grained pegmatites.

PLATE 13

Fig. 1 Deformed pegmatite sills forming boudinage structure.

Fig. 2 Inclusion of quartzite and schist cut by pegmatite in granite. Note sharp contact.

Ferland Lake Granite

Introduction

An area of approximately ten square miles in the northwest corner of the map-area is underlain by coarse-grained granite. This rock varies from reddish pink to grey and is generally massive. The distinctive feature of the rock is the large size of the feldspar crystals in comparison to the remaining minerals. In some exposures, these are lath-shaped and have a preferred orientation parallel to the contact of the granite. Jointing in the granite is very pronounced, one set strikes approximately at right angles to the contact and a second set is parallel to it.

Petrography

In thin-section, the granite is coarse-grained, hypidiomorphic and inequigranular. The large feldspar crystals impart a porphyritic texture to the rock.

The average mineralogical composition of three thin-sections of this granite is:

Quartz	25 percent
Potash Feldspar	40 percent
Plagioclase Feldspar	20 percent
Biotite	15 percent
Accessories	magnetite, sphene, apatite, zircon

Crystals of microcline and plagioclase feldspar, two centimeters long and more than one centimeter wide, are enclosed in a matrix of quartz, biotite and feldspar. The plagioclase is invariably altered to sericite, whereas the microcline is relatively fresh. The composition of the plagioclase is An_{19}. Many lath-shaped microcline crystals contain altered remnants of plagioclase. Tongues and apophyses of fresh microcline were observed eating into the large plagioclase crystals, indicating that this mineral has been partly replaced by microcline.

Quartz is clear and has an undulatory extinction. Platy crystals of biotite form clusters in the matrix and single grains are present between quartz and feldspar. The biotite is pleochroic with X = straw yellow, Y = olive green, Z = grass green. The absorption is $Z>Y>X$. It is optically negative with a very small optic angle. All but a few crystals have been altered to chlorite (penninite). This mineral is uniaxial, negative and has abnormal blue interference colours. Both potash and plagioclase feldspar are present in the matrix. Potash feldspar (microcline) is highly altered to sericite and kaolin, whereas the alteration of the plagioclase is moderate. In one thin-section, quartz and microcline are intergrown in granophyric fashion.

Of the accessory minerals, magnetite and sphene are present only in the matrix. Zircon forms inclusions in biotite and apatite is included by all the essential minerals.

Field Relationship and Age

The age relationship between the granite, gabbro and sedimentary rocks is well established. Numerous inclusions of gabbro and metasedimentary rocks were observed in the granite. They have a wide range in size and are irregular in shape. The attitude of the bedding of the quartzite is different in each inclusion and differs from the attitude of the quartzite of the country rock.

This granite is separated from the Turgeon lake granite by a wide band of metasedimentary rocks and gabbro. Consequently, the age relationship between the two bodies is unknown. Petrographically, the

Turgeon lake granite is finer-grained and fairly homogeneous. Southwest of Ferland lake, two narrow dykes of medium-grained pink granite which, in hand specimen, resemble the southern granite, cut the Ferland lake mass. This suggests that the Ferland lake granite is older than the Turgeon lake body.

Medium-Grained Pink Biotite Granite

Distribution

Four, more or less, distinct units of medium-grained pink biotite granite are exposed in the map-area. The largest of these, the Turgeon lake granite, underlies approximately 53 square miles in the western half of the map-area. It extends from the south side of Tanguay lake to a point 2 miles north of Turgeon lake in a north-south direction, and from the east side of Little Piashti lake westward beyond the west limit of the map-area.

Two small stocks are exposed along the coast. At Johan Beetz, biotite granite extends from Mine Bay to a point 2-1/2 miles northwest of the village. The Johan Beetz granite is divided into two parts by a band of quartzite and schist, which outcrops east of the village. The Corneille river granite extends from the mouth of Corneille river westward to about a mile east of Appititatte bay, a distance of four miles. It is exposed north from the coast for a maximum distance of one mile.

The fourth granite stock outcrops over an area of less than one square mile around the northwest bay of Villeneuve lake. Granite is exposed on a small island two and three-quarter miles east of Johan Beetz and on the west side of Watshishou Knoll.

In general, the composition and texture of all the granite masses are similar. Quartz, potash feldspar, plagioclase feldspar and biotite are the essential constituents, but the relative amount of these minerals varies slightly in each granite. The Turgeon lake granite contains more plagioclase and less potash feldspar than any of the other bodies. The granites are medium-grained and massive. Slight differences in texture were noted within each mass and between any two separate bodies. For example, west of Little Piashti lake crystals of microcline feldspars, measuring from one-half to two inches long and one-half inch wide, impart a porphyritic texture to the granite. Northwest of Tanguay lake, the parallel orientation of biotite flakes gives the granite a slight gneissic structure. Most of the Corneille river granite is massive, but in some places an obscure foliation was observed. The Johan Beetz and Villeneuve lake stocks are massive.

Petrography

In thin-section, the granite is medium-grained, hypidiomorphic and inequigranular (Plate 14, Fig. 1). The mineralogical composition of the rock is shown in the table below.

Quartz	25 - 35 percent
Potash Feldspar	30 - 45 percent
Plagioclase	15 - 25 percent
Biotite	5 - 15 percent
Accessories	magnetite, apatite, sphene, zircon and epidote

The average grain size of the granite is 0.5 mm. in diameter. Quartz forms interlocking anhedral crystals, which contain small gas bubbles and flakes of mica. Most of the grains show undulatory extinction. In two thin-sections, taken from specimens of the Turgeon lake granite, small fractures in quartz have been filled with secondary quartz and

PLATE 14

Fig. 1 Photomicrograph of medium-grained biotite granite. Crossed nicols. (X20).

Fig. 2 Inclusion of quartzite in Turgeon lake granite. Note sharp contact.

small crystals of white mica. Small oval-shaped grains of quartz are intergrown with microcline in myrmekitic fashion. The predominant feldspar of the rock is microcline. This mineral forms equidimensional and lath-shaped crystals. The lath-shaped crystals contain small irregular patches of altered plagioclase. This feature was observed in three thin-sections of the Turgeon lake granite. Small irregular shaped crystals of microcline were observed between the larger minerals. Where they are in contact with plagioclase, tongues and small apophyses of microcline encroach and partly replace that mineral. The composition of the plagioclase varies between An14 and An17. Invariably, it is lath-shaped and a few crystals have curved cleavages. Albite and Carlsbad twinning were observed in most crystals.

Biotite forms elongated tabular-shaped crystals. They are completely enclosed by microcline and were observed interstitial to all minerals. Biotite is pleochroic; X = straw yellow, Y = grass green, Z = dark green to opaque. The absorption is $Z>Y>X$. The mineral is biaxial, negative and has a small optic angle. Magnetite, apatite, sphene and zircon form small inclusions in biotite, but any one or all of these minerals may be absent. Zircon, if present, is surrounded by pleochroic halos. Elsewhere, the accessory minerals form small subhedral to euhedral crystals scattered throughout the rock. Microscopic crystals of sphene frequently form a coating around magnetite. Muscovite and epidote were observed in one thin-section. The muscovite forms an intergrowth with biotite. Several small crystals of epidote occur between quartz and feldspar.

The feldspars and biotite in the granite have been altered, but the alteration has been most intense in the Villeneuve lake mass. The alteration of the microcline has produced a small amount of sericite and kaolin, whereas this alteration has been more intense in the plagioclase. Several plagioclase crystals are coated with a thin film of albite which, in some crystals, has partly replaced that mineral. Chlorite has formed at the expense of biotite and is now intergrown along the cleavages of that mineral.

Dykes of granite are numerous throughout the southern part of the area. They are fine-grained and pink coloured. Mineralogically, they have a composition similar to the larger granite masses. The dykes contain considerable more secondary albite than the granite. This mineral has filled the interstices between the feldspars and veinlets of albite have replaced both the microcline and the plagioclase. The greater part of this replacement is confined to the outer edges of the crystals, forming a saw-tooth type of perthite.

Field Relationship and Age

The intrusive character of the granite cannot be doubted if one examines the geological map which accompanies this thesis. All the granite bodies exhibit cross-cutting relations with the surrounding rocks and large tongues of granite cut indiscriminately across both the metasedimentary rocks and the gabbro. The grain size of the granite is variable, but, as an average condition, the smaller bodies and granite dykes are finer grained. The contact between the granite and inclusions contained therein is sharp (Plate 14, Fig. 2). The inclusions are frequently angular and have no mutual orientation. The contact between the large granite bodies and the quartzite is well-defined. These facts verify the hypothesis that the granite crystallized from a silica-rich melt.

The granite is younger than all the Precambrian rocks, except the younger pegmatite. The cross-cutting relations between the granite and the metasedimentary rocks and gabbro have been described. Inclusions of granite gneiss and gneissic granite were observed in the Corneille river granite. Granite dykes were observed to cut all the older rocks. Large pegmatite dykes and irregular masses of pegmatite cut all the granite masses, except the Villeneuve lake body. At several localities north of Turgeon lake, narrow pegmatite dykes fill fractures in the granite. This indicates that these fractures acted as a passage for the pegmatitic solutions.

The close association between the Turgeon lake, Corneille river and Johan Beetz granites, their textural and mineralogical similarity and age, suggest they are genetically related and probably contemporaneous. They probably join to form a single body at depth. The Villeneuve lake granite is believed to be an outlier of the main intrusion.

Mechanics of Intrusion

The mechanics of intrusion of granites are extremely complex and no single hypothesis has been advanced which will explain, satisfactorily, all the features observed around many granite masses. That certain so-called "granites" have been formed in place by the replacement of pre-existing rocks is recognized by many geologists. No conclusion has been reached as to the mechanisms by which the granite reached its present position in the earth's crust, even among the geologists who favour the intrusive hypothesis for the origin of granite. Of the various mechanisms which have been advanced, magmatic stoping and forceful injection have received favourable consideration. However, which of these two processes has been most active is still undecided, one group favours the former method, while another group considers forceful injection as the dominating process. The literature on the subject is too large to review at this time. An annotation of selected papers on the mechanics of igneous invasion has been compiled under the auspices of the Committee on Batholith Problems of the division of Geology and Geography of the National Research Council, Washington, D.C. (Sundeen, 1935). Most of the controversy is undoubtedly the result of personal experiences which may have been localized in one area where all the available evidence favours one method over the others. However, in the present state of our knowledge, it is impossible to state the relative importance of these various mechanisms.

The evidence collected during the mapping of the Johan Beetz area indicates that at least three methods have been employed by the granite during its ascent through the earth's crust. It was not possible, however, to conclude which of these methods had been most active, although two seem to have predominated over the other.

Magmatic stoping, forceful injection and assimilation of the stoped-out blocks are considered to have taken place during the intrusion.

North of Turgeon lake the sediments strike south and dip east between 30° and 60°. Near the contact of the granite they have been forced aside, away from the contact. The dips of the sediments in this area are from 50°E. to vertical. This is well illustrated on the east side of the Turgeon lake granite where the sediments and gabbro are in the form of a bulge, whose concave side faces the granite. A similar phenomenon was observed north of the granite exposed at Mine Bay. At the contact with the granite the southwest trending sediments have been deflected to the east and southwest. An examination of the geological map, which accompanies this thesis, will illustrate this phenomenon. The map also shows that the sediments invariably dip away from the granite. This suggests the intrusion was accompanied by doming of the overlying metasedimentary rocks and gabbro.

A description has already been made of the inclusions of the older rock types contained by the granite. Because of the wide variation in the size of the inclusions, it was possible to show only the large blocks on the map. The contact between the granite and host rock is very irregular and several large tongues project into the surrounding country rock. These have partially isolated large blocks of country rock. West of Turgeon lake a long narrow xenolith of quartzite has been almost completely detached from the sediments of that area. These features are considered to be evidence that magmatic stoping was the second mechanism employed by the granite during its intrusion. Most of the inclusions have sharp well-defined contacts, but some, particularly the smaller fragments and those which are highly sheared, such as the various mica schists, have been partly digested by the granite. This suggests, therefore, that, although the granite has assimilated some of the stoped-out blocks, the process was relatively moderate.

No structures, such as marginal fissures, flow lines, flow layers and faults, were recognized in the field. Detailed mapping of the granite and its contact may result in outlining such structures which would allow a better understanding of the mechanics of intrusion of the granite. It is conceivable, however, that magmatic stoping, forceful injection and possibly minor assimilation were active during the granite intrusion.

Pegmatite

Sills and dykes of pegmatite are the youngest rocks in the area. They were observed cutting all the other Precambrian rock types and inclusions of quartzite, schist, gneiss and gabbro were seen in pegmatite.

Although pegmatite dykes are common throughout the area, they are most abundant and of greatest size in the vicinity of Quetachou bay, where many dykes are more than 1000 feet wide. Large pegmatites are also exposed between Quetachou bay and Watshishou Knoll and east of Little Piashti lake. Several dykes and numerous streaks of pegmatite are common along the coast.

All the dykes are characterized by frequent pinching and swelling along their strike.

The pegmatites vary greatly in grain size. The most coarsely crystalline types were observed in the vicinity of Quetachou bay, where crystals of feldspar up to one foot across are common. Crystals of feldspar, measuring three feet by two feet, were observed in the pegmatites on each side of Quetachou bay. These very coarse-grained pegmatites are composed predominantly of microcline and orthoclase. Quartz occurs interstitial to, as well as in graphic intergrowth with, the feldspar (Plate 15, Fig. 1). This phenomenon is clearly visible in hand specimens of the rock. Some feldspar crystals, however, are relatively free of quartz, but they constitute only a small percentage of the pegmatites. Some biotite and muscovite are present and, locally, the latter

PLATE 15

Fig. 1 Photomicrograph of pegmatite showing intergrowth of quartz and microcline. Crossed nicols. (X15).

Fig. 2 Pegmatite dyke cutting quartzite, one and one-quarter miles east of Gull Island. Note shallow dip of dyke.

is abundant. The muscovite crystals are of large size, but have been shattered by tectonic deformation to such an extent that it is impossible to obtain a sheet more than four inches across.

The finer-grained pegmatites are composed essentially of quartz, potash feldspar (microcline and orthoclase) and a small amount of muscovite. Tourmaline crystals up to one inch long and one-quarter inch wide were observed in some of the dykes near Quetachou bay and Ferland lake, but the amount is small. Many dykes contain streaks of fine-grained granular quartzitie material rich in garnet. Other minerals locally present include magnetite, and, more rarely, beryl.

The contact between pegmatite and gabbro is sharp, but between pegmatite and quartzite the contact is, in places, gradational, particularly where the dykes pinch-out. This is considered to be due to the assimilation of the quartzite by the pegmatite in these areas.

The majority of the dykes have a steep dip. One mile east of Quetachou bay, however, pegmatite forms the centre part of a large peninsula and quartzite and gabbro are exposed around the shore. Where the contact is exposed between these rocks, the pegmatite was observed to "sit" on the underlying quartzite and gabbro. The dip of the contact in this case dips 25 degrees to the west (Plate 15, Fig. 2).

The headland, of which Watshishou Knoll is a part, is formed partially of pegmatitic masses which trend northeast and dip 60° northwest. The pegmatite here differs from that encountered in any other part of the area. This rock, as well as the quartzite and amphibolite which it includes, has been thoroughly brecciated and recemented with opaque, milky white quartz in an intricate mesh of small veinlets. In places, over one-half the volume of the rock is quartz. Considerable hydrothermal alteration, probably related to the introduction of the quartz, has affected this zone. Quartz ridges extend northeastward along the line of strike of the zone for a distance of two and one-half miles. Owens (1951) believes the introduction of the quartz took place following folding, recrystallization and fracturing of a large band of quartzite between sills of amphibolite. He cites evidence that the deposits are controlled by drag folding and rupturing of the quartzite during the formation of the anticline east of Watshishou Knoll. The quartzite, being more brittle than the adjacent amphibolite, was easily fractured and later penetrated by quartz, whereas the smaller quartz beds were protected by bands of amphibolite which acted as a barrier to the migrating solutions.

The distribution of the pegmatite dykes in the area suggests that they were injected along a zone of weakness, coinciding with the line of contact between the quartzite and gabbro and, to a lesser degree, into the quartzite and gabbro alone.

STRUCTURAL GEOLOGY

Introduction

The general structural trends of the area are clearly reflected by the distribution of the multiple sills and dykes of gabbro, as shown on the accompanying map. Thus, in the northern part of the area the strike of the metasedimentary rocks varies between N. 15° E. and N. 40° W. This general trend changes abruptly in the southern part of the area and south of Ferland lake to a southwest direction. South of Tanguay lake the strike of the formations is about due west. Structures observed in the metasedimentary rocks which were useful in interpreting the structure are, primary bedding, ripple marks and cross-bedding. Locally, the last two structures are well enough preserved to give a reliable indication of the direction of tops.

In the southern part of the area, the metasedimentary rocks, particularly the micaceous members, and the gabbro have been sheared. All the rock types are traversed by joints. No structures which could be recognized definitely to be faults were observed.

Folding

The attitude of the metasedimentary rocks in the northern part of the map-area indicates that they have been folded into two anticlines and two synclines. The strike of the formations is generally due north, except between Ledoux lake and Bellanger lake where it varies between N. 15° E. and N. 40° W. Dips are variable in direction and amount. East of Ferland lake all the rocks dip west, whereas west of Big Piashti lake the bedding dips between 30° and 70° east. From these observations it is inferred that the rocks in this area form an anticline. The exact location of the axis of this fold is not known because of the large body of gabbro which separates the two limbs. The attitude of the bedding in the large band of quartzite in the centre of the gabbro sill suggests that the axis passes through the western part of the band in a north-south direction.

South of Bouchard lake the outcrop pattern formed by a band of quartzite indicates a syncline plunging southward. East of Goeland lake the beds dip west, whereas west of the lake, the dip of the formations is east. The plunge of the fold could not be determined accurately, but is estimated at approximately 20° in a south-southeast direction. This fold could not be traced southward, owing to erratic changes of the direction of dip of the metasedimentary rocks south and east of Cabane-Brulée lake.

Between Goeland lake and Bellanger lake the metasedimentary rocks dip west. Determinations of stratigraphic tops in grey quartzite, using cross-bedding and ripple marks, show that the strata face west. Between the east and west bays of Bellanger lake and south of this lake, there is considerable variation in the direction of dip. Many beds dip east, but an equal number have west dips. Determinations of stratigraphic tops show that at least some of the west dipping formations are overturned, whereas no overturning was observed in the east dipping beds. It is conceivable, therefore, in view of the above observations, that all the formations which dip west are overturned. Several drag folds were observed on the south shore of Bellanger lake. The axes of these minor folds plunge between 15° and 25° in a S.10° E. direction. Thus, the attitude of the metasedimentary rocks in this are indicates that they form an anticline, plunging to the southeast. The east limb of the anticline is overturned. The exact location of the axis of this fold is not known, but probably passes through the west bay of the lake. Due to the prevailing easterly dip of the strata south of this area, it was possible to trace this structure only for a distance of three miles south of the north boundary.

South of the east bay of Bellanger lake and east of this lake, the majority of the beds dip west. Top determinations in this area indicate that the formations are upright, except one observation at the foot of Theodule lake where east dipping strata face west. The metasedimentary rocks of this area, therefore, belong to the east limb of a syncline. The west limb corresponds to the overturned east limb of the anticline described above.

Throughout the southern part of the area, except in localized areas, the majority of the beds strike northeast and dip northwest. One exception is shown by the attitude of the formations near Pierre lake. Northwest of the lake the beds dip northwest, whereas northeast and southwest of the lake the quartzite dips southeast. These observations indicate a northeast trending anticline. The axis of this fold strikes N. 45° E.

On the west side of Quetachou bay the quartzites dip southeast, whereas on the east side of the bay they dip northwest. This belt of metasedimentary rocks extends northward to Bellanger lake. It is possible, therefore, that the syncline at Quetachou bay is the southern extension of the Bellanger lake syncline. It was not possible to obtain sufficient readings in the intervening area, however, to correlate the two folds.

The dips of the formations in the vicinity of Tanguay lake are south, whereas north of the gneissic granite all the metasedimentary rocks dip toward the north. The rocks of this belt, therefore, form an east-west trending synclinal structure.

Several minor folds are shown by the strike and dip of the gneissic structure in the migmatites east of Watshishou Knoll. West of Pontbriande bay they form an anticlinal structure, plunging north, and east of the bay, the strike and dip of the migmatites indicate an overturned syncline plunging north.

A discussion of the regional structure and its interpretation will make this section unduly long, so it will be considered in a separate section.

Schistosity

The mica-rich members of the metasedimentary series show a well-developed schistosity. These rocks are most numerous in the southern part of the area where they form narrow bands intercalated with grey quartzite. In all cases, the schistosity is parallel to the next more resistant formation, that is, layers of quartzite. Where bedding can be observed in quartzite, the schistosity of the schist members is parallel to the bedding.

The formation of bedding schistosity has been attributed to several controlling factors. The more important of these are listed below.

1. Initial anisotropism of the sediments.

2. Rotation of bedding into the plane of axial cleavage.

3. Rotation or development of slip surfaces parallel to the

bedding.

4. Mimetic recrystallization.

5. Plastic flow.

6. Incipient recrystallization parallel to bedding under load or geothermal metamorphism.

7. Bedding acting as channels for escaping fluids.

Any one or any combination of the above factors may be the cause of the development of bedding schistosity. Undoubtedly, several factors were operative in the development of bedding schistosity in the present area. However, there is a lack of knowledge of the mechanical principles of the phenomenon, as well as a lack of laboratory and field data. For these reasons, the writer cannot form any definite conclusions.

In the southern part of the area parallelism of platy minerals in the gabbro imparts a poorly developed schistosity to the rock. The strike of this schistose structure is parallel to the strike of the sills and is also parallel to the attitude of the enclosing metasedimentary rocks. In places, shearing has been intense and has transformed the rock to biotite and amphibole schist. The schistosity in the southern parts of the gabbro bodies is attributed to deformation during warping of the masses from a north-south to southeast and east-west direction.

Schistosity was observed in the large gabbro sill east of Ferland lake. It is confined to within a mile of the contact of the Ferland lake granite and is not developed throughout the entire western part of the body. The schistosity strikes parallel to the contact and dips toward the granite. The origin of the schistosity in this body, close to the granite, is ascribed to the effects of the emplacement of this body.

Jointing

All the rock types are traversed by joints, but they are most prominent in the granitic rocks. Joints in the metasedimentary rocks have various trends, but no regular pattern. One set which is vertical, strikes perpendicular to the bedding. Another set, which is not discernible in the field, but which can be seen on the aerial photographs, trends northeast. These joints are reflected by the drainage pattern and the shapes of the lakes such as, for example, the lakes and streams east of Villeneuve lake. The origin of the joints is somewhat obscure, but they are probably related to the period of regional folding. The vertical dip joints may be interpreted as tension joints resulting from slight elongation parallel to the fold axis (Billings, 1946, p. 125). Near the granite, various other joints, having diverse orientations, were observed in the quartzite. They are probably related to the intrusion of the granite.

Two prominent sets of joints were observed in the gabbro. One set trends parallel to the length of the sills and the other strikes perpendicular to the elongation of the bodies. Both sets have steep dips or are vertical. These joints are probably related to contraction in the gabbro during cooling and crystallization. Besides the two joint sets outlined above, various other joints were observed in the gabbro near the Turgeon lake granite. These joints vary in strike and dip and their origin is considered to be related to the emplacement of the granite.

Joints are prominent in all the granitic rocks. East of Pontbriande bay two sets of vertical joints were observed. One set strikes N. 10° E;

the other S.80° E. West of the bay the joints have no regular trend, but strike approximately perpendicular to the foliation of the gneiss and are vertical. They may be tension joints. In the gneissic granite the majority of the joints are vertical, but have no regular strike. Two sets of joints were observed in the Turgeon lake granite. One set strikes northeast, the other northwest. The dip of the former varies between 70°SE. and vertical and that of the latter between 85°NE. and vertical. The Ferland lake granite is traversed by numerous joints which have various orientations and dips. It was not possible to obtain sufficient readings of the joints in the various rock masses to analyse their pattern or to arrive at any conclusion as to their origin. The majority of the joints are probably due to contraction during cooling of the various masses and would be classified as tension joints.

Faulting

Observations made in the field afford little evidence of faulting. This does not eliminate the possibility that faults are existent, particularly longtitudinal or bedding faults which would be difficult to recognize. However, the writer did not observe any long zones of intense shearing or mylonitization in the area.

A steep cliff of medium-grained gabbro forms part of the west shore of the north bay of Cabane-Brulée lake. At several places in the gabbro slickensides were developed, but they could not be traced for any distance, nor could the sense of movement be determined.

On the southeast tip of the headland at Watshishou Knoll, a pronounced valley trends N.50° E. It is underlain by quartzite intruded by narrow sills of amphibolite. Both rock types have been highly sheared and contorted. It is possible that there is a fault at this locality.

A prominent topographic feature of the west central part of the map-area is a long well-defined east-west trending valley. This valley is occupied by a series of long narrow lakes, including Turgeon lake, the east and west arms of Little Piashti lake and the west bay of Cabane-Brulée lake. Such a topographic feature may indicate the presence of a fault zone. However, no evidence of shearing, rupturing, offsetting of ridges or formations was observed anywhere along the length of this valley.

Regional Structure

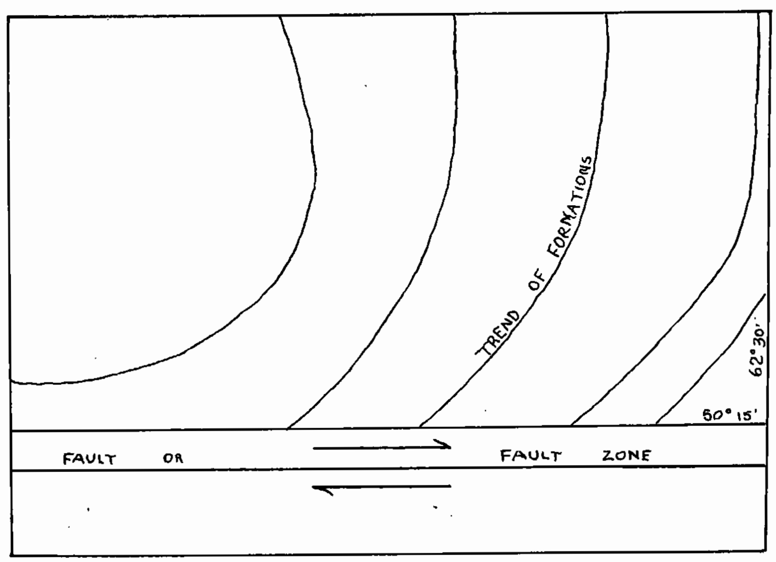
The regional structural trends of the area are clearly reflected by the distribution of the metasedimentary rocks and gabbro on the geological map, which accompanies this thesis. The most conspicuous feature of the regional structure is the abrupt curvature of the formations from north-south to southwest and, south of Tanguay lake, to an east-west direction. This general change in the attitude of the formations is not confined to the present map-area, but is, apparently, the general condition for a large part of this section of the north shore. It can be appraised from a study of the topographic maps of the area and has been confirmed, at least in part, by geological investigations along the Romaine river (Retty, 1944) and exploration work of mining companies east of the present map-area (unpublished information).

There are several possible interpretations of the regional structure. These are discussed below.

The outcrop pattern of the formations resembles that of a single major fold whose axis strikes northwest. Close examination of the map will show, if all the available evidence is considered, that such an interpretation is not feasible. The majority of the dips around the nose of the proposed fold are northwest. Hence, the major structure would be interpreted as a syncline plunging northwest. This interpretation meets with the unsolvable difficulty of explaining the direction of plunge of the minor folds on the northeast limb of the structure. Moreover, minor folds such as the fold at Pierre lake could not form on the nose of a major fold. Another difficulty is the explanation of the greater deformation of the metasedimentary rocks and gabbro on the southwest limb of such a structure, as compared with the relatively mild deformation of the formations on the northeast limb of the fold.

A structure pattern similar to that shown on the accompanying map could be formed in the following manner. Following folding and intrusion of the gabbro, deformation continued during the late stages of, or after the intrusion of, the granite caused by forces moving from the southeast. A large body of granite, such as the Turgeon lake mass, could act as a "buffer" about which the formations would tend to be wrapped as deformation continued. In such an event, the granite should show some effects of deformation and, near the contact, the metasedimentary rocks would be extensively sheared, ruptured, possibly crushed and faulted. Observations of the granite in the field and petrographic studies of thin-sections of the rock show that it has not been deformed. The greater part of the rock is massive. The minor foliation, observed in the western part of the body, is probably due to local movements in the magma during crystallization. Moreover, the contact relations between the granite and the host rocks show that the granite was intruded during the late stages or following the period of deformation.

Another explanation considered during the examination of the area, assumes the presence of a large fault or fault zone south of the area. The present attitude of the formations could thus be explained by relative movements along this fault, dragging the strata on the north side to the west. This idea is illustrated schematically below.



If such a fault zone were present, it would be logical to expect minor fractures or breaks along the coastal section. Evidence of faulting along the coastal section of the north shore is very meagre. Furthermore, it is very doubtful that such a fault could be responsible for the east-west trend of the formations in the southwest part of the area. Evidence in the area indicates that at least part of the deformation has been accomplished by flowage in response to stress.

The majority of the dips of the metasedimentary rocks which surround the Turgeon lake granite dip away from the granite. If it is assumed that the band of metasedimentary rocks north of the granite joins with the band south of the granite west of the map-area, the structure so formed is a large dome (Figure 4, A).

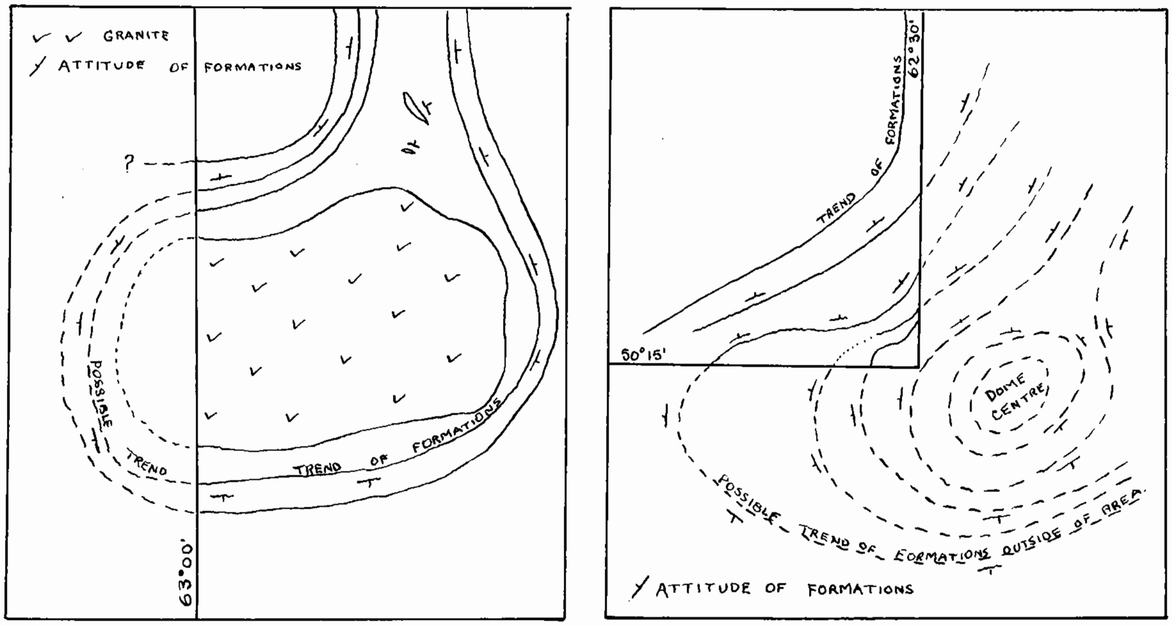


Figure 4. A. Turgeon lake Dome. B. Dome east of Johan Beetz Area.

The centre of the dome is underlain by granite. This suggests the possibility that, following the initial folding and intrusion of the gabbro sills and dykes, the strata at this locality were arched upward, forming a dome. The cause of the doming is not known, but may be related to the emplacement of the granite. This hypothesis of doming, however, does not explain the overall northwest dip of the formations in the southeast part of the area. Possibly these formations are the western part of a second dome structure east of the map-area (Figure 4, B). Additional mapping is required in the adjacent areas to test this hypothesis. The position of the gabbro body south of Tanguay would be difficult to explain by this theory, because the available evidence indicates that all the gabbro bodies in the area dip at a high angle.

The hypothesis of doming does not explain satisfactorily, the general increase in deformation in the rocks from the northern to the southern part of the area.

In the northern part of the area the fold axes strike southward. However, due to the abundance of westerly dips of the formations in the central and southeastern parts of the area, it was impossible to trace the folds the entire length of the map-area. Furthermore, the gabbro masses in the northern part of the area show no evidence of mechanical deformation (except the west side of the sill east of Ferland lake). The quartzites, on the other hand, have been deformed. In the southern part of the area, the gabbro has been recrystallized, sheared and transformed to amphibolite and, locally, amphibole and biotite schist. Similarly, the metasedimentary rocks show evidence of greater deformation and they have been transformed to migmatites at some localities. At many places in the southern part of the area, there is evidence that the rocks have deformed by plastic flowage. Two examples may be cited.

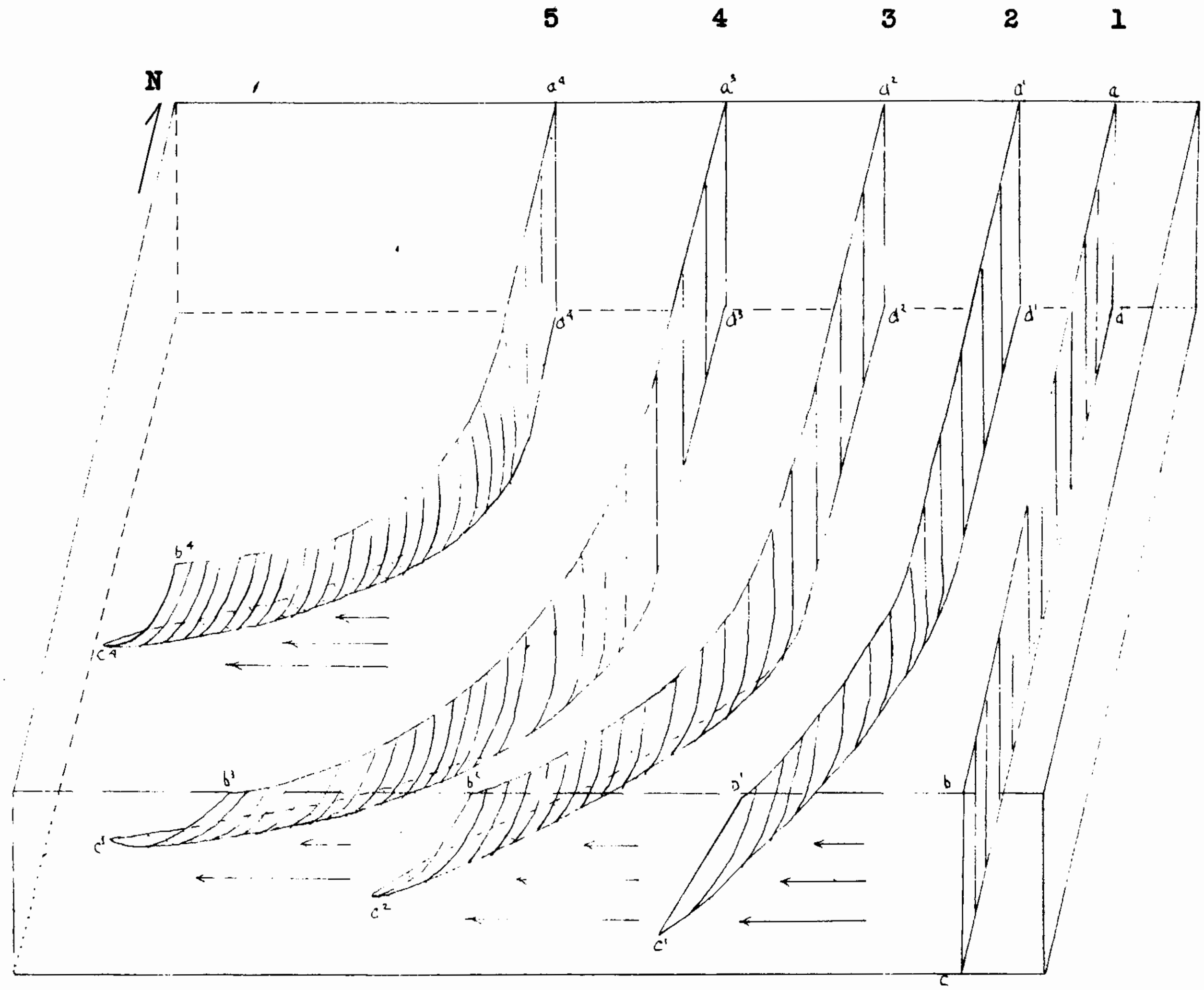
In the area underlain by migmatites east of Watshisheu Knoll the amphibolite sills have been elongated under stress until the plastic state could not be maintained, with the result that they have been pulled apart. The disconnected pieces are arranged in lines following the strike of the rock. The resulting cracks were filled with more mobile gneiss and pegmatite. A similar phenomenon was observed by Adams (1897) north of Montreal.

Plastic flowage of the quartzite was observed in the band of metasedimentary rocks exposed south of Tanguay lake. A good example is illustrated by Figure 1 of Plate 13 on page 97. In this case, deformation in the direction of bedding formed tension fractures in the friable pegmatite sills. The more flexible material, that is, quartzite and schist, flowed into the gaps between segments of pegmatite, rounding off the broken edges and forming typical boudinage structure. These observations show that, in response to stress, the rocks deformed in part by flowage.

The increase in deformation described above is very gradual. The writer believes that the rocks in the southern part of the area show a greater depth of erosion than those of the northern part. This hypothesis of increasing depths of erosion from north to south would explain the greater amount of granite exposed close to the sea, as well as the increasing deformation from north to south.

It is conceivable, therefore, that the structural pattern of the formations in the southern part of the area was formed at a greater depth than that of the northern part and north of the area where the folds are of the more open shallow type. In the lower depths, close to and in the zone of flowage, relative movements of the rocks would probably produce minor folds, which have no apparent relation to major structures, such as the folds shown by the migmatites east of Watshishou Knoll.

The broad warping of the formations in the area may be explained by dragging effects, caused by flowage during the movement of material from one zone to another. In Figure 5 below, abcd represents an originally north-south trending vertical formation. The arrows show the direction of movement of material at depth. As deformation continued, drag effects, caused by movement, would cause formation abcd to assume positions shown by 2, 3, 4 and 5 respectively. The formation need not be



⟵ = direction of movement at depth.

abcd = vertical north-south trending formation.

a' b' c' d' etc. = position of abcd in 2, 3, 4, 5 respectively.

Figure 5. Sequence of deformation of a vertical formation.

vertical. A steeply dipping formation would act in the same manner.

The writer is fully aware that the above hypothesis is highly speculative and it is not proposed as a conclusive explanation of the structure. However, he believes that the idea of movement, due to flowage in the deeper parts of the earth's crust, may lead to a better understanding of the complex structures in deeply eroded areas, such as the Grenville Province (Gill, 1949) of the Canadian Precambrian Shield.

ECONOMIC GEOLOGY

Occurrences within the area of copper minerals, feldspar, silica, beryl and mica have been known for several years and have been reported and described by earlier investigators. These, and additional occurrences of metallic minerals observed by the author, are described below.

Metallic Minerals

Copper On the northwest tip of a small point in Quetachou bay, three-quarters of a mile southwest of the mouth of Piashtibaie river, chalcocite was observed filling a fracture in impure quartzite. The fracture, which is one-quarter inch wide, is exposed for a length of eight feet and is mineralized along its whole length. Chalcocite was also observed disseminated in the quartzite for a distance of two inches on each side of the fracture. Some malachite and azurite occur with the chalcocite. A grab-sample, assayed in the laboratories of the Quebec Department of Mines, yielded 7.59 percent copper.

Three-quarters of a mile west of Watshishou river, on the northwest corner of a small island, a gabbro dyke is cut by a narrow pegmatite. At the contact, bornite with some chalcopyrite occurs in small irregular pockets and fractures in the pegmatite. No mineralization was found in the gabbro. The zone of mineralization is exposed for twelve feet and is two feet wide. This mineralization does not continue either to the north or south. A grab-sample from this zone yielded 6 percent copper and 0.742 oz. silver per ton (Longley, 1950).

Pyrite and Chalcopyrite Very small quantities of chalcopyrite in fine grains disseminated through the gabbro were observed at several localities, particularly in the sheared gabbro near the coast. Some chalcopyrite in scattered specks and irregular small patches was observed in massive and sheared granite on the east side of Watshishou Knoll.

Pyrite, as small irregular grains or well-formed cubes, was observed disseminated in the fine-grained facies of uralite gabbro at a few localities, but the quantity is small. A few quartz veins and shear zones in the metasedimentary rocks exposed in Appititatte bay are sparsely mineralized with pyrite and occasionally with chalcopyrite.

Lead On the southeast shore of a small bay in Quetachou bay, one and one-half miles southwest of the mouth of Piashtibaie river, some galena was observed in a one foot quartz vein and at the contact between the vein and carbonate-bearing quartzite. It was not possible to determine the trend or possible extent of the mineralized zone, as it is exposed only at low tide and, then, only in a small round patch of about four square feet. A grab-sample in this zone, assayed in the laboratories of the Quebec Department of Mines, yielded 17.55 percent lead.

Iron Some occurrences of iron, though not of economic interest, are worthy of mention.

Noticeable quantities of magnetite in small dykes of pegmatite were found in the vicinity of Pontbriande bay, the mouth of Corneille river and west of Turgeon lake.

On the east side of the head of Quetachou bay, magnetite as well-defined crystals is disseminated through impure grey quartzite. In some places this mineral forms twenty percent of the volume of the rock.

Hematite is an abundant constituent of the thin black bands, which, with average thicknesses of 1/32 of an inch, occur in the quartzites at several localities. There is also some magnetite, in small amount, in these bands.

See the next paragraph for a further description of these occurrences.

<u>Titanium</u> As already mentioned, black bands in impure grey quartzite have been observed at several localities in the map-area. The best known exposures are east of Villeneuve lake, north of Cabane-Brulée lake, east of Little Piashti lake and on the west side of Quetachou bay. Magnetite, hematite and rutile are abundantly present in these black bands. The bands range in size from 1/64 to 1/4 of an inch in thickness and they alternate with bands of grey quartzite that are from one-half to six inches thick. They occur in zones that vary in thickness from one-half to three feet; two or three such zones may occur in twenty feet of quartzite. Most of these iron- and titanium-bearing zones are lense-shaped and do not extend, along their strike, for more than 25 or 30 feet. One three foot zone, two miles north of Cabane-Brulée lake, was observed, however, to have a length of more than 100 feet.

<u>Molybdenite</u> Small irregularly scattered flakes of molybdenite were observed in a narrow dyke of pegmatite cutting gabbro on the east side of the east point of Quetachou bay. The gabbro is a large inclusion in the pegmatite which underlies most of the point. It is cut by a narrow irregular dyke of fine-grained pegmatite, composed of white plagioclase (oligoclase) and a small amount of quartz and biotite. The trend of the dyke is N. 55° E. and parallels the long direction of the gabbro inclusion. Scattered grains of molybdenite occur in the dyke, usually near its contact. No mineralization was observed in the country rocks.

Non-Metallic Minerals

Beryl The writer observed crystals of beryl, previously reported by Claveau (1943) and Longley (1950), on the point east of the mouth of Watshishou river. More than a dozen crystals were found on the tip of the point and several others were observed on an island composed of pegmatite on the west side of the river. These crystals, which average one-half inch in diameter, occur in a muscovite-rich band in pegmatite. Several crystals of beryl were observed in pegmatite dykes cutting the granite on the east side of Ferland lake. These crystals are small, the largest measuring one inch in length and one-quarter inch in diameter. They occur in a muscovite-rich band in the pegmatite.

Feldspar The largest pegmatite dykes of this area are found on each side of Quetachou bay. They strike in a northeasterly direction. These dykes consist mainly of microcline and orthoclase feldspar with quartz and some biotite and muscovite. Although the average grain size of the pegmatite is between one-quarter and one-half of an inch, there are many zones in which crystals of feldspar measuring three feet by two feet were observed. These zones of coarse-grained feldspar are dispersed along a belt in the large pegmatite on the northeast side of the east side of Quetachou bay. The belt trends about N. 60° E. and is approximately 300 feet wide over a length of at least one-half a mile. Quarrying operations were carried out on the most favourable exposures at various times between 1914 and 1927. These were unsuccessful due to the presence of quartz, which occurs as an intergrowth with and interstitial to the feldspar crystals.

Garnet Many pegmatites contain streaks of fine-grained granular quartzitic material very rich in garnet. The garnets are very small, less than one-quarter inch in diameter. The greatest number and the largest size garnets are present in biotite schist on the east side of Mine bay. Garnets range up to one-half inch in diameter and form as much as twenty percent of the volume of the rock.

Mica Pegmatites of the area contain both muscovite and biotite mica. The largest exposure of mica is situated on the tip of a point east of the mouth of Watshishou river. Other exposures of mica were observed in pegmatite east-southeast of Ferland lake. The mica, muscovite which once formed large crystals, has been shattered to such an extent that it is impossible to obtain a sheet of more than four inches across. In no place where it occurs is the mica found in sufficient quantity to be mined, even as a low-grade mica.

Silica From Watshishou Knoll, a series of low hills, striking northeast, is composed, in part, of large pegmatite dykes. At the southwest end of the point pegmatite has been brecciated and recemented with a milky white quartz, which, in some places, forms over fifty percent of the rock. To the northeast, however, the percentage of quartz increases until, at Watshishou Hill, two miles northeast of the "Knoll", it is a body of fairly pure quartz more than 2,000 feet long and 200 feet wide at its widest point. Analysis of cross-sectional grab-samples, taken across the deposit at four localities (see Figure 6), gave the following results (Claveau, 1945).

Sample Line	Fe_2O_3	SiO_2	TiO_2	CaO	MgO	P_2O_5
1	0.03	98.73	0.009	nil	0.02	nil
2	0.06	97.67	0.014	nil	0.043	nil
3	0.015	99.35	0.006	nil	0.007	nil
4	0.03	98.81	0.007	nil	0.02	nil

There are indications of a large tonnage of high-grade silica being available at this locality.

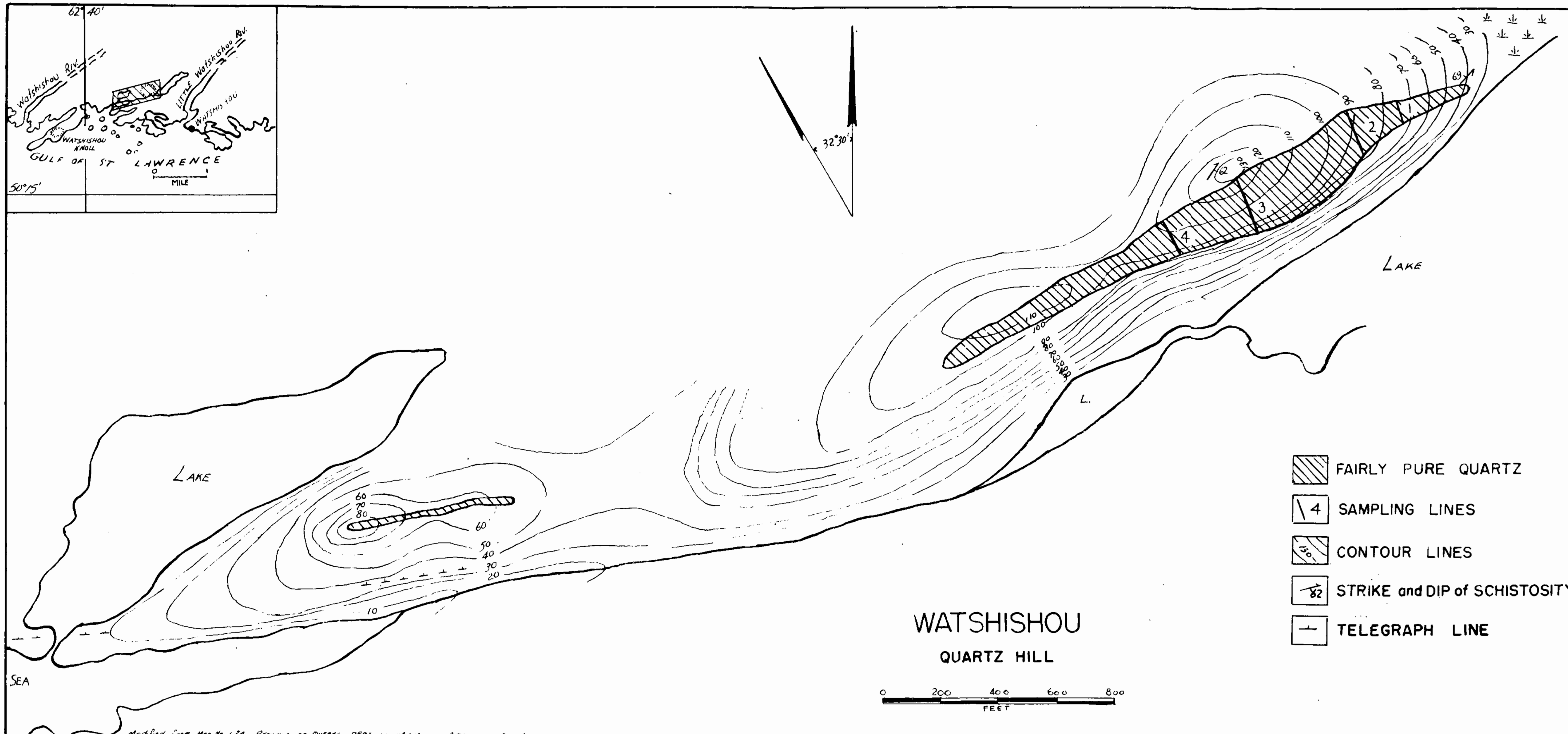


Figure 6. Map of Watshishou Quartz Hill.

SUMMARY AND CONCLUSIONS

The Johan Beetz Area is situated on the north shore of the Gulf of St. Lawrence, 440 miles below Quebec City. The area is most easily reached by boat or by seaplane.

The land rises from a low, flat irregular shore to an average height of less than 600 feet. The area may be divided into three topographic units. The underlying rocks and their structure are the most important factors in controlling the shape of the topography. The coastline is low, irregular and indented by numerous bays. Inland, the country is more rugged. Long narrow gabbro ridges, which alternate with narrow valleys underlain by quartzite, form a ridge and valley topography in the eastern part of the area. In the western part, the inland surface has the form of a gentle, southward sloping plateau. Lakes are abundant throughout the area. Glacial erosion during Pleistocene times has scoured the valleys and smoothed and polished the hilltops. Deposits left by the glacier are few and consist of sand, gravel and clay, some of which have been reworked by the present streams.

All the consolidated rocks of the area are of Precambrian age. The distribution of the various rock types is shown on the geological map which accompanies this thesis. The oldest rocks consist of a series of metamorphosed sediments. Fine-grained grey quartzite is most abundant. Calcareous quartzite, hematite- and rutile-bearing quartzite and, in the southern part of the area, micaceous quartzite, quartz-biotite gneiss and schist are interbedded with grey quartzite. All gradations between quartzite and schist were observed. These rocks have been metamorphosed under the temperature - pressure conditions corresponding to those of the albite-epidote amphibolite facies. The distribution of the metasedimentary rocks indicates that they were deposited in a shallow basin and that the conditions of sedimentation were undergoing continual changes. No correlation could be made between the rocks of this area and those of better known regions. The similarities between these rocks and those of the Grenville are discussed.

Migmatites are exposed at four localities within the area. These rocks have been formed by the introduction of granitic and pegmatitic material to the metasedimentary rocks. The gneisses east of Watshishou Knoll fit into the middle of three indefinitely defined depth zones as outlined by Eskola. The formation of the gneisses at Puyjalon Island appears to be related to the pegmatites which form an auriole around the gneissic granite. The close association between the Ferland lake granite and the migmatite of that area suggests that the solutions which formed them were derived from the granite. The origin of the solutions which transformed the metasedimentary rocks to migmatite west of the mouth of Watshishou river is unknown.

A series of sheet-like bodies of altered gabbro are the oldest intrusive rocks. In the southern part of the area they have been deformed to amphibolite and, close to and between the granites, to various hybrid rocks. In view of the ophitic texture and the secondary nature of the amphiboles present in the rock, the term uralite gabbro is proposed for the less altered types, indicating the former presence of pyroxene. The alteration of the gabbro has been complex, involving the redistribution of the original constituents and the addition of new material. The granite appears to have been the cause of the alteration of the gabbro.

The association between the gabbro and the anorthosite exposed north of Havre St. Pierre suggests that the two rocks are genetically related. The gabbro may be a late differentiation product of a magma formed by the partial melting of primordial gabbroic or anorthositic horizons of primordial layers in the earth's crust.

There are two ages of granite in the area. The older granite, which is gneissic, resembles the mantled gneiss domes of Finland. The source of the granite is uncertain, but it may represent the product of palingenesis, which was forced upwards, lifting the overlying country rock and injecting into it. Four bodies of medium-grained biotite granite outcrop in the area. They have similar mineralogical compositions and textures and are considered to be contemporaneous and genetically related. Field evidence shows that the largest bodies have been intruded by magmatic stoping, forceful injection and assimilation of the stoped-out blocks of the country rocks. Coarse-grained granite is exposed in the northwest corner of the area. Because it is separated by a band of metasedimentary rocks and gabbro, its relation to the remaining granites is obscure. It may be slightly older, inasmuch as it is cut by two dykes of medium-grained granite.

There are two ages of pegmatite dykes and sills. One group is older than the medium-grained granite; the other younger. These latter dykes are of large size and coarse-grained.

The attitude of the metasedimentary rocks in the northern part of the area shows that they have been folded into two anticlines and two synclines which plunge southward. It was not possible to trace these folds the entire length of the map-area, owing to the general northwest dip of the formations in the southern part of the area. All the rock types are jointed. Most of the joints in the gabbro and granitic rocks are interpreted as tension joints formed during cooling and crystallization. In the schistose members of the metasedimentary rocks, schistosity has been developed parallel to the bedding. No structures which could definitely be recognized as faults were observed in the area.

In the northern part of the area, the trend of the formations is south, but the trend changes to southwest and west in the southern part of the area. Various interpretations of the regional structure were discussed. It is shown that there is a gradual increase in the degree of deformation of the rocks from north to south. This increase in deformation is shown by a greater depth of erosion in the southern part of the area. The change in the trend of the formations is tentatively interpreted as caused by drag effects, due to the movement of material at depth.

No deposits of metallic minerals of economic importance were observed in the area. Small occurrences of copper minerals, lead, iron and molybdenite and a few non-metallic minerals are described. There are indications of a large tonnage of silica at Watshishou Hill.

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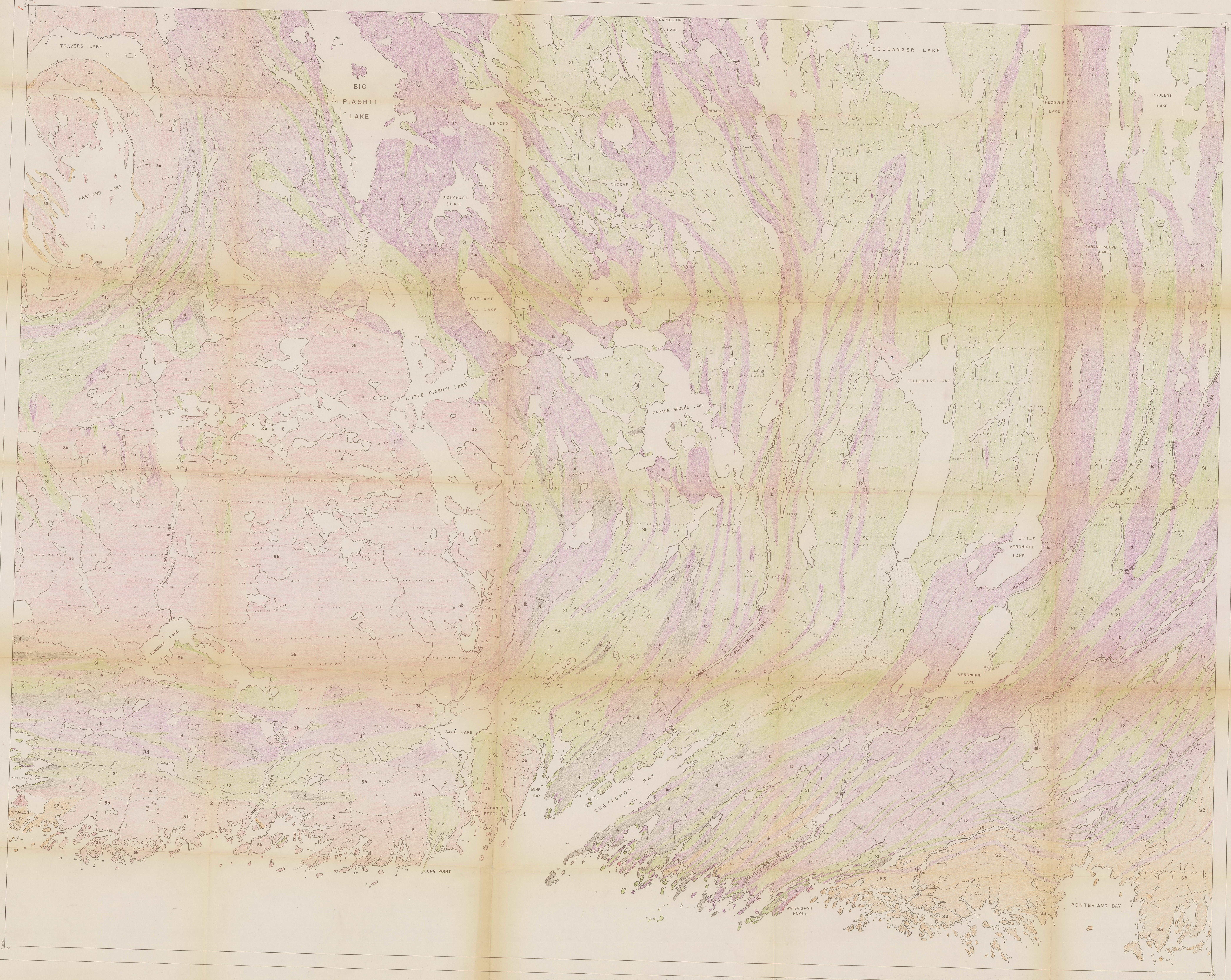


JOHAN BEETZ AREA

SAGUENAY COUNTY

LEGEND

PRECAMBRIAN

4	PEGMATITE
3	(3a) COARSE-GRAINED BIOTITE GRANITE (3b) MEDIUM-GRAINED BIOTITE GRANITE
2	GNEISSIC GRANITE
1	URALITE GABBRO AND DERIVATIVES (1a) URALITE GABBRO (1b) AMPHIBOLITE (1c) AMPHIBOLE GNEISS (1d) HYBRID ROCKS
S3	MIGMATITE
S2	MICACEOUS QUARTZITE; QUARTZ-BIOTITE SCHIST; QUARTZ-BIOTITE GNEISS
S1	GREY QUARTZITE; CALCAREOUS QUARTZITE; CRYSTALLINE LIMESTONE; THIN CONGLOMERATE LENSE

a b c d — STRIKE AND DIP OF BEDDING: (a) INCLINED (b) VERTICAL (c) OVERTURNED (d) DIP NOT DETERMINED

a b — STRIKE AND DIP OF SCHISTOSITY: (a) INCLINED (b) VERTICAL

a b — STRIKE AND DIP OF GNEISSIC STRUCTURE: (a) INCLINED (b) VERTICAL

a b — STRIKE AND DIP OF JOINTS: (a) INCLINED (b) VERTICAL

OBSERVED OUTCROP

a b c — GEOLOGICAL BOUNDARY: (a) OBSERVED (b) APPROXIMATE (c) ASSUMED

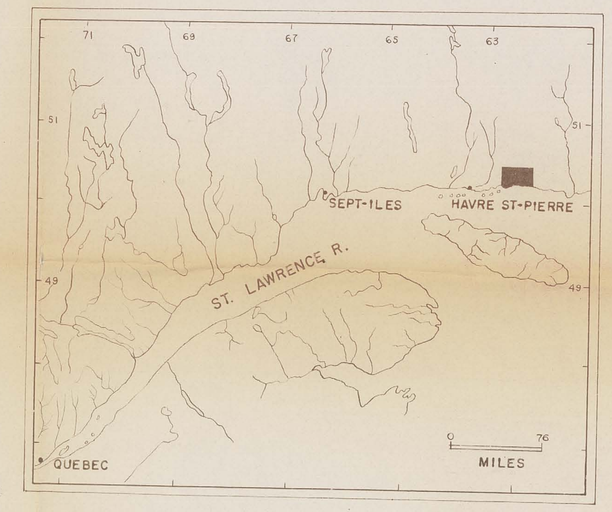
GLACIAL STRIAE

RAPIDS CHUTE PORTAGE

GEODETIC TRIANGULATION STATION

CLAY, SAND

APPROXIMATE MAGNETIC DECLINATION 32°30' WEST



INDEX MAP

1 ½ 0 1 2

SCALE: 1 MILE TO 2 INCHES

GEOLOGY BY GERALD E. COOPER, 1951, 1952.