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GEOLOGY OF THE SURPRISE LAKE AREA, QUEBEC

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GEOLOGY

of the

SURPRISE LAKE AREA, QUEBEC

by

A. N. Doland

A Dissertation Presented to the Faculty
of the Graduate School of Yale
University in Candidacy for the
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MAPS AND ILLUSTRATIONS

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GEOLOGY OF THE SURPRISE LAKE AREA, QUEBEC

Abstract

The area lies in Abitibi-East county, Quebec, about 35 miles southwest of the village of Chibougamau and 240 miles northwest of Quebec city. It comprises three fifteen minute sheets (about 600 square miles) mapped in the summers of 1952, 1953 and 1954.

All the consolidated rocks of the area are of Precambrian age. They belong to two different geologic and geographic divisions of the Canadian shield, the Timiskaming and the Grenville subprovinces. Except for scattered outcrops, these Precambrian rocks are covered by Pleistocene drift.

The rocks in the north-northwest half of the area are Keewatin-type rocks and belong to the Timiskaming subprovince. They consist mainly of altered lavas ranging from basalts to rhyolites, with sedimentary rocks, pyroclastics and intermediate to basic intrusives making up the remainder. These rocks, for the most part belong to the greenschist metamorphic facies.

The south-southeast half of the area is underlain by hornblende and biotite gneisses which are Grenville-type. These gneisses belong to the amphibolite metamorphic facies, and in places, they are coarse-grained and rich in garnet.

The Keewatin-type sedimentary and volcanic rocks grade eastward through a zone of transition into the Grenville-type biotite and hornblende gneisses and amphibolites. The zone of transition, which separates the Keewatin- and the Grenville-type rocks, is 2 to 3 miles wide and crosses the area diagonally from the northeast corner to the south central part. Thus, the Grenville-type gneisses are the more highly metamorphosed equivalents of the Keewatin-type lavas and sedimentary rocks.

The Keewatin- and the Grenville-type rocks are intruded by granite and granite gneiss masses of different varieties. Late Precambrian diabase dikes intrude the granite, and are the youngest consolidated rocks in the area. They may be of Keweenawan age.

The east-trending Keewatin-type rocks are not truncated by the structure of the Grenville-type gneisses. Most of the Grenville-type gneisses continue the east-west trend of the Keewatin-type rocks, but in places swing to the northeast, the change in strike being gradual. A fault and diabase dikes, trending northeast, are superimposed on the general east-west trend. Here, the so-called Grenville front is a zone in which rocks of one time-stratigraphic series pass from a lower to a higher grade of metamorphism.

Numerous shear zones in the Keewatin-type rocks are mineralized with sulphides and gold, and may become producers of gold and copper. Uranium occurs in some pegmatites associated with the granite.

INTRODUCTION

The Surprise Lake region was studied geologically to examine and to map the relationship between the Keewatin type rocks found in the northwest part of the area and the Grenville-type rocks found in the southeast part. The relationship between the Timiskaming and the Grenville provinces of the Canadian Shield is still one of the most puzzling problems of Precambrian geology, and it was hoped that further work along the boundary of these two provinces might shed some light on the relative ages of the different rock types.

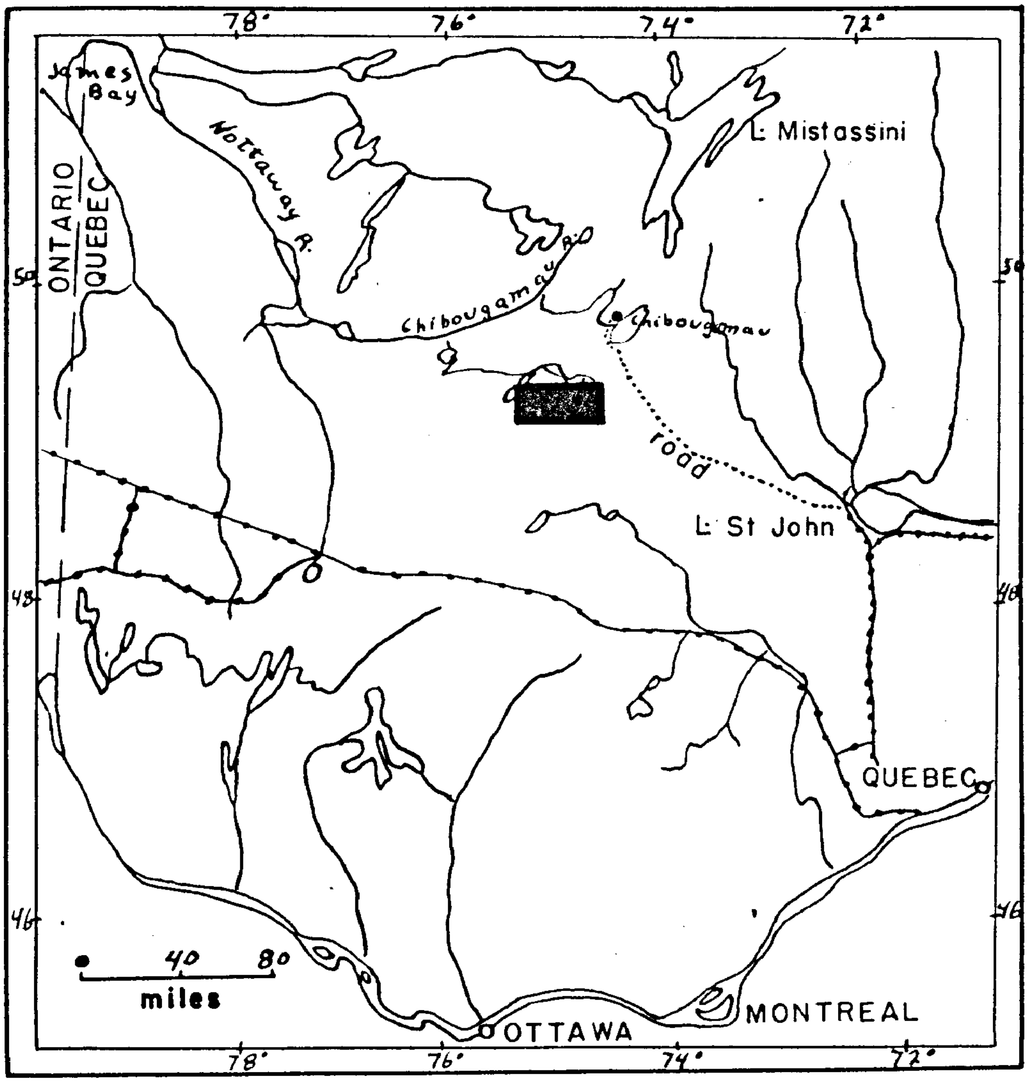
Part of the writer's work also consisted of investigating and studying the occurrences of mineralized zones in the Keewatin-type rocks, and of determining if the mineralization extended into the region of the gneisses.

The work was done in the summers of 1952, 1953, and 1954, under the direction of the Quebec Department of Mines.

Location and Access

The Surprise Lake area lies in Abitibi-East county, Quebec (Fig. I, p. 2). The center of the area is located about 240 miles northwest of Quebec city and some 45 miles southwest of the village of Chibougamau. The map-area includes the townships of Druillettes and Hazeur, large parts of Gradis, Gamache, Langloiserie and Pambrun, and smaller parts of Crisafy and Machault townships. It is bounded by latitudes 49° 15' and 49° 30' North and by longitudes 74° 30' and 75° 15' West, and comprises about 575 square miles.

The adjoining area to the east was mapped by Gilbert (1952)



Fig·I·– Location of Area

in the summer of 1951, and part of the area to the north was mapped in 1952 (Lyall, 1953). The northern boundary of the Buteux Area, mapped by B.C. Freeman (1943), is approximately seven miles south of the map-area.

The area is easily accessible. The St. Felicien-Chibougamau all-weather highway passes only 12 miles from the northeast corner of the map-area. A side road, which leaves the highway at mile post 121 (i.e. 121 miles from St. Felicien) enters the northeast corner of the area one mile to the north of Meston lake. This side road, approximately 15 miles long, extends only one mile west of Meston lake, and the only practical way of reaching the other parts of the area is by sea-plane.

Lakes that afford good landing places are numerous and well located to provide access to all parts of the area. From Windy, Caopatina, Surprise and Doda lakes, the greater part of the area is accessible by canoe. There are three short portages along the part of the Opawica river that links Caopatina and Windy lakes. A single longer portage of 6500 feet offers a second more direct, although more laborious, passage between these two lakes. There is but one short portage between Caopatina and Surprise lakes. Caopatina and Windy lakes are also separated by one short portage. Travelling between lake Surprise and lake Doda is most easily done by sea-plane as the canoe route involves six portages, one of which is more than a mile long and over swampy ground. The long bays of Surprise lake were very helpful in covering the south central part of the area. Numerous other smaller lakes can also be used for plane landings.

The two main navigable rivers, the Opawica and de l'Aigle rivers, permit easy access of the southeastern and southwestern parts of the area respectively. These rivers have many rapids and falls but canoe portages by-pass the hazardous places. These portages, as well as those linking the smaller lakes and rivers are in good condition. The smaller Hebert and Roy rivers permit easy access to the western and south central parts of the area respectively.

Previous Work and History of Development

The history of the development of the Chibougamau district started in 1903 when discoveries of copper and asbestos were made of the shores of lake Chibougamau. Subsequent findings of gold and iron led more prospectors into the district. By 1909, people interested in the development of this region asked the Quebec government for construction of a railroad to the Chibougamau area. As a response to this request, the Quebec government formed the Chibougamau Mining Commission. This commission had to judge the value of the discoveries already made and estimate if future mining possibilities warranted the construction of the railroad. The report of the Mining Commission (Faribault, Guillim and Barlow, 1911) did not favor the immediate construction of the railroad. The prospectors, however, kept going into the area, and other finds were made.

In 1927, 1930 and 1935, The Geological Survey of Canada sent geologists into the district to do more mapping. Geological Survey of Canada memoir 185 on the Chibougamau Lake Map-Area, (Mawdsley and Norman, 1935) and a preliminary report on the Opawica-Chibougamau Map-Area (Norman, 1936) were published by the Canadian Survey. In 1938, two geologic maps on the Chibougamau Sheet were issued by the Canadian Department of Mines and Resources (Mawdsley and Norman, 1938; Retty and Norman, 1938). These two maps published on a scale of four miles to the inch, are accompanied by marginal notes but no final report has yet been issued. Discoveries of massive sulphide mineralization with gold values in the area immediately south of lake Doda led to the geologic mapping of the Buteux area by the Quebec Department of Mines (Freeman, 1943). Further development of the region was greatly handicapped by transportation difficulties.

In 1949, the Quebec Department of Mines completed the all-weather St. Felicien-Chibougamau highway. With easier access to the area, exploration, prospecting and geologic mapping was carried out at a much accelerated pace. This renewal and intensification of activity resulted in the discoveries of many important prospects, some of which were made in the area covered by this report. Prior to and during the writer's investigation, prospecting was carried out especially in the north and northeast parts of the area. Geophysical surveys were also made near lake d' Eu and near Moston lake.

A program of geologic mapping was started by the Quebec Department of Mines after completion of the highway.

Present Work

Field work was carried out in the summer months of 1952, 1953, and 1954. During each field season, a fifteen minute sheet was covered. Preliminary reports (Grenier, 1953; Deland, 1953) covering two of these three areas have been published by the Quebec Department of Mines. The third report covering the westernmost fifteen minute sheet will be available in May 1955.

A total of slightly more than 300 days were spent in the field. Whenever weather conditions were favorable, two and occasionally three parties were used for the mapping. The area was covered by pace and compass traverses and shoreline work. The traverses were spaced every 2000 feet to 2500 feet apart, and whenever possible were run in a north-south direction across the trends of the formations. This was found more profitable than trying to walk the contacts because the latter are transitional and are covered with glacial drift in most places. Much information was derived from work along the shorelines where bedrock was better exposed than in the areas between the lakes.

The traverses and shoreline geology were plotted on an accurate half a mile to the inch base map. The base map was compiled in the offices of the Quebec Department of Mines from preliminary surveyed maps and a set of vertical aerial photographs taken by the Royal Canadian Air Force. The positions of mile posts along the surveyed lines and of bench mark stations on the shorelines provide good control in plotting the outcrops on the base maps. The aerial photographs were carried in the field and proved very useful in locating positions while mapping. Aneroid barometers were used to determine the elevations of some of the highest hills.

Laboratory work included a petrographic study of about 300 thin sections. Heavy liquids and magnetic separators were used in studying the minerals. The universal stage and oil immersion methods were also used to determine the compositions of some of the minerals. The mineral constituents of 18 rock specimens were determined by x-ray methods in the laboratories of the Quebec Department of Mines. The geology was plotted on a half a mile to the inch base map, and the map was then sent to the Quebec office for reduction of scale. The final map is on a scale of one mile to the inch.

An attempt was made to use the rock color chart distributed by the National Research Council. The color chart proved helpful in determining the colors of the less metamorphosed sediments and of some lava flows. The chart could not be used in describing the higher grade metamorphic rocks.

Fourteen samples from mineralized zones were also analysed in the laboratories of the Quebec Department of Mines to determine the presence and amounts of gold, silver, copper, nickel, lead, zinc, or iron.

Acknowledgements

The dissertation was written under the direction of Professors Alan M.Bateman and Matt S.Walton. Deep appreciation is expressed for their valuable guidance and constructive criticism.

The writer is grateful to Professor John Rodgers who read and edited the section of this report dealing with structural geology.

The writer wishes to express his indebtedness to the staff of the Survey's branch of the Quebec Department of Mines and especially to Dr. I.W. Jones, chief of the branch. During the summer of 1952 Dr. P.E. Grenier, now with the Mines branch of the Quebec Department of Mines spent about two months with the writer pointing out the main geologic problems of the area. His guidance in the field as well as his mapping and his collaboration are deeply acknowledged here. Grenier (1953) wrote the preliminary report on the Gamache area.

Much of the information used in the present work was collected by Jerome H. Remick III of the University of Michigan. Remick acted as senior assistant during the 1953 and 1954 field seasons, and his valuable help is gladly acknowledged.

Additional help from field assistants and from fellow graduate students is also acknowledged.

DESCRIPTION OF AREA

Topography

The area lies immediately west of the height-of-land separating the Hudson Bay and the St. Lawrence River basins. South of Deux Iles lake, near the boundary of the map-area, the height-of-land is only four miles to the east. The area slopes very gently to the northwest towards Hudson Bay. The area has a general elevation of 1300 feet above sea level near the eastern boundary, and of slightly over 1100 feet near the western boundary. The elevations of the main lakes, listed from east-southeast to northwest, are: Deux Iles - 1280; Surprise - 1223; Caopatina - 1198; Windy - 1172; Doda - 1109.(1)

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(1) Elevations of lakes are given on Chibougamau-Roberval Sheet, National Topographic Series - 32SE, 1951.

The difference in elevation between the easternmost lake and the westernmost one is 171 feet, and the distance between these two lakes is over 35 miles. The Opawica river which connects all these lakes thus has a general gradient of less than 5 feet per mile, reflecting the flatness of the area.

The topography of the map-area is typical of this part of the Canadian shield. The local relief is not marked, and the land surface, in general, is remarkably flat. Closer examination, either in the field or from aerial photos, shows that in most places this flat surface is slightly irregular with many low hills. There are places where tracts of land 6 or more miles long can be followed without a change of 50 feet in elevation. Most hills have gentle slopes, and few rise more than 100 feet above the general level of the lakes. A large portion of the map-area not covered by bodies of water consists of swamps and muskeg or low ground. There are, however, a few hills that constitute exceptions to this low gentle topography. The highest hill in the area is about one mile west of the south west bay of Surprise lake. This hill, on which the Quebec Department of Lands and Forests has erected an observation tower, rises 550 feet above the level of lake Surprise within a distance of a mile. Another ridge between Renick and No Rock lake rises about 300 feet above the level of these lakes. On Tower peninsula of Doda lake a hill rises 400 feet above the level of the lake and is the site of another observation tower. A third tower, erected in the summer of 1954, is located on a low hill near the south east shore of lake Caopatina.

In general, the local relief bears little or no relation to the underlying bedrock. Thus hills and low swampy grounds are observed over the granitic areas, as well as over the Keewatin-type rocks or their metamorphosed equivalents. However, when dealing with individual rock exposures, some rocks are more resistant than others and may account for some of the smaller topographic features.

Lakes and Rivers

A striking feature of the area is the profusion of lakes. More than 31 percent of the map-area is covered by bodies of water. The major lakes listed on page 9 are all connected by the Opawica river, which drains much of the eastern part of the area. The western part is drained by de l'Aigle river, a tributary of the Opawica. From Doda lake, the Opawica river continues westward and then northward into James Bay through Waswanipi and Nottaway rivers.

The lakes and rivers constitute a complex drainage system that cannot be placed into any of the standard drainage patterns. Some of the larger lakes, like Windy and Caopatina are characterized by very intricate shorelines. There is apparently no structural nor lithologic control over the sizes and shapes of these lakes. Windy lake occupies a depression in bedrock, and its shores are characterized by nearly continuous exposures. Lake Caopatina, on the other hand, occupies a basin filled by glacial material, and outcrops are very rare on its shoreline. Both these lakes are shallow, and the outcrops of Windy as well as the boulders of Caopatina make travelling by canoe rather hazardous. Other lakes, such as Doda and Surprise, have been only partly filled by drift and their shores are partly rocky and partly made of glacial material. These two lakes are deep and constitute excellent canoe routes.

During the uplift that followed deglaciation, the Opawica and de l'Aigle rivers have deepened their channels across unconsolidated glacial material. The channels are twenty to thirty feet deep in most places, but where the rivers cut through coarser glacial material, these channels are not so deep, and rapids and waterfalls are numerous. Nearly all the rapids on the Opawica and de l'Aigle rivers are on coarse boulders.

Glacial Topographic Features

Looking at a small scale map of Abitibi-East and Roberval counties, one is struck by the very pronounced lineation of topographic features. There is a marked northeast trend of most of the large lakes. This trend is not indicated by the large lakes in the map-area, although the non-rocky shores of these lakes do show this pronounced lineation. Most of the medium and smaller size lakes show this northeast trend. The most striking glacial topographic features of the area are the long northeast trending points on the north shore of lake Caopatina.

Aside from giving this pronounced lineation, the glaciers also contributed to flattening a surface that was already flat before glaciation. Most of the glacial features of the area are depositional features and they will be discussed in the section on Cenozoic.

Inhabitants, Climate and Resources

The area is uninhabited save for one indian family living on the east shore of Doda lake at the mouth of the de l'Aigle river. During the summer months, the Quebec Department of Lands and Forests operates three observation towers. Two men are stationed at the towers of Caopatina and Surprise lakes. The main camp of this department in the region is located at the mouth of the de l'Aigle river on the east shore of lake Doda. From five to ten men inhabit this base camp during the summer months.

The climate is rigorous and the summers are short. The "break up" of the ice occurs in May and the "freeze up" in November, and the best season to do field work is from the first days of June to the first days of October. Night frosts are common in June and September.

Because of the rigorous climate, and the lack of good soil or clays, there are practically no agricultural possibilities. The Quebec Department of Lands and Forests has developed a garden on a sandy area, and has had some success in growing potatoes and other vegetables. Wild blueberries and raspberries are abundant in some parts of the area.

The area is thickly covered by various characteristic trees. Black spruce is the most abundant tree and some beautiful stands constitute large reserves for the pulp industry. Other varieties of conifers include the jackpine, tamarack, white cedar and balsam fir. White birch and poplar are the only deciduous trees but they are much less common than the conifers.

Falls on the de l'Aigle and Opawica rivers constitute a potential source of electrical energy.

Fish are abundant in all the lakes; pike and pickerel are the most common varieties. Sturgeon and grey trout have been caught occasionally. Brook trout have been caught in some of the small creeks, but they are rare.

Among the larger game animals, moose are common, and black bear rare. Beaver and muskrat are the most common small fur-bearing animals.

GENERAL GEOLOGY

All the consolidated rocks of the map-area are of Precambrian age. The north and northwestern parts are underlain by an assemblage of typical Keewatin-type rocks. These consist mainly of altered lavas ranging from basalts to rhyolites with sedimentary rocks, pyroclastics and intermediate to basic intrusives making up the remainder. This complex assemblage has been intensely folded and deformed so that now the strata are either steeply inclined or in a vertical position and generally strike easterly. Shear zones also strike easterly and are common in this northern half of the area and many of them are mineralized.

The south and southeastern parts of the area are underlain by gneissic granite, biotite and hornblende paragneisses, hornblende gneiss and amphibolite. Some of these metamorphic rocks are rich in garnet , are highly crystalline, and resemble Grenville-type rocks. The paragneisses and hornblende gneiss also generally strike east; however, near the southeast corner of the map-area the formations and the schistosity tend to assume a north-northeast trend. This change in the direction of the structure is rather gradual. In the gneissic granite, the gneissosity is much less regular, although the easterly trend still seems to be the rule.

A few dikes of diabase, probably of late Precambrian age, cut the gneissic granite and the Keewatin-type rocks.

Very little prospecting was done in the part underlain by gneisses prior to the summer of 1954 when uranium was discovered in pegmatites associated with the gneissic granite.

The Keewatin-type rocks in the northern part of the area are located at the southeastern border of the Timiskaming subprovince of the Canadian Shield, and the crystalline gneisses and granite of the area are at the northwestern boundary of the Grenville subprovince. Thus, a segment of the postulated boundary between the two subprovinces crosses the area diagonally from the northeastern to the south central part. Lithologic and structural evidence indicates that the metamorphic hornblende and biotite gneisses are the metamorphosed equivalents of the Keewatin lavas and sedimentary rocks into which they pass gradationally. Faulting forms only a minor part of the structural features.

Except for scattered outcrops, all the Precambrian rocks are covered by unconsolidated glacial material of Pleistocene age.

The major types of rocks are represented in the table of formations (Table 1, p. 16).

Table I

Table of Formations

Cenozoic	Pleistocene	clay, sand and gravel, till
	Great unconformity	
Late Precambrian	Keweenawan (?)	diabase dikes
	Intrusive contact	
Early or Late Precambrian	Grenville (?)	gneissic granite, syenite, diorite, pegmatite, aplite
	Intrusive contact	
Early Precambrian	Keewatin(?) Progressive metamorphism during Grenville (?) orogeny	**Grenville-type rocks** hornblende gneiss amphibolite biotite and/or hornblende paragneisses (may be partly from source other than Keewatin-type rocks) **Modified Keewatin-type rocks** mica schist hornblende schist hornblende-chlorite schist amphibolite **Keewatin-type rocks** sedimentary rocks gabbro-diorite sills basalt, andesite, rhyolite and some pyroclastic rocks

KEEWATIN (?)

Keewatin-type rocks underlie a belt that trends east-west across the northern half of the map-area. This belt is about three and a half miles wide at the eastern boundary and it attains a width of eight miles at the western boundary of the area. Measured from the western end of lake Surprise northward, the belt has a maximum width of about ten miles. The belt occupies more than one third of the map-area or about 225 square miles. It is the extension to the south and to the west of the belts described by Holmes (1952), Lyall (1953) and Gilbert (1952).

The Keewatin-type rocks consist essentially of basic to acidic flows, small amounts of pyroclastic rocks, sedimentary rocks, and intrusive sills of metagabbro and metadiorite. These rock units are not interbedded at random but tend to be grouped in several characteristic associations. Thus, the intermediate and basic lava flows are always intimately associated with sills of metagabbro and metadiorite. These sills, on the other hand, were never observed in contact with the more acidic flows. Rhyolites and trachytes form units that can easily be separated from the andesites and basalts. Pyroclastics such as volcanic breccia and agglomerate are associated with the rhyolites and trachytes. The sedimentary rocks seem to have a more complex distribution. They occur in thick units such as the belt south of lake Caopatina and the one north of lake Surprise, and they also occur in thinner units intimately associated with the andesites and basalts or with acidic flows. Sedimentary rocks were never observed in contact with the metagabbro and metadiorite.

All the Keewatin-type rocks have undergone regional metamorphism and in more deformed zones of the belt some have been affected by hydrothermal alteration. As expected, the acidic flows and the quartzo-feldspathic sediments have undergone less change than the rocks of intermediate to basic composition. Because of this metamorphism, the andesites and basalts cannot be separated on the present scale of mapping, and they have been grouped together on the geologic map. The intrusive sills of gabbro-diorite have been differentiated from the lavas on the basis of texture alone, but the separation is difficult in places, as a schistose gabbro-diorite may look very much like a schistose andesite or basalt.

Andesites and Basalts

Occurrence

Flows of andesites and basalts are widely distributed in the belt of Keewatin-type rocks. The best exposures are on the shores of Windy lake and also on the hill east of No Rock lake. It is difficult to measure the thicknesses of individual flows because regional metamorphism has obliterated many of the contact features that might have been helpful in separating one flow from another. A continuous exposure along the east point of Windy lake gives some clues as to the nature of these flows. The sequence here from north to south, or from top to bottom, is as follows:

andesite, brecciated	110 feet	
andesite, schistose	90 feet	
andesite, brecciated	100 feet	
diorite, massive	15 feet	
diorite, schistose	25 feet	
andesite, schistose	25 feet	
diorite, massive	145 feet	(lower 60 feet has disseminated sulphides)
andesite, pillowed	25 feet	

From the exposures on the shores of Windy lake it appears that many of the individual flows are from 25 to 100 feet thick. This estimated thickness rests on very feeble evidence, and some of the flows might very well fall outside this range. Detailed mapping in an area northwest of lake Chibougamau (Smith, 1953, p. 5) has shown that the individual lava flows have an average thickness of ten to twenty feet but that some of them may be as much as a hundred feet thick. Ellipsoidal structures are the most striking primary features of the intermediate types of lava, and vesicular and amygdaloidal structures are rare. Flow structure was never observed in the field, and columnar jointing is absent, although basaltic flows are generally well jointed (Pl. V-A).

Ellipsoidal structures are best developed in the andesites and, on Windy lake, about half of the less deformed flows have pillowed structures. The individual pillows (Pl. II-A) are generally about one foot long, although many of them may measure as much as five or six feet. The ellipsoids are separated by layers of darker material one half to one and one half inches thick. This material weathers more easily than the pillows themselves and accentuates the structure, (Pl. II-B). Two of the main types of pillows described by Shrock (1948, p.364) are commonly observed: the balloon type, which is the most common, and the loaf-shaped pillows. These two types, however, are not always easily separated and they grade into each other. Many pillows have been deformed and stretched during the periods of deformation but some of the less deformed balloon-type are useful in determining the tops of the flows. A few of the pillows are characterized by vesicular structures near their margins and some of the vesicles have been filled with calcite.

Petrography

The andesites and basalts are fine-grained, greenish gray (5GY4/1)[1] to dark gray (N3), and are generally grouped under the general field term of "greenstone". The rock is slightly schistose in some places and highly schistose in others.

Microscopic examination of the less schistose andesite and basalt shows that the rock has a homogeneous texture consisting of a mass of secondary minerals. Most of these minerals are fibrous and have random fabric orientation so as to give the sections a characteristic interwoven texture. In some of the sections, the original ophitic or sub-ophitic texture can still be observed. The grain size is 0.01 mm and the individual grains, whether they are anhedral or fibrous, lack sharp boundaries and seem to grade into each other. Under crossed nicols, the sections are gray to very dark gray, as nearly all the minerals have low birefringence. Veinlets

1. Symbols are those of the Rock Color Chart distributed by the National Research Council.

of quartz, calcite, epidote and a few sulphides attest to the amount of introduced material. Many of the veinlets are microscopic in size and cannot be seen in the hand specimens. The essential mineral constituents of these lavas are colorless amphiboles, plagioclase, epidote, chlorite and minor quartz, and the accessories include biotite, magnetite, pyrite and sphene.

Colorless amphiboles, mostly of the actinolite variety, occur as fibrous or feathery grains that have a characteristic wavy extinction. The mineral has grown in a porphyroblastic form but there is no relict primary mineral to show whether the actinolite is secondary after a pyroxene, an amphibole, or some other mineral or mineral aggregate. Actinolite tends to form grains that are slightly larger than the other minerals. The long needle-like grains give an extinction angle $Z \wedge c$ of 10 degrees in some sections but as much as 17 degrees in others. The fibrous mineral is length-slow, and has rather weak birefringence ranging up to about 0.01. In some sections, the amphibole is slightly pleochroic, from light green to nearly colorless and is believed to be tremolite.

Some euhedral laths that may be as much as 0.5 mm long are completely saussuritized plagioclase and the composition of the original plagioclase cannot be determined. Other smaller grains of feldspar are clear and anhedral and have a negative relief against Canada balsam. This clear plagioclase is twinned in a few sections and has a composition of An_{10}. It is believed to be secondary albite resulting from the alteration of a more calcic plagioclase.

The two varieties of epidote, namely pistacite (iron epidote) and clinozoisite (iron-free epidote) constitute the next most common minerals and, in some sections, may account for thirty percent of the rock. The microscopic examination of the andesites and basalts affords a very good illustration of the great ease with which epidote moves or reacts to metamorphic conditions. In some of the sections, clinozoisite is found surrounded by aggregates of saussurite grains. The clinozoisite grains are colorless, biaxial positive, and have a 2V of about 80 degrees. Epidote grows in a porphyroblastic manner at the expense of cloudy grains of saussuritite and clear clinozoisite. The iron concentrates in the centers of these porphyroblasts and gives the grains a slight yellowish pleochroism and first order yellow to red interference colors, whereas the borders give anomalous grayish blue interference colors typical of clinozoisite. The borders of the porphyroblasts still show aggregate structure but the centers do not. The iron epidote is biaxial negative, has a 2V of about 80 degrees and has negative elongation. Most of the epidote is definitely secondary and probably formed more or less directly from the alteration of plagioclase; however, some grains are associated with quartz, calcite and sulphides in veinlets and may have been introduced.

Chlorite occurs as small flakes that are slightly pleochroic from colorless to very light green, and have very weak birefringence and characteristic wavy extinction. Greenish brown and purplish gray are the most common interference colors but anomalous berlin blue is occasionally observed. Most of the chlorite appears to be of the clinochlore variety although penninite and prochlorite may also be present. Most chlorite is secondary after hornblende.

Quartz is rare in the meta-andesites and meta-basalts, and was observed in only one of the sections, although it may be common in the aphanitic groundmass. The grains are clear and anhedral and are very likely secondary.

Anhedral sphene, euhedral pyrite and some secondary iron oxide, probably limonite, are the accessories.

Mineral Assemblage and Metamorphic Facies

The percentages of the various mineral constituents in the andesites and basalts are highly variable as indicated below:

	%
actinolite-tremolite	20-80
saussurite and epidote	5-45
chlorite	0-35
albite	0-30
calcite	0-10
biotite	0-10

Estimated mineral compositions of fourteen sections give the following average.

	%
actinolite-tremolite	50
epidote and clinozoisite	15
saussurite	10
chlorite	10
albite	5
accessories:	sphene, calcite, biotite quartz, magnetite, pyrite

This assemblage indicates that these rocks belong in the biotite-chlorite subfacies of the greenschist facies for rocks deficient in potash and with excess silica (Turner and

Verhoogen, 1951, p. 466-469).

Metagabbro and Metadiorite

Occurrence

Widely distributed throughout the intermediate and basic lavas and intimately associated with them are sills and lense-like bodies of altered gabbro and diorite that, wherever observed, are conformable with the flows. These rocks were nowhere seen in contact with the sediments or the rhyolites. The largest single unit is about 1500 feet wide and more than two miles long and is exposed along the central part of Windy lake. Most of the intrusive sills, however, are of much smaller size and their width generally varies from 10 to 100 feet. They are thus too small to be indicated on the accompanying map. By using different symbols, an attempt was made to separate the intrusive sills from the flows, although, as mentioned previously, a schistose gabbro-diorite rock cannot in some places be differentiated from a schistose andesite.

Petrography

The gabbro-diorite rock is more commonly massive than schistose, and has a greenish gray to dark gray color, which is very similar to that of the intermediate and basic lavas. They are altered to a largely secondary mineral assemblage and may be grouped with the andesites and basalts under the term "greenstone". The massive rock has a distinct granular texture and is fine- to medium-grained. In most of the sections examined, remnants of diabasic or sub-diabasic texture are preserved. Although this texture can still be recognized, it is now subordinate to a new crystalloblastic texture. The latter is characterized by large feathery hornblende porphyroblasts, 1 to 4 mm in diameter, set in a mass of chlorite, plagioclase and epidote. The plagioclase is highly altered and forms lath-shaped crystals that are generally half a mm long but that may be as long as 3 mm. In some sections, the new crystalloblastic fabric has obliterated all traces of primary texture and it becomes impossible to estimate what percentage of the gabbro-diorite rock originally had a diabasic texture. It would probably be reasonable to assume that diabasic texture was general in the unaltered rock.

In some sections, pyroxene has not been completely replaced but uralitization has proceeded far enough to prevent the determination of the composition of the original mineral. The uralitization of the pyroxene and the saussuritization of the plagioclase give the sections a very cloudy appearance. The thin sections show that the mineralogy is quite similar to that of the extrusive andesites and basalts. The minerals are nearly all secondary, and consist of colorless to green amphiboles, saussuritized and clear plagioclase, epidote and minor amounts of chlorite, magnetite, and ilmenite. The accessories include sphene, biotite, calcite, pyrite and leucoxene.

The amphibole occurs as large anhedral grains that are either green or colorless. Many of the grains are partly green and partly colorless with the green color commonly concentrated near the edges of the grains. The amphibole is clearly secondary after pyroxene, but it is difficult to determine what varieties of amphibole and of pyroxene are present. The optical properties of the green amphibole grains are as follows:

pleochroic formula : z=green
y=green
x=very light green

$z \wedge c = 20$ degrees
(-) 2V=80 degrees
absorption $z > y > x$

These properties and the common occurrence of colorless amphibole indicate that the most common amphibole is in the tremolite-actinolite range. However, some sections contain much darker amphibole identified as hornblende. The fact that green and greenish amphiboles are present in the intrusive sills and nearly absent in the lavas suggests that the gabbro-diorite may have been more iron-rich than their extrusive equivalents or that they have been differently altered. The first hypothesis is more probable.

The plagioclase grains are found as euhedral lath-shaped crystals that are highly saussuritized. The composition of the plagioclase is that of an albite or sodic oligoclase (An_{10} to An_{15}) which is secondary after a more calcic plagioclase. The alteration has not destroyed the original shape of the crystals, and in many grains concentration of epidote has been such as to accentuate the zoned structure.

Pistacite, clinozoisite and saussurite have the same occurrences as those observed in the lavas, and commonly formed zoned porphyroblasts.

Chlorite occurs as colorless to greenish flakes or shreds that have a characteristic wavy extinction. The proportion of chlorite given below is lower than that given for the lavas simply because only the massive variety of gabbro was used for thin section studies. The schistose gabbro-diorite rock is rich in chlorite.

The accessory sphene is found either as well crystallized diamond-shaped crystals or as anhedral grains forming at the expense of ilmenite and locally encircling it completely.

Mineral Assemblage and Metamorphic Facies

Column I below shows that the minerals in the altered gabbro-diorite vary between wide limits, and that the mineral assemblage is nearly the same as that given for the lavas. Column II gives an average of twenty estimated mineral compositions.

	I	II
	%	%
amphibole	20-75	52
plagioclase (An_{10-15})	trace-40	19
epidote & saussurite	0-45	12
chlorite	0-15	4
quartz	0-35	4
biotite	0-15	1
magnetite-ilmenite	0-5	1
accessories	sphene pyrite calcite	

These altered gabbro-diorite rocks appear to be transitional between the greenschist and the albite-epidote amphibolite facies (Turner and Verhoogen, 1951, p. 460-469), the schistose variety of gabbro-diorite belonging to the first facies and the massive one to the second facies. The preservation of original texture in the massive intrusive shows that the rocks have not passed through a higher grade of metamorphism than the albite-epidote amphibolite facies.

Placing the massive gabbro-diorite rock in the albite-epidote amphibolite facies and the surrounding schistose andesites and basalts in the greenschist facies seems to be contradictory. However, the contradiction is not a very serious one when one considers that the two facies are transitional and cannot always be easily separated. It is therefore very likely that the intimately associated sills and flows were regionally metamorphosed under the same pressure and temperature conditions. The most likely explanation that can be advanced to answer the problem seems to be that, during regional metamorphism, the sills acted as resistant buttresses, and the intrusive rocks remained massive whereas the flows gave way more easily and the rocks became schistose. Under the same conditions of temperature and pressure, the lavas became altered to chlorite schist and the intrusive sills changed into amphibolites, thus giving rise respectively to the greenschist and the amphibolite facies.

It is also a well known fact that rocks of a certain metamorphic facies have not necessarily passed through all the lower facies of metamorphism, and it seems that the sills of gabbro-diorite here constitute an example of this phenomenon.

Rhyolites and Trachytes

Occurrence

Rhyolites and trachytes underlie about ten square miles in the vicinity of Remick lake. Here, the rocks are concentrated in an oval-shaped mass that is in contact with sedimentary rocks on the eastern side and bordered by andesites on all other sides. Acidic flows are found near the western shore of Windy lake, close to the northern boundary of the map-area where they form a belt three miles long and less than one mile wide. The exposures of Windy lake are on the extension of a northeast trending belt mapped by Lyall (1953, p. 4-5). Other more isolated exposures are found about three miles northeast of Doda lake and about half a mile east of lake Bernard. All these exposures are concentrated in the northern part of the belt underlain by Keewatin-type rocks. Another outcrop of acidic lava is found in the southern part of the Keewatin belt where it is intimately associated with chlorite and hornblende schists. This outcrop is located about two miles west of the southern end of Des Claudes lake.

Petrography

In contrast with the andesites and basalts, the rhyolites and trachytes are light-colored; some specimens are either light gray (N7) or greenish gray (5GY6/1) to light greenish gray (5GY8/1), whereas others are light bluish gray (5B7/1). The rock commonly weathers a characteristic very light gray (N8), and the weathered surface is helpful in distinguishing the acidic lavas from the andesites and basalts. Highly sheared rhyolite is well exposed at the falls on the Opawica river about a mile east of Doda lake. Here, the rock is pinkish gray (5YR8/1) and very schistose with much crenulation and development of talc. Subangular grains of quartz can still be observed. In most places however, the rock is massive, hard to break under the hammer and is resistant to weathering. The exposures northeast of Windy lake show much brecciation, and it is possible that, during the periods of deformation, much of the brecciation formed in the acidic lavas whereas schistosity developed in the intermediate and basic lavas. Part of the brecciation may also be the result of the cooling history of the flow, but it is not possible to estimate how much of the brecciation in the rhyolites is primary and how much is due to subsequent deformation. The close association of the rhyolites and trachytes with agglomerate and volcanic breccia may be an indication of the explosive nature of these acidic lava flows.

Under the microscope, most sections show a cataclastic texture and a slight schistose structure that is not seen in the hand specimens. Many sections show porphyritic texture. The phenocrysts are anhedral grains of quartz or subhedral grains of plagioclase that may be as much as 7 mm long but are generally 1 or 2 mm. These plagioclase and quartz phenocrysts may account for as much as 70 percent of the rock. The groundmass consists of very small (0.01 to 0.05 mm) anhedral and equigranular grains of quartz and feldspar. In nonporphyritic varieties of acidic flows, there seems to be two preferred grain sizes, 0.05 mm and 0.5 to 1 mm. No lithophysae were seen, but in one of the thin sections, flow structure was observed. Primary quartz and plagioclase grains are nearly all elongated parallel to the structure, whereas the secondary needles of sericite have a random orientation.

Aside from quartz and plagioclase, which are the main rock forming minerals, minor amounts of sericite, epidote and chlorite are observed. The rhyolites do not contain potash feldspar and are soda rhyolites.

The plagioclase phenocrysts are either clear or very slightly altered, and have a moderate negative relief against Canada balsam. They show albite twinning and have the composition of albite or oligoclase (An_5 to An_{12}).

Quartz is found as clear anhedral grains that are commonly augen-like in form. This form is believed to represent former quartz fragments or phenocrysts that were crushed during the periods of deformation. In one of the sections, quartz constitutes only five percent of the minerals and the rock might then be classified as a trachyte. The plagioclase of that section accounts for seventy percent of the rock, and is a sodic oligoclase (An_{11}).

The accessory minerals found in the rhyolites and trachytes include hornblende, biotite, magnetite, ilmenite, pyrite, limonite, sphene, schorlite, calcite and apatite.

<u>Mineral Assemblage and Metamorphic Facies</u>

The mineral composition of three representative specimens of acidic lava are given below. Column I represents a lava of trachytic composition, and columns II and III give the mineral contents of rhyolites.

	I	II	III
	%	%	%
plagioclase	70	25	60
quartz	5	55	15
sericite	10	10	-
epidote	15	-	10
chlorite	acc.[1]	acc.	10
biotite	-	10	5
hornblende	-	-	10
accessories	-	pyrite limonite	sphene pyrite magnetite limonite
Composition of plagioclase	An_{11}	An_{10}	An_{10}

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[1] Acc. is the abbreviation used for accessory.

As shown by these assemblages of minerals, the acidic flows belong to the chlorite-muscovite subfacies of the greenschist facies (Turner and Verhoogen, 1951, p. 469-472). These rocks represent a product of the lowest grade of regional metamorphism of quartzo-feldspathic rocks with excess silica and complete lack of CO_2.

Pyroclastics

Distribution and Occurrence

A few scattered exposures of tuff, agglomerate, and volcanic breccia are found here and there interstratified with the lava flows. An outcrop of tuff is well exposed on a small island in the central part of Windy lake about 2000 feet from the south shore. The band of tuff here is about two feet wide and occurs between pillowed andesite and a gabbro-diorite sill. Exposures of black weathering agglomerate are found close to where the Druillettes-Hazeur township line meets the northern boundary of the map-area. Agglomerate also crops out at the tip of the long point extending from the east shore of Windy lake. Here, a band of about 100 feet wide is bounded on the north by schistose basalt and on the south by pillowed andesite. A third exposure of agglomerate is found near mile post VIII a mile and a half northwest of Remick lake. Volcanic breccia is exposed about a mile and a half west of Remick lake.

Petrography

The tuffs are fine-grained rocks, schistose, and they break into slabs parallel to the bedding. They are medium light gray (N6) to dark gray (N3) with a few yellowish gray beds (5Y8/1). The tuffs are finely laminated indicating that they were waterlaid. A thin section from the Windy lake exposure shows that the grain size varies from 0.05 to 0.2 mm, and that the main rock-forming minerals are sericite (50%), plagioclase (30%), quartz (20%) and accessory pyrite and sphene.

The section shows a characteristic layered structure with layers made of coarser-grained anhedral plagioclase (An_{12}) and a little sericite alternating with layers consisting of very small sericite flakes and minor small quartz grains. Epigenetic cubes of pyrite have grown across the schistosity.

The agglomerate exposed at the northern boundary of the map-area consists of feldspathic fragments from one fourth of an inch to four inches in length that have been stretched parallel to the east-west schistosity. The fragments are set in a dark gray groundmass that is probably the equivalent of a basic tuff. No bedding was seen in these rocks. Near Remick lake, the fragments are embedded in a light greenish gray matrix and make up 50 percent of the rock.

The matrix of the volcanic breccia exposed near Remick lake looks very much like a rhyolite and contains small angular grains of quartz and feldspar. The fragments which make up 65 percent of the rock are either whiter than the matrix or dark gray to black. The white fragments are subangular, the black ones angular with sharp outlines. One of the black fragments is obsidian. The ejected blocks average three inches in diameter with some up to six inches, and they show no definite orientation. The dark fragments weather more easily than the matrix, leaving some depressions on the surface of the rock, whereas the white ones are more resistant and form small raised areas.

Sedimentary Rocks

Occurrence

Two separate belts in the central parts of the area are underlain by sedimentary rocks. Both of these belts trend slightly south of east and alternate with the bands of volcanics already described. The northern zone is about eleven miles long, less than a mile wide at its western boundary near the eastern shore of Remick lake, and broadens eastward to a width of three and a half miles at Caopatina lake. The southern band is more constant in breadth being about two and a half miles wide over its seven mile length. The band stretches from the northeast shore of Surprise lake westward to a point about two miles northeast of lake Jay. Both of these belts pass transitionally eastward into biotite para-gneiss. Other small exposures of sedimentary rocks are found associated with the lavas, particularly on the shores of the central part of Doda lake and about two miles east of No Rock lake. These exposures cannot be shown separately on the accompanying map. The best outcrops of sedimentary rocks can be observed on the south shore of Caopatina lake and near the survey line two miles southwest of Windy lake.

The sediments on the north shore of Surprise lake have undergone greater metamorphism than those of Caopatina lake. Only the higher grade metamorphosed equivalents of this group are found east of lake Caopatina.

Petrography

The sediments consist largely of a well bedded assem-blage of regularly alternating light colored feldspathic rocks and dark slates (Pl. IV.A). The individual layers are from one to seven inches thick. Differential weathering has accentuated the bedding even more, with resistant quartzo-feldspathic layers as much as five inches higher than the adjacent softer slates.

The rock of the quartzo-feldspathic beds is generally massive, very fine-grained, and similar in hand specimen to the acidic lavas. The slaty layers are well laminated and fissile, and the rock is fine-grained. The color varies from medium light gray (N6) in the quartzo-feldspathic layers to grayish black (N2) in the slaty layers. Most specimens are medium gray (N5) but some have a brownish gray color (5YR5/1). The sedimentary rocks lack the greenish color so characteristic of the altered andesites and basalts.

Cross-bedding is noticeably absent and grain gradation could be used in only two places to determine the tops of beds. Locally disseminated pyrite may be abundant and, by altering to limonite, it gives a pitted weathered surface. South of lake Caopatina, a few narrow bands of magnetite-rich sediments were found interstratified with the quartzo-feldspathic and slaty beds.

Conglomerate is well exposed on some of the islands in the southern parts of Caopatina lake. The groundmass is fine-grained and varies from a light gray feldspathic rock to a darker hornblende-rich rock. The pebbles generally make up about one quarter of the rock but in one exposure they account for sixty percent. Most of them are from one to two inches long but some are as much as six inches long and three inches wide. Some of the pebbles are feldspathic, others are rich in amphiboles. This conglomerate occurs along a zone of shearing (Pl. IV.B), and many of its original characteristics have been obliterated. The pebbles have been stretched and are now elongated parallel to the schistosity. In places, the boundaries between the fragments and the groundmass are not sharp. No evidence of bedding was seen in any of the exposures. From the number of outcrops observed, it appears that conglomerate and other coarse grained rocks form only a small percentage of the sedimentary assemblage.

Most sections examined under the microscope show compositional layering and the beds vary from 0.1 mm upwards. The texture is slightly schistose, and the schistosity, although generally parallel to the bedding, may form angles up to 25 degrees with the beds. Individual grains are anhedral, equigranular, less than 0.05 mm in diameter, and segregate to form bands of different composition. Thus, some bands are composed entirely of sericite (50 %), quartz (40%), and some epidote (10%), others consist of quartz (75%) and sericite (25 %). In darker layers, the epidote (pistacite and clinozoisite) increases to 30 percent. Aside from the essential minerals quartz, feldspar, sericite, epidote and chlorite, the rock also contains biotite, hornblende, magnetite, pyrite, calcite, sphene and schorlite as accessories.

The plagioclase occurs as small clear anhedral grains usually untwinned, and has indices of refraction close to those of quartz and it is difficult to estimate the relative content of the two minerals.

Mineral Assemblage and Metamorphic Facies

The mineral contents of three typical sections are given below and they indicate that each mineral varies between wide limits.

	I	II	III
	%	%	%
quartz and feldspar	50	15	35
sericite	40	15	30
epidote	10	60	30
hornblende	-	10	-
chlorite	-	-	5
accessories	schorlite	-	sphene

Accessories in other sections include biotite, pyrite, and calcite.

These sediments have all been metamorphosed to a slight degree and belong to the greenschist facies (Turner and Verhoogen, 1951, p. 465-473) characterized by abundant mica and the absence of garnet. The rocks are equivalent to the muscovite-chlorite subfacies for quartzo-feldspathic rocks with excess silica and deficient potash. The rocks derived from pelitic sediments contain more epidote.

Deposition of the Sediments

The bedded and laminated structures of the sedimentary rocks indicate that deposition took place in bodies of water. The occurrence and nature of these sediments give little clue as to the nature and size of the bodies of water. One must not conclude that a lens of sedimentary rocks two miles long and one mile wide was deposited in a basin of that size. This conclusion could only be accepted in an undeformed terrain where erosion has not taken place. Here, erosion has necessarily been very great and deformation has been intense. The present masses of sediments therefore represent only remnants of a sedimentary cover of much wider extent than what is now seen in the field. It is quite probable that water covered the area completely or nearly completely at one or more periods in Precambrian time.

The composition of the sediments is quite similar to that of the volcanics from which they were probably derived. Even after some recrystallization has taken place, all grains of the thin sections examined vary from medium silt to fine silt to grains of clay size. Although coarser sediments of sand and pebble size are seen, they are much less abundant than the finer particles. The sediments, therefore, represent for the most part, very fine products of weathering. The grain size, the very regular bedding and the lack of cross-bedding indicate that accumulation took place under quiet-water conditions and in shallow basins. A specimen of black slate collected on the shores of Windy lake probably has a high carbon content. The specimen includes many small disseminated nodules of pyrite about one eighth of an inch across. The mode of occurrence of this iron sulphide suggests a primary origin, deposition under foul bottom conditions, and the possibility of the existence of organic life in early Precambrian time.

ZONE OF TRANSITION

The Keewatin-type sedimentary rocks pass gradationally eastward into biotite and hornblende paragneisses, and the andesites and basalts grade eastward into hornblende gneisses. A zone of transition, within which this gradational change takes place, is shown on the accompanying map. This is a more accurate representation of the geology than an attempt to fix an arbitrary line of division between the Keewatin-type and the Grenville-type rocks. The transition zone occupies an east-west trending belt that extends from the eastern boundary of the area one mile south of Meston lake to the southern shore of Caopatina lake. South of this lake, the belt assumes a southwest-northeast trend, and reaches the northern boundary of the granitic stock of Surprise lake. Rocks characteristic of this group also appear south of Des Claudes lake where hornblende schist, hornblende gneiss and amphibolite are intimately associated. Although the Pleistocene cover prevents the precise delimitation of the zone of transition, it seems to change in a regular way from about one mile wide at the eastern boundary of the map-area to two miles wide south of Caopatina lake. Although rocks belonging to this group are found east and southeast of Surprise lake, it is very difficult to delimit the zone in this area, mainly because of the large intrusion of granitic rocks. Other exposures of schists are found outside the limits of the zone, but they are minor and cannot be shown on the accompanying map. The rocks of the zone of transition show the advent of a more advanced grade of metamorphism of the lavas and sedimentary rocks, and since no sharp boundaries exist between the various facies, the gradational contacts indicated on the map are arbitrary and rather subjective.

The rocks belonging to this group are highly diversified; they include amphibolites and amphibolite schists, hornblende schists, hornblende-chlorite schists and mica schists. The amphibolites and amphibolite schists appear to be derived from a coarse grained intrusive rock whose original characteristics and composition are extremely problematical. The hornblende schists are derived from intermediate to basic lavas, the hornblende-chlorite schists are the metamorphosed equivalents of both the lava flows and the sedimentary rocks, and the mica schists are metamorphosed sedimentary rocks.

Amphibolite and Amphibolite Schist

Occurrence

All the rocks described under this heading are found in the zone of transition southeast of lake Caopatina. They form a rectangular mass measuring about five miles long and one and a half miles wide. The best exposures can be observed half a mile north of lake d'Eu, on both shores of the Opawica river, and on the south shore of the eastern part of Caopatina lake.

Petrography

The amphibolite is a dark gray to black, heavy, and medium- to coarse-grained rock. It is either massive or slightly schistose and lacks banded structure. Some zones of shearing are found in the rock; they are generally narrow, varying from six inches to four feet in width and they all strike in an east-west direction, thus paralleling the shear zones observed in the Keewatin-type rocks. The surface of the rock is rough with hornblende crystals one half to three quarters of an inch in diameter standing out in strong relief on the weathered surface. The rock is very hard and breaks in sharp edged irregular blocks.

Under the microscope, the amphibolite is seen to consist of secondary amphibole (60-80%), minor quartz (10%), epidote (5%), chlorite (5%), and accessory plagioclase, calcite, biotite, magnetite and sphene. The amphibole occurs as anhedral grains 2 to 6 mm in diameter and they either form a mosaic with a granular texture typical of deep-seated intrusives or they form porphyroblasts set in a very fine-grained granoblastic groundmass. In the schistose variety of amphibolite, the amphibole porphyroblasts are elongated subparallel to the structure, and all the minerals of the groundmass except quartz, are elongated in the direction of the structure.

In many sections, the amphibole is hornblende, which occurs as large feathery or fibrous porphyroblasts that lack any sharp boundaries. It has the following properties:

Pleochroic formula: Z=green
Y=bluish green
X=yellowish green
$Z \wedge c$= maximum of 27 degrees
(-) 2V= 80 degrees
Absorption: $Z > Y > X$.

Some of the hornblende grains are very dark green, and where small opaque inclusions are concentrated, the dark color has been bleached. In other sections, the amphibole is tremolite-actinolite. The form of the grain is the same but the color is much paler, even colorless, and the extinction angle is smaller. Both varieties of amphibole are partly altered to chlorite.

Quartz and plagioclase are both in the form of small clear anhedral grains. The plagioclase is untwinned and unzoned, has indices of refraction very close to those of quartz and it is difficult to estimate the relative abundance of each of these two minerals. As far as can be ascertained, it appears that quartz is more abundant than plagioclase in the ratio of about five to one.

Chlorite is rare to absent in the massive variety of amphibolite. Where observed, it is secondary after the amphibole and also after plagioclase.

Small grains of zircon were observed in many sections. They are generally dark grey, cloudy and are metamict. They are optically isotropic and are surrounded by pleochroic haloes if found in colored minerals such as hornblende and biotite. Some grains are clear. These are short and tabular, and have a golden yellow color. The smaller grains are colorless and have very high relief.

<u>Mineral Assemblage and Metamorphic Facies</u>

The estimated mineral compositions of five representative sections are given below.

	I	II	III	IV	V
	%	%	%	%	%
amphibole	90	65	80	50	85
epidote	5	-	10	-	acc.
quartz and plagioclase	acc.	35	10	35	10
chlorite	5	-	-	-	-
calcite	acc.	-	-	5	acc.
magnetite	acc.	-	acc.	5	-
pyrite	-	-	acc.	-	5
accessories	sphene biotite	sphene biotite		biotite	

The amphibolite and amphibolite schist fall into the albite-epidote amphibolite facies (Turner and Verhoogen, 1951, p. 462-463).

Origin

The origin of this mass of amphibolite and amphibolite schist is highly conjectural. The appearance of the rock both in the field and in the hand specimen is strongly suggestive of an igneous origin. Microscopic examination also reveals textures that are suggestive of igneous origin.

The original nature of this igneous rock is difficult to determine. For three reasons the writer does not believe that this intrusion represents a metamorphosed gabbro-diorite sill such as those found in the belt of Keewatin-type rocks. First, the amphibolite south of lake Caopatina consists mostly of amphibole and minor quartz, whereas the sills of gabbro-diorite contain much plagioclase (average 19%) and epidote (average 12%). Secondly, the gabbro-diorite sills show remnants of ophitic and subophitic textures whereas the coarser texture of the amphibolite consists of a mosaic of anhedral grains of secondary amphibole. The third and probably most important reason is that of the occurrence. The gabbro-diorite rock found in the belt of Keewatin-type rocks forms small bodies rarely more than a few scores of feet wide, whereas this amphibolite is a mass five miles long and more than a mile wide.

The rock may represent the altered equivalent of pyroxenite or peridotite as has been observed in the Keewatin-type rocks of the Chibougamau region (Barlow, Guillim and Faribault, 1911, p. 167-174).

Hornblende Schists

Distribution

Fine-grained hornblende schists are found at the outlet of Surprise lake where they form a narrow east-west trending belt about two miles long and half a mile wide. The belt is bounded on the south by metasediments. Other exposures of hornblende schists are found near the granite stock on the two largest islands of Surprise lake. Another group of hornblende schists are exposed east of Surprise lake and south of Des Claudes lake.

Petrography

The hornblende schists are similar in many respects to low grade metaandesites and metabasalts. They are fine-grained rocks, dark gray to greenish black, and have a pronounced schistosity. The greenish color is noticeable but to a much lesser extent as darker colors are becoming predominant. The dark gray color is due to the abundance of small needle-like crystals of hornblende which, in some specimens, may account for as much as 90 percent of the rock. Aside from the abundance of small dark needles of hornblende, the hornblende schists are commonly characterized by the presence of stringers of plagioclase feldspar and also of small lenticular or rounded porphyroblasts of the same feldspar (Pl. V-B). Outcrops of hornblende schists with feldspar stringers are well exposed at the outlet of Surprise lake. Here, the stringers are generally irregular and discontinuous, and are all aligned parallel to the schistosity. They are narrow and rarely attain more than one quarter of an inch in width. These stringers give the exposures the appearance of bedded structure but the complete lack of bedding and lamination plus the irregularity of the stringers rule out the possibility that the rocks may be of sedimentary origin. Hornblende schists with feldspar stringers are also found near the granite contact on the two largest islands of Surprise lake. Other exposures at this locality are characterized by the abundance of lenticular creamy feldspar porphyroblasts (Pl. V-B). About 100 feet from the granite contact, a band 10 feet wide contains about 50 percent of these feldspar lenses. This band is bounded to the north by a coarse-grained hornblende-rich rock and to the south by fine-grained hornblende schist devoid of creamy feldspar stringers and lenses. This arrangement is believed to represent a lava flow ten feet thick bounded by a thin intrusive sheet on the north and by another flow on the south. The feldspar lenses are white to cream colored, one to three inches long and one to two inches wide. The lenticular concentrations of feldspar are more commonly elongated parallel to the schistosity than otherwise.

Practically all the primary structures and textures of the lavas have been obliterated at this stage of metamorphism. Vesicular and amygdaloidal structures are noticeably absent and pillowed structures were observed in only two localities, one on the south shore of Des Claudes lake and the other on the west shore of a small lake half a mile south of Des Claudes lake. The metamorphism of these lavas must have taken place, in the absence of strong penetrative deformation in order to preserve the original ellipsoidal structures.

A thin section of hornblende schist shows that it consists essentially of hornblende (60-70%) and of altered plagioclase (25-35%) and accessory quartz, chlorite, sphene, epidote, garnet, pyrite and limonite. The structure is schistose and the hornblende needles are arranged parallel to the structure.

The mineral assemblage, which is very similar to that of the coarse-grained amphibolite described above, and the appearance of garnet as an accessory mineral indicate that the hornblende schists belong in the albite-epidote amphibolite facies (Turner and Verhoogen, 1951, p. 462-463).

Hornblende-Chlorite Schists

Occurrence

The hornblende-chlorite schists are found in the zone of transition associated with fine-grained hornblende schists but they are less common than the latter. Because of rare occurrences, the exposures of hornblende-chlorite schists could not be grouped together and form a separate mappable unit. Representative specimens were collected around lake d'Eu and north of the northern shore of Surprise lake.

Petrography

In the Keewatin-type rocks, many of the schistose lavas are very rich in chlorite and in the transition zone, rocks similar to chlorite schists in many respects are found. The rocks are greenish grey (5GY6/1) to greenish black (5GY2/1), highly schistose and have a pronounced sheen on flat surfaces. The rock is very fine-grained and breaks in thin slabs when struck by the hammer. A feature that differentiates the hornblende-chlorite schists from the chlorite schists in the belt to the north is that the hornblende-chlorite schists are characterized by long thin black needles of hornblende that stand out conspicuously on the weathered surface. Most of the needles vary between one quarter to one half inch in length and they are everywhere randomly oriented.

Under the microscope, the grains in the matrix are very small (less than 0.05 mm) except for a few porphyroblasts of biotite and augen-like structures of granular quartz. Large anhedral grains of hornblende as much as 5 mm long have grown in a porphyroblastic manner (Pl. VI-B). Aside from their large size, the hornblende grains are characterized by their clear boundaries and the common poikilitic inclusions of quartz. The hornblende is very likely rich in aluminum and iron as it is quite dark colored and strongly pleochroic.

Chlorite occurs as very small (0.05mm) individual flakes or as large aggregates of flakes. It has slight pleochroism from light green to colorless, and dark brown interference colors. The paragenesis of the hornblende porphyroblasts and of the chlorite is rather complex. Most specimens and thin sections show clearly that the hornblende porphyroblasts developed later than the chlorite but one of the sections from north of Surprise lake shows some hornblende cut by later chlorite. Thus, the chlorite crystals formed both before and after the development of the hornblende porphyroblasts. This suggests a local retrograde effect.

Quartz and plagioclase both occur as clear anhedral grains and, because of their small size and the lack of twinning in the plagioclase, the relative abundance of these two minerals is difficult to estimate. However, as in the fine-grained hornblende schists, the quartz appears more abundant than the plagioclase in a ratio of about four or five to one. Calcite is very common and is present in nearly all the sections examined. Garnet was observed in one section.

Mineral Assemblage and Metamorphic Facies

The dark color of the hornblende, the appearance of garnet and the presence of epidote and chlorite indicate that the hornblende-chlorite schists belong in the albite-epidote amphibolite facies and are of the same metamorphic grade as the hornblende schists with which they are associated.

Mica Schists

Occurrence

Mica schists occur immediately west of the river flowing between Surprise and Caopatina lakes. Here, the rocks form an ill-defined northeasterly trending belt about one to two and a half miles wide and four miles long. The belt covers approximately five square miles and exposures along this belt are not common. Other outcrops are observed northeast of lake d'Eu where they are associated with hornblende schists and have been grouped with them. The best exposures are found on the south shore of Caopatina lake.

The mica schists grade eastward into biotite paragneisses and westward into low grade metasediments. The series of exposures along the south shore of Caopatina lake shows this transition very well. The sedimentary assemblage along the southwestern part of the lake displays no bands that are rich in biotite, although scattered flakes of this mineral have developed in these rocks. Here too, gneissic structure is lacking. Farther eastward, along the central part of the lake, biotite becomes concentrated within certain bands. Still farther eastward, bands rich in biotite are just as abundant as the quartz rich layers. South and southeast of lake d'Eu, the sedimentary rocks have become completely changed over to biotite paragneiss. This rock is described separately in a subsequent section on higher grade metamorphic rocks.

Petrography

The mica schists are light gray, fine-grained, thinly foliated, and have remnants of primary bedded structure. Under the microscope, the rock is seen to have a strong schistose structure and compositional layering that probably represents original bedding. The schistosity and the compositional layering are generally parallel to each other but in two of the sections, the schistosity is at angles of 15 to 20 degrees to the bedding. In one of these sections, an introduced veinlet of quartz is parallel to the bedding whereas in the other section, a quartz veinlet is parallel to the schistosity.

The grain size in general is very fine (0.01mm) although epidote in places forms porphyroblasts measuring as much as half a mm in diameter. The main constituents consist of quartz, biotite, muscovite, plagioclase and chlorite. Accessories include calcite, epidote, schorlite, magnetite, pyrite and limonite.

Mineral Assemblage and Metamorphic Facies

Unlike the lavas, intrusive sills and hornblende schists, the mineral content of the mica schists does not vary between wide limits. Three estimated compositions are given below.

	I	II	III
	%	%	%
quartz	55	60	55
plagioclase	5	5	-
biotite	20	10	20
muscovite	15	20	-
chlorite	5	acc.	10
hornblende	-	-	10
accessories	magnetite pyrite limonite epidote schorlite	magnetite epidote schorlite	epidote apatite

Column I and II give the compositions of two specimens taken along two adjacent bands of the same exposure. Column I represents the mineralogy of a specimen from a dark grey band whereas column II comes from a light grey band. These two tables show very little change in the composition, the variation being noticeable only in the relative abundance of dark and colorless micas. Column III represents the composition of a specimen collected three and a half miles west of lake d'Eu on the south shore of Caopatina lake.

The mineral assemblage of the mica schists indicates that the rocks belong either in the greenschist or in the albite-epidote amphibolite facies (Turner and Verhoogen, 1951, p. 460-473).

HIGHER GRADE METAMORPHIC ROCKS

The rocks described in this section include biotite paragneisses, hornblende gneisses and amphibolites but not the gneissic granite which will be discussed separately.

Exposures of biotite and hornblende gneisses and amphibolites form two east-west trending belts in the central part of the area, and east of Vercheres lake, these two belts merge together and continue to the eastern boundary of the map-area near Deux Iles lake. The eastern extension of the belt of higher grade metamorphic rocks was mapped by Gilbert (1952).

Gneisses and amphibolites are also found as inclusions in the granitic rocks, and these occurrences have been shown on the accompanying map. West of Surprise lake between Des Claudes and Eva lakes, hornblende gneisses and amphibolites are intimately associated with hornblende and hornblende-chlorite schists. A transition from hornblende schist to hornblende gneiss to amphibolite can be observed north of Eva lake. Amphibolite is found close to the granite contacts, hornblende gneiss farther away, and hornblende schist still more distant from the granite. This change takes place in a width of about one and a half to two miles. It was found impossible to separate the hornblende schist from the hornblende gneiss and amphibolite at this locality, and the various rock types have all been mapped together.

There is no sharp delimitation between the meanings of the terms hornblende gneiss and amphibolite either on the basis of texture and structure or composition (Holmes, 1920, p. 118; Adams and Barlow, 1910, p. 163: Williams, Turner and Gilbert, 1954, p. 240-243). It appears, however, that the term hornblende gneiss places more emphasis on the rock structure whereas amphibolite refers mostly to the composition of the rock, but both the structure and the composition of these two rocks are highly variable. Because of their intimate association in the field and their variable petrographic properties, the hornblende gneiss and the amphibolite are not mapped separately.

The hornblende gneiss and amphibolite and the biotite paragneiss are believed to represent a more advanced stage in the metamorphism of the Keewatin-type volcanics, intrusive and sedimentary rocks.

The higher grade metamorphic rocks are divided into two groups: The hornblende gneiss and amphibolite group and the biotite paragneiss[1] group.

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1 The term paragneiss is used here to refer to those gneisses derived from sedimentary rocks. Gneisses derived from lava flows are not considered paragneisses.

Hornblende Gneisses and Amphibolites

Occurrence

Approximately 50 square miles of the map-area are underlain by hornblende gneisses and amphibolites. These rocks crop out in a more or less regular east-west trending belt that is divided into two segments between Mossino and Surprise lakes. The northern segment extends from the north end of Mossino lake to the northeast end of Surprise lake. It is about ten miles long and one to one and a half miles wide. The southern segment extends from south of Grimaldi lake to the southwest shore of Surprise lake. From lake Grimaldi to Pierre lake, the belt is about eight miles long and two miles wide, and from Pierre lake to the southwest end of Surprise lake, it is eleven miles long and half a mile wide. These two segments are separated by the Mossino lake belt of biotite paragneiss near their eastern part, and by a three-mile-wide stock of granite near their western part. North of lake Grimaldi, the two segments join and continue to the eastern boundary of the map-area east of Deux Iles lake. In addition to this main belt, inclusions or remnants of hornblende-rich rocks are found in the granitic rocks.

Petrography

The rocks included in this group are highly diversified. They show a wide range of compositions and a great variety of textures. They may consist almost entirely of amphibole, or of amphibole and plagioclase or of amphibole, plagioclase and quartz. They may be fine- medium- or coarse-grained, massive, schistose or gneissic, equigranular or porphyritic. They may show indications of primary stratiform structures although, in most cases, the origin of the rock cannot be ascertained.

Most specimens show a well developed gneissic and schistose structure. Lenses and veinlets of quartz paralleling the structure are common. Light colored plagioclase feldspar is commonly segregated in parallel stringers and lenses very similar to the structure observed in the hornblende schists. In general, the hornblende gneisses and amphibolites are more recrystallized than the hornblende schists and the grain is coarser. A few specimens from the small inclusions in the granite show no definite fabric orientation and the anhedral grains form a granulitic texture. All relicts of primary structures are wanting but it is probable, though far from certain, that these granulitic rocks have passed through a schistose stage.

The individual grains of the hornblende gneisses and amphibolites have sharp boundaries and are in smooth contacts with their neighbors. In most sections, the grains vary between 0.2 mm to 2 mm, but in a few places large porphyroblasts of garnet and hornblende are as much as 2 centimeters in diameter. Most of these porphyroblasts show no tendency to be elongated parallel to the schistosity thus indicating growth under uniform pressure conditions. In some specimens however, the large crystals of hornblende are all elongated parallel to the structure.

The essential minerals occur in highly variable proportions as shown below.

	%
hornblende	30-80
plagioclase	5-30
quartz	5-50
garnet	0-20
biotite	0-10
epidote	0-5
sphene	0-5
accessories	calcite, tourmaline, epidote allanite, pyrite, magnetite leucoxene

The hornblende found in the northern parts of the main belt occurs as anhedral to euhedral grains that are slightly larger than the other minerals. The hornblende is normally green, strongly pleochroic but may be colorless in places and peppered with many minute magnetite dots. In a few places, it is slightly chloritized. The grains of hornblende found in the southern part of the belt occur as large porphyroblasts full of small poikilitic inclusions of quartz. They are characterized by a darker color and do not have the colorless spots of the hornblende found in the northernmost parts of the belt. The optical properties of this hornblende are:

pleochroic formula: z=dark green
y=bluish green
x=light yellowish green

$z \wedge c$=25-30 degrees
(-) 2V=75-80 degrees
absorption: $z > y > x$

The hornblende of the inclusions occurs as anhedral rounded grains that have sharp and smooth boundaries. The grains also have poikilitic inclusions of quartz but they have a darker color than the hornblende grains found in the main belt. Except for the pleochroic formula, the optical properties of this hornblende are the same as that found in the main belt of hornblende-rich rock.

The plagioclase of all the hornblende gneisses and amphibolites is found as anhedral clear grains that have positive relief against Canada balsam. Twinning, though better developed in the more thoroughly recrystallized rock of the inclusions, is rare. A faint zoning structure is occasionally observed. There is no variation in the composition of the plagioclase to parallel the apparent variation in the composition of the hornblende. The composition of the plagioclase varies unsystematically between that of a calcic oligoclase (An_{25}) to that of a sodic andesine (An_{35}).

Epidote occurs mostly in the northern parts of the central belt, is rarely observed in the southern parts, and is wanting in the hornblende gneiss found as inclusions in the granite. In the northern part of the belt, the two varieties of epidote, pistacite and clinozoisite, have grown in a porphyroblastic manner.

Quartz is found as clear anhedral grains and is more abundant in the hornblende gneiss of apparent sedimentary origin whereas plagioclase predominates in rocks which have no relict of sedimentary structures.

Garnet is found as large anhedral porphyroblasts that may measure as much as 6 mm in diameter. It is characterized by the large number of poikilitic inclusions of quartz, plagioclase, hornblende and magnetite. In some sections, 50 percent of the porphyroblasts consist of these inclusions. The garnet is a red variety and it has a slight pinkish tinge under the microscope. The index of refraction (1.786) and the color indicate that the garnet is almandite.

Mineral Assemblage and Metamorphic Facies

One representative sample of hornblende gneiss taken from an inclusion in the granite two miles northeast of lake Monaco was selected for a Rosiwal analysis. The section is characterized by clear unaltered equigranular anhedral grains. Column I below gives the mineral composition as determined on the mechanical stage, and column II gives the chemical composition calculated from the mineral composition.

I		II	
	volume % of minerals		weight %
hornblende	54.3	SiO_2	47.1
plagioclase	19.0	Al_2O_3	14.2
garnet	15.7	Fe_2O_3	9.0
quartz	9.3	FeO	8.7
biotite	0.7	MgO	4.6
epidote	0.1	CaO	4.5
sphene	0.5	Na_2O	1.5
magnetite	0.2	K_2O	0.1
tourmaline	0.1	TiO_2	0.2

As shown by table I above and that given on page 56, all the hornblende-rich rocks belong to the amphibolite metamorphic facies. Some of them are equivalent to the staurolite-kyanite subfacies derived from rocks deficient in potash (Turner and Verhoogen, 1951, p. 452-454).

<u>Origin of the Hornblende Gneisses and Amphibolites</u>

The origin of the hornblende gneisses and amphibolites is one of the most interesting problems that has attracted the attention of petrologists. It has long been recognized that many different types of rocks can give rise to amphibolites. Adams (1909, p. 1-18) lists three possible modes of origin for the amphibolites of the Laurentian area.

"(1) by metamorphism and recrystallization of impure calcareous sediments
(2) by the alteration of basic dykes and similar igneous intrusions
(3) by the alteration of limestone through the action of the intruding bathyliths of granite."

Adams and Barlow (1910, p. 121-160) in their memoir on the Haliburton-Bancroft areas, mentioned that the hornblende-rich inclusions found in the gray gneisses may represent basic differentiates of a granitic magma. Osborne (1936, p. 202) believes that the amphibolites of the Shawinigan Falls district are the metamorphosed equivalents of Keewatin lava flows, basic tuffs and greywacke as well as basic dykes and impure calcareous sediments. The evidences for the origin of the amphibolites in the Shawinigan Falls district, however, seems to be less reliable than those found in the Haliburton-Bancroft area. Further south in the Adirondack region, Buddington and Sederholm (1939, p. 12-13) believe that the amphibolites are derived from tuffs and lava flows. Thus, hornblende gneisses and amphibolites may be derived from at least five different kinds of rocks. These are:

(1) calcareous sediments
(2) basic dikes
(3) volcanic rocks
(4) graywacke
(5) basic differentiate of a granitic magma.

In the present map-area, the amphibolites and hornblende gneisses are believed to be derived from the four different types of rocks listed below:

(1) andesite and basalt flows
(2) gabbro-diorite sills
(3) the ultrabasic intrusive south of Caopatina lake
(4) tuffs and sedimentary rocks

(1) The andesites and basalts are the most common Keewatin-type rocks, and they probably account for the greater part of the amphibolites of the area. In the preceeding pages, it

was pointed out that the lavas give rise to chlorite schist, hornblende schist and finally to hornblende gneiss and amphibolite. The transition from one end member to the other can be seen more easily where it takes place within a short distance such as half a mile or so. Thus, near the contacts of the granite on the shores of Doda lake, the progressive change of the lavas into hornblende gneiss and amphibolite can be followed without difficulty. The same gradation between chlorite schist, hornblende-chlorite schist and hornblende gneiss can also be observed between Des Claudes and Eva lakes, with the higher grade metamorphic rocks being found closer to the granite contacts.

(2) Nearly all the intrusive sills of gabbro-diorite associated with the volcanics have been metamorphosed to amphibolites. The field occurrence and the preservation of the original ophitic texture leave little doubt as to the origin of these amphibolites.

(3) As mentioned in the description of the rocks of the transition zone, the coarse grained amphibolite south of Caopatina lake is believed to be an ultrabasic intrusive. The abundance of amphiboles, together with the very low content of plagioclase and quartz are very suggestive of an original ultrabasic intrusive. The abundance of light-colored magnesium-rich amphiboles is also indicative of a derivation from ultrabasic rocks. (Williams, Turner and Gilbert, 1954, p 243).

(4) There are also evidences that some of the hornblende gneisses and amphibolites of the area are derived from

sedimentary rocks though this origin cannot be traced as easily as the igneous origin of the amphibolites. The sedimentary origin of some of the amphibolites is uncertain for two reasons. First, impure calcareous sediments, which in many places have given rise to hornblende gneiss and amphibolite, are absent in the belt of Keewatin-type rocks. Secondly, most sediments of the area have been metamorphosed to biotite paragneiss, and only rarely to quartz-rich hornblende paragneiss. The quartz-rich hornblende paragneiss contains as much as 50 percent quartz, and it is difficult to see how the paragneiss could become freed of so much quartz and be changed to amphibolite. The slaty layers that are interbedded with the quartz-rich beds may have given rise to quartz-poor hornblende paragneiss and amphibolite.

Tuffs of the same general composition as the intermediate and basic lavas could also easily be transformed to amphibolites. However, because of the paucity and small size of the tuff exposures, the derivation of amphibolites from tuff cannot be demonstrated.

The problem of determining the origin of the amphibolites becomes increasingly difficult as the grade of metamorphism increases and as the original features of the rocks are obliterated. As noted by Adams and Barlow (1910, p. 164):

> "When the origin of a body of amphibolite is not discoverable from its field relations, it is impossible to determine whether it is an altered igneous or a body of altered sediment".

Thus in the granitic areas, the original nature of the hornblende gneisses and amphibolites found as inclusions cannot be easily ascertained. There are, however, some criteria, although not very dependable, that can be used to determine if the amphibolite is derived from sedimentary rocks, volcanic rocks, or basic intrusives. A high percentage of quartz for instance may be suggestive, although not a proof, of a sedimentary origin. The presence of sphene and epidote may suggest a medium- or high-grade metamorphism of basic or magnesian rocks, as these minerals are common in the metamorphosed basic igneous rocks of the amphibolite facies (Turner and Verhoogen, 1951, p. 446-460).

Garnet in relatively low-grade hornblende gneisses and amphibolites may suggest that the rocks have been derived from aluminous sediments probably near the composition of shale. The occurrence of garnet in an amphibolite, however, is not in itself criterion of sedimentary origin. As mentioned previously, the altered lavas of the transition zone contain some small garnet grains in places. However, where the garnet is concentrated in regular bands and where the garnetiferous hornblende gneiss is interbanded with biotite paragneiss, it suggests sedimentary origin. Because of its mineralogy and its field occurrence, the rock whose Rosiwal analysis is given on page 59 is believed to be of sedimentary origin.

In the amphibolites found as inclusions in the granite, the evidence of bedding has been obliterated. There is, as already noted, some banding and compositional layering that may suggest sedimentary origin. It must be pointed out, however, that the banding and compositional layering observed in the amphibolites and hornblende gneisses is not a reliable criterion of sedimentary origin. It is obvious that a schistose lava can give by metamorphism and metasomatism banding similar to that found in paragneisses. The new material that is being added to the lavas, whether it is silica, potash, soda, lime or other complexes, forms compounds that would tend to follow the planes of schistosity and give rise to banding and compositional layering. Similarly, metamorphic segregations of minerals will form parallel to the structure where pressure is least. These injections and segregations can give rise to compositional layering that may under megascopic and microscopic examinations be wrongly interpreted as evidences of former sedimentary structures.

Biotite Paragneisses

Occurrence

Biotite paragneisses underlie about 20 square miles of the map-area, and most outcrops occur along three east-west trending belts. The northernmost one adjoins the southern boundary of the belt of chlorite, hornblende and mica schists, and extends eastward from the river flowing between Caopatina and Surprise lakes. This belt has not been extended to the eastern boundary of the map-area as glacial material covers the bedrock completely, but its extension is warranted by the presence of biotite paragneiss east of the boundary (Gilbert, 1952). The central and southern belts encircle the granitic stock between Vercheres lake and the western shore of Surprise lake. The central belt is about twelve miles long, less than half a mile wide and is covered by glacial debris in its central part. The southern belt is thirteen miles long and one half mile wide and trends east-west very regularly. East of Verchores lake, the two belts join and form a U-shaped band, one-mile-wide, that ends north of Messine lake. Other exposures of biotite paragneisses forming lenticular masses in hornblende gneisses and schists, are found east of Deux Iles lake, east of lake Pierre, and south of Noel lake. Inclusions of biotite paragneisses are also observed in the granite areas east and west of lake Monaco and on the south shore of Eva lake. Outcrops of biotite paragneisses are found in the two belts of hornblende gneisses especially where hornblende paragneiss predominates as on the south shore of Surprise lake. The demarcation between the biotite and the hornblende paragneisses is gradational in many places.

Petrography

The biotite paragneiss is a light to dark gray, fine- to medium-grained rock consisting essentially of biotite, gray plagioclase feldspar and quartz. Relict bedding is indicated by the regular alternation of bands rich in biotite and others rich in lighter colored minerals. In a few places, the rock contains red to reddish garnet (as much as 20 percent) and the garnet grains are concentrated along certain layers, further accentuating the already pronounced banding. The exposures east of Vercheres lake and around Messine lake are characterized by a greater abundance of garnet. The arrangement of garnet-rich bands alternating with garnet-poor bands is quite similar to the alternating beds of shale and quartzo-feldspathic sediments seen on the south shore of Caopatina lake. The biotite paragneiss is a rather friable rock that weathers quite readily, but the more resistent garnet grains stand out prominently on the weathered surface. The rock has a characteristic rusty-weathering surface typical of many biotite-bearing schists and gneisses. Greenish veinlets of epidote, either parallel or at various angles to the structure, are common in the paragneiss near the granite contact. In places, strongly elongated lenses of darker gneisses rich in hornblende are embedded within the biotite-rich rock.

Seen under the microscope, the rock shows a schistose structure and granoblastic texture. In many sections the granoblastic texture is more strongly developed than the schistosity.

Quartz and plagioclase occur as anhedral equigranular grains that have diameters from 0.1 mm to 0.5 mm, and the biotite flakes, which are mostly 0.5mm long, are aligned parallel to the structure. These three minerals are generally segregated into biotite-rich bands and bands rich in feldspar and quartz. Epidote, garnet and tourmaline which are minor minerals also have tendencies to be segregated in layers. Accessories include muscovite, calcite, magnetite, limonite, chlorite, sphene, sericite, zircon, saussurite and pyrite.

In the granular as well as in the schistose rocks, garnet has formed porphyroblasts that may be as large as 3 mm in diameter. These porphyroblasts, although highly irregular, tend to be rounded, and are characteristically full of poikilitic inclusions of quartz and feldspar. In places, muscovite and biotite form porphyroblasts that are perpendicular to the gneissosity (Pl. VI-A).

The plagioclase of the biotite paragneiss of the northern belt is clear, untwinned, and has indices of refraction close to that of balsam. It cannot be readily differentiated from quartz grains with which it is closely associated in the fine-grained groundmass. The plagioclase found in the biotite paragneiss of Messine and Vercheres lakes is more easily determined. The grains are twinned here and there, and have indices of refraction higher than balsam. The composition varies between that of calcic oligoclase (An_{25}) to that of sodic andesine (An_{33}), and is therefore nearly the same as that of the plagioclase observed in the hornblende gneisses.

Tourmaline, suggestive of metasomatism and contact metamorphic phenomena, is observed in about a third of the sections examined. In two sections, it accounts for 5 percent of the rock and forms grains that are as much as half a mm in diameter. The tourmaline is the iron-rich variety schorlite, and it occurs as anhedral grains, rectangular crystals or spherical triangles. It has a marked pleochroism from gray to light gray with rectangular grains showing greater absorption when elongated perpendicular to the vibration direction of the polarizer.

Mineral Assemblage and Metamorphic Facies

Column I below gives an average estimated composition of 13 sections from the northern belt and column II, an average of 14 sections of biotite paragneiss of the southern belt. The main differences between these two columns seems to be the greater amount of chlorite in the northern band and the higher proportion of epidote in the southern band.

	I	II
	%	%
quartz and plagioclase	50-60	60-70
biotite	15-25	5-15
muscovite	10-15	5-10
chlorite	5-15	0-5
epidote	0-5	0-10
garnet	acc.	0-5
hornblende	acc.	0-5
calcite	0-5	acc.
schorlite	acc.	acc.

Some of the garnetiferous biotite paragneisses belong to the amphibolite metamorphic facies equivalent to the staurolite-kyanite subfacies derived from feldspathic sandstone deficient in potash (Turner and Verhoogen, 1951, p. 452-454). Others belong to the albite-epidote amphibolite facies equivalent to the chloritoid-almandine subfacies derived from pelitic rocks high in Al_2O_3 and low in K_2O (Turner and Verhoogen, 1951, p. 461-463).

Origin

The northern and central belts of biotite paragneisses form eastward extensions of the two belts of sedimentary rocks previously described. A complete gradation from slightly metamorphosed sedimentary rocks through fine-grained schists to garnetiferous paragneisses exists and can be clearly observed on the south shore of Caopatina lake. The biotite paragneiss thus represents the metamorphosed equivalent of sedimentary rocks found within the belt of Keewatin-type rocks.

GRANITE[1]

1. Unless specified, the terms granite and granitic are taken in their broader sense and include massive and gneissic soda granite, syenite, granodiorite and quartz diorite.

Occurrence

Approximately 200 square miles (one third) of the map-area are underlain by granite. The granitic rocks are found in the southern parts of the area where they form an east-west trending belt that is 2 to 4 miles wide throughout most of its length but attains widths of 9 and 8 miles respectively at the eastern and western boundaries of the map-area. In the center of the map-area, the main belt of granite is bordered to the north by a belt of hornblende gneisses, immediately north of which another belt of granite reappears and forms an east-west elongated stock about 20 miles long and ½ to 3 miles wide. Other smaller granitic bodies are also found in the Keewatin-type rocks and in their metamorphosed equivalents. Near the western boundary of the area, the Tower peninsula is underlain by granite, and other masses of granite crop out southeast of Noel lake, near lake d'Eu, and on a small island in the northern part of Caopatina lake. A geophysical survey made around Meston lake suggests the presence of granite underneath the lake and immediately east of it. One outcrop of granite was submerged when the level of the lake was raised to allow landing of hydroplanes.

Varieties

The rocks described in this section include the following varieties: quartz diorite, granodiorite, syenite, soda granite, pegmatite and aplite. These rocks except for the pegmatite and aplite and most of the soda granite are either massive or have a well developed gneissic structure. They can be divided into two groups: an intermediate group including quartz diorite, syenite and granodiorite, and an acidic group represented by soda granite, pegmatite and aplite. The relationship between these two groups is not a simple one. In places, the soda granite, pegmatite and aplite cut into the rocks of the more basic group, and in others they grade into them. The more acidic varieties of granite, however, appear to be a later facies of the intermediate granitic rocks. The various facies will be discussed separately under the 4 following headings:

Intermediate group
- 1-quartz diorite-granodiorite
- 2-syenite

Acidic group
- 3-soda-granite
- 4-pegmatite and aplite

Quartz Diorite-Granodiorite

More than 50 percent of the gneissic granitic rocks consist of quartz diorite and granodiorite. In the field, these rocks were referred to as gray granite gneiss because of their characteristic gray color and generally well developed gneissic structure.

The granodiorite and quartz diorite are composed essentially of feldspar, quartz, biotite and hornblende with accessory epidote and chlorite. In most of the rock, biotite is the dominant mafic mineral, although in places, biotite and hornblende are equally abundant and locally the latter is more plentiful. Disseminated sulphides are present in places, especially near the borders of the intrusive masses. The rock is generally medium-grained, though some facies are coarser. Gneissic structure is generally well developed. In places, it is extremely complex and contorted with well developed ptygmatic folding. Rarely is the rock massive, though in the finer-grained specimens, the gneissic structure is not everywhere obvious.

The exposed surfaces of the fine-grained rock are smooth and even, but the coarser grained rock has a rough and irregular surface. Exfoliation is not common but is occasionally observed in the more gneissic rock.

Under the microscope, the rock is seen to consist of anhedral grains of quartz and plagioclase feldspar arranged in a mosaic pattern, and of biotite flakes, hornblende and epidote crystals that are commonly elongated parallel or subparallel to the gneissoid structure. Quartz grains, which in general are smaller than the feldspar grains, may show elongation parallel to the structure. Accessory minerals are apatite, allanite and sphene.

Plagioclase ranges from An_{20} to An_{35}, and is found as anhedral grains that are commonly twinned and more or less altered to sericite and epidote.

Epidote forms idioblastic grains, is biaxial negative and is the iron rich variety pistacite. Allanite grains are light to dark brown and are characterized by high relief and parallel extinction. Most grains are partly or completely surrounded by epidote.

Sericite occurs as long flakes as much as 1 mm long, or as very small secondary needles in plagioclase. The larger crystals of colorless mica formed later than the biotite flakes and the other rock-forming minerals.

Microcline, which is not common in most of these rocks, has a replacement relation to plagioclase. In places, microcline gives the rock a slight pinkish tinge.

The estimated compositions of 5 representative sections are given below.

	I	II	III	IV	V
	%	%	%	%	%
plagioclase	60	55	25	35	45
microcline	acc.	acc.	15	-	-
quartz	20	20	30	40	20
biotite	10	15	10	10	10
hornblende	-	acc.	15	10	25
epidote	5	10	acc.	5	acc.
muscovite	5	acc.	-	-	-
accessories	zircon apatite	pyrite limonite sphene	pyrite sphene	magnetite pyrite	sphene
Composition of plagioclase	An_{21}	24	25	28	35

Specimens of columns I, II, III and IV can be termed granodiorite and specimen of column V is a quartz diorite.

Syenite

South of Doda lake, exposures of massive quartz diorite and granodiorite grade into syenite. The merging is very abrupt in places as one end of an exposure may contain 15 to 20 percent quartz and the other end be quartz-free. The syenite is a medium- to coarse-grained rock, with many crystals as much as 5 or even 8 mm in diameter. Pink feldspar and hornblende are the only essential constituents and quartz and epidote are the accessories. The rock varies in composition from 35 percent hornblende and 60 percent feldspar to 35 percent feldspar and 60 percent hornblende. It occurs either as large masses in the quartz diorite and granodiorite or as dikes cutting across the hornblende gneisses.

The hornblende syenite is well exposed one mile east of the southern end of Doda lake and about 6 miles south of the boundary of the map-area on De l'Aigle river. Near the river, the rock is massive with a mottled gray and pink color. Some pink feldspar crystals, as much as 2 or 3 cm in diameter give the rock a porphyritic texture. Locally, the feldspar phenocrysts constitute 30 percent of the rock. Epidote is common and occurs either as disseminated grains or as veinlets cutting the syenite porphyry.

A section from the exposures southeast of Doda lake shows that the rock consists of plagioclase (40%), microcline (35%), hornblende (20%) and minor quartz, sphene and epidote. The average grain cross-section is about 2 mm and the rock has a typical interlocking hypidiomorphic granitic fabric. The plagioclase is strongly sericitized albite (An_5). The grains have a moderate negative relief against Canada balsam and they have been partly replaced by microcline.

The microcline, believed to be secondary after plagioclase, is very clear, has indices of refraction lower than balsam, and shows the characteristic twinning.

The hornblende forms subhedral to euhedral grains that are pleochroic from green to light green, and have numerous poikilitic inclusions of feldspar.

Sphene is the most common accessory, and is generally found as well-formed diamond-shaped crystals that have strong relief and very high birefringence.

Three more exposures of syenite are found near the outlet of Surprise lake, at the contact of the biotite paragneiss with the granite. The rock, however, is quite different from the hornblende syenite just described. It is a medium-grained gray rock that has a well developed gneissic structure. Some of the light grey constituents have a slight pinkish tinge.

Under the microscope, the rock is seen to consist essentially of microcline (40%), hornblende (30%), plagioclase (10%), garnet (10%) and biotite (5%). The accessories are quartz, sphene, calcite, apatite and pyroxene. The rock may be termed a garnetiferous hornblende-pyroxene syenite.

The plagioclase is present as euhedral to anhedral unaltered grains of composition An_{27}, and microcline forms an anhedral clear grains that have the characteristic twinning.

The pyroxene is diopside. It is pleochroic from light green to colorless, length-slow, biaxial positive and has a 2V of 66 degrees and an extinction angle $Z \wedge C$ of 34 degrees.

The garnet is seen under the binocular microscope to be a brownish variety with an index of refraction of 1.813. It is believed to be intermediate in composition between almandite and spessartite.

Soda Granite

Most of the granite found in the belt of Keewatin-type rocks belongs to this group. The best exposures of soda granite are found on Tower peninsula of Doda lake. Here, the rock is massive, medium-grained, pink to red on the fresh surface and light pink to gray on the weathered surface. The content of dark minerals is lower than that in the quartz diorite and granodiorite. Light green epidote accounts for about half of the non-felsic minerals and its content increases near the granite contacts. The rock is well jointed and some of the joints have been filled with quartz.

The granite of the small island in the northern part of Caopatina lake is made up of albite (40%), microcline (15%), quartz (30%), muscovite (5%), chlorite (5%) and epidote (5%). The structure is gneissic with bands of quartz alternating with feldspar-rich bands. Epidote also forms layers parallel to the structure. The grain size is about 1 mm but some grains may be as much as 3 mm in diameter.

The pink granite facies is also well exposed on the southwestern tip of the large island in Surprise lake, and on the adjacent island to the west. The rock here is fine- to coarse-grained and lacks any pronounced gneissic or schistose structure.

A thin section of the fine-grained variety shows that the rock has a well developed granitoid texture. The grains are 0.5 to 1 mm in diameter and all have sharp boundaries. A Rosiwal analysis of the section gives the following mineral composition:

	%
quartz	32.6
microcline	11.7
plagioclase (An_{15})	51.2
biotite	3.5
sphene	0.5
epidote	0.3

From this mineral composition the percentages of the various oxides were calculated and are given in column I.

	I	II
	%	%
SiO_2	75.7	71.38
Al_2O_3	13.8	13.29
Fe_2O_3	-	1.46
FeO	0.4	1.75
MnO	-	0.03
MgO	0.3	0.45
CaO	2.6	1.07
Na_2O	4.5	3.01
K_2O	2.4	6.76
H_2O	0.1	0.52
TiO_2	0.2	0.36
P_2O_5	-	0.08
CaF_2	-	0.07

Compared with the average of 4 sodaclase granites (Johannsen, 1931, v. II, p. 112) listed in column II, the rock is seen to be slightly rich in silica and calcium and low in potash and iron. The low content of iron and magnesium is a reflection of the low mafic mineral content of the rock.

Pegmatite and Aplite

The complex of quartz diorite, granodiorite, syenite and soda granite is invaded by scattered bodies of pegmatite and aplite. The pegmatitic bodies occur as irregular lenses or as dikes as much as ten feet wide. The contacts of the pegmatite masses are more generally transitional than sharp, while the contacts of the aplite dikes are sharp.

Pegmatite is rather sparsely distributed within the granite as well as within country rocks near the granite contacts. The rock is pink and coarse-grained with feldspar grains measuring as much as two inches in length. It consists mainly of feldspar and quartz with minor amounts of dark minerals such as ilmenite and magnetite.

One thin section of coarse pegmatite shows that the rock consists essentially of plagioclase An_{13} (45%), quartz (35%) and microcline (20%). The texture is somewhat cataclastic with granulation common near grain boundaries and with strained grains of quartz. Plagioclase and quartz commonly form myrmekite intergrowths giving rise to micrographic texture.

The aplite, like the pegmatite, is rare and forms only small dikes cutting the other granite or small lens -like masses making up as much as 10 percent of some outcrops. The aplite is a massive, fine-grained, pink, sugary rock with a low percentage of dark minerals. Two specimens associated with the main mass of granite have the following mineral compositions.

	I	II
	%	%
quartz	25	30
microcline	60	10
plagioclase	10	20
saussurite-epidote	-	20
muscovite	5	20
accessories	garnet epidote topaz magnetite allanite	allanite sphene

composition of plagioclase An_{10} An_{13}

The presence of topaz in the specimen of column I is indicative of the action of mineralizers. The garnet is pink to red, has an index refraction of 1.811 and is believed to be intermediate in composition between almandite and spessartite.

Emplacement of Granite

The pink granite of the Tower peninsula is a massive rock. Here, the east-west trending Keewatin-type rocks have been truncated near their contacts with the intrusive. The attitude of the strata, the schistosity and the shear zones around the granite conform to the contacts with the intrusive. Apophyses of granite and pegmatite and veinlets of quartz and epidote projecting into the country rocks are very common indeed. The country rocks near the granite has undergone contact metamorphism, and the chlorite schists have been changed to hornblende gneisses and amphibolites. All these features suggest that the lava flows and the sedimentary rocks around the Tower peninsula have been displaced but not replaced, and that the granite is of magmatic origin.

The granite stock extending from Vercheres lake to the eastern shore of Noel lake is massive in its western half and gneissic in its eastern half. In the eastern half, the gneissic structure parallels the contacts of the intrusive and is better developed near the margins than near the center of the stock. The granite is in sharp contact with the country rocks and, like the granite of the Tower peninsula, it has projecting apophyses that cut the structure of the country rocks. This granitic stock has been emplaced partly in low grade metamorphic rocks of the greenschist facies and partly in higher grade metamorphic rocks of the amphibolite facies. In the western part, where the granite is 'disharmonious' (Walton, 1955, p. 11), the greenstone near the contact has been changed to amphibolite. Tourmaline is a common mineral in the country rocks near the granite which indicates that it was introduced by magmatic gases. All these features suggest that the country rocks have been displaced but not replaced and indicate that the granitic stock between Vercheres and Noel lakes is of magmatic rather than of metamorphic origin.

South of Doda lake, the main body of granite has characteristics similar to those of the granite mass between Vercheres and Noel lakes. Near the south shore of Doda lake, the lavas have been changed to hornblende gneisses and amphibolites and the sedimentary rocks now contain garnet and tourmaline. It must be pointed out, however, that the contact metamorphic effects on the greenschists and on the sedimentary rocks are neither widespread nor of too much intensity.

The pegmatite and aplite associated with the granitic rocks are massive and cut across the schistosity and gneissosity of the granite. The aplite dikes have sharp boundaries, and the pegmatite masses generally have gradational contacts in the granite but sharp contacts and cross-cutting relations where found in the country rocks. Topaz formed by the action of mineralizers, and is indicative of pneumatolytic action during the later stages or after the crystallization of a magma. Because of their occurrence and composition, the pegmatite and aplite of the area are believed to be of magmatic derivation.

In the main granite mass, many outcrops are remnants of the volcanic and sedimentary rocks found north and east of the granite contact. In some outcrops, however, country rocks and magmatic material are intimately associated, and the nature of these composite gneisses is not easily deciphered. The mineralogy and chemical compositions of certain of these rocks may suggest either a magmatic or a metamorphic origin. Thus, the mineral composition of the garnetiferous hornblende-pyroxene syenite given on page 6 is more indicative of a composite gneiss than a rock of purely magmatic derivation. The high percentage of mafic minerals, especially hornblende, the absence of quartz, the high content of potash feldspar and of garnet are features that, where found together, are suggestive of rocks of composite origin.

The gneissic structure in some parts of the main granite mass is very irregular and highly contorted. This complex gneissosity was probably caused not during magmatic crystallization, but by subsequent deformation. There is also microscopic evidence that indicates that the granite has been produced during metamorphism with the introduction of potassium and the change of plagioclase to microcline. Many of the thin sections give evidence of a feldspathization process in

the form of plagioclase grains only partly altered to micro-
cline.

DIABASE DIKES

Occurrence

Nearly all the diabase dikes of the map-area are found in the granite or in the higher grade metamorphic rocks. However, two exposures of diabase were observed in the Keewatin-type rocks. One of them is a dike 60 feet wide that occurs in pillowed lavas on the northeast shore of the east point of Windy lake. The other exposure of diabase in contact with the Keewatin-type rocks is found north of Meston lake, where it occurs as a 200-foot-wide dike cutting lava flows and tuff beds. The dike north of Meston lake strikes northeasterly, but the attitude of the dike on the shore of Windy lake is not known.

Eight other diabase dikes were observed in the gneissic rocks. Nearly all of them strike in a general N 30°E direction and the dip, as far as can be ascertained, is steep or vertical. One of the main dikes west of lake Grimaldi strikes slightly west of north. Only short segments of the dikes have been shown on the map, and these segments very likely extend much farther than actually shown. The most extensively exposed dike is near Oriol lake. It has a known length of more than ten miles and is exposed intermittently from one mile north of Oriol lake to the southern boundary of the map-area east of Roy river. This main diabase dike and that of Meston lake may very well be the continuation of the Dauversiere dike (Imbault, 1951, p. 9). If so, the dike would be more than 25 miles long and strike N 40°E wherever exposed. The dike does not form a perfectly straight line but bends north of Oriol lake. The dike is more than 500 feet wide on the east shore of Oriol lake but its width generally varies between 150 and 300 feet. The other dikes are narrower, and the one east of Grimaldi lake for instance is only about 25 feet wide. The diabase dikes tend to form resistant ridges but these rarely rise more than 20 feet above the surrounding country. No dikes were observed west of Surprise lake.

Petrography

The diabase is a black rock, massive, heavy, and has a characteristic ophitic texture. The grain gradation from coarse-grained (5 mm) in the center of the dike to fine-grained (1 mm) near the margins is clearly shown along the southern shore of Oriol lake particularly near the western contact of the dike. The essential mineral constituents are plagioclase and pyroxene with accessory quartz, biotite, magnetite-ilmenite and epidote.

In thin sections, the plagioclase is more abundant than the pyroxene. The diabasic texture with lath-shaped crystals of plagioclase and interstitial pyroxene is characteristic of all sections examined. The plagioclase grains are clear and the pyroxene grains may be clear or altered. Two stages of alteration of the pyroxene were noticed in the sections of the more altered diabase. In the first stage, the centers of the pyroxene grains are altered to tremolite, light-colored hornblende, biotite and quartz. Most of these secondary products form needle-like grains or flakes that radiate from the centers of the grains. The first stage of alteration may also result in the formation of rims of dark green hornblende and biotite. In the second stage of alteration, the hornblende is altered to chlorite. Chlorite was not observed as a secondary mineral formed directly from pyroxene.

The pyroxene of the diabase is augite, with a 2V ranging from 40° to 43°; N_y, 1.691; and birefringence, 0.023. In one section, the determination of 2V on progressively altered grains gave the following values: 40, 41, 42, 45 and 62 degrees. The grain with a 2V of 62 degrees is completely altered to hornblende and traces of the original pyroxene are wanting.

The plagioclase grains characteristically remain unaltered. Their composition varies from dike to dike between a calcic andesine (An_{48}) to a sodic bytownite (An_{62}). The grains are mostly twinned. Aside from the accessories already mentioned, the altered diabase contains muscovite, chlorite, leucoxene and sphene.

Tabulation of mineral percentages of 11 sections show a strikingly uniform composition. Modal analyses of three representative specimens are given below. Column I and II are analyses of specimens from the main dike, and column III of a specimen from the narrow dike just west of lake Grimaldi.

	I	II	III
	%	%	%
plagioclase	50.9	52.5	55.0
pyroxene	39.2	44.0	35.4
quartz	4.5	2.3	1.0
magnetite[1]	2.0	1.5	4.6
biotite	3.2	0.7	3.6
epidote	-	-	0.6
composition of plagioclase	An_{50}	An_{62}	An_{48}

1. All opaque minerals are considered to be magnetite although they may include ilmenite. For that reason no TiO_2 is shown in the following chemical compositions.

From these mineral compositions, the following chemical compositions were calculated. The optical properties of the augite show that it consists of 42 percent $MgSiO_3$, 40 percent $CaSiO_3$ and 18 percent $FeSiO_3$. The percentage of the different oxides in the augite is taken as SiO_2 = 50%, CaO = 20%, MgO = 21%, and FeO = 9%.

	I	II	III	IV
	%	%	%	%
SiO_2	52.7	52.1	50.8	50.48
Al_2O_3	17.5	15.8	16.5	15.34
Fe_2O_3	1.3	1.1	3.2	3.84
FeO	4.5	4.5	4.2	7.78
MgO	9.3	9.3	7.8	5.79
CaO	13.0	15.2	12.6	8.94
Na_2O	3.0	2.2	3.3	3.07
K_2O	0.3	0.8	0.4	0.97
H_2O	0.6	trace	0.8	1.89
TiO_2	-	-	-	1.45
MnO	-	-	-	0.20
P_2O_5	-	-	-	0.25

An average of 90 analyses of diabase (Daly, 1933, p. 18) is given in column IV for comparison. The diabase of the map-area has a higher CaO content but lower FeO and Fe_2O_3 contents than the average diabase.

The diabase is the youngest consolidated rock of the map-area, and the dikes have discordant relationships with the gneissic structure of the granite against which they have chilled borders. The diabase dikes have undergone very little deformation and alteration after their emplacement.

CENOZOIC

Distribution and Occurrence

The greater part of the map-area is mantled with glacial till and fluvio-glacial deposits of varying thickness. The dense cover of trees and undergrowth together with the lack of roads make a study of the glacial features rather difficult. Once recognized in the field, however, many of the glacial features are best studied with the aid of aerial photographs.

In general, the mantle is rather thin near the hill tops where outcrops are numerous. In the low areas, like around Jay, No Rock and Eva lakes, the mantle, if not thicker, is at least a lot more continuous, and the bedrock is not exposed at these localities. A 45 degree diamond drill hole, one mile west of Meston lake, went through 90 feet of glacial till before reaching the bedrock, indicating that the mantle is over 60 feet thick at that locality. It is also reported by Riverside Chibougamau Mines Limited that the overburden is 100 feet thick on the south side of the Opawica river, just east of Windy lake. It is probable that this is near the maximum thickness of the Pleistocene, but there is no evidence to prove that it cannot be much thicker locally.

The distribution of the older rocks has no control over the thickness of the Pleistocene cover. The larger boulders do not show evidence of long transport and they can be used to a limited extent in mapping the underlying bedrock. Thus, southeast of Doda lake, and west of Eva lake, large granitic boulders are common south of the granite contact but they are rare north of that same contact.

Glacial Material

The glacial material consists mostly of till ranging from boulder to fine silt in size. In places, sorted material such as boulders, gravel, sand and clay may form accumulations but these are rare and of small extent in comparison with the unsorted drift.

Forms of Glacial Deposits

The unsorted drift occurs for the most part as ground moraine forming a gently undulating topography of very low relief. Small hills or depressions show no particular form and pattern.

The till in places forms low drumlin-like ridges. Good examples of these topographic forms are the long points extending southwestwards from the northeast shore of Caopatina lake. Many similar forms are distributed throughout the area but they are not as easily recognized. Most of these drumlin-like accumulations are less than one mile long but some may be as much as three miles in length. Their width varies between 500 and 3000 feet and their height rarely exceeds 50 feet even in the largest ones.

Accumulations of boulders were occasionally observed in the granitic areas. The boulders are subangular and average about two feet in diameter. The boulder accumulations do not form elongated narrow tracts but are more or less oval-shaped or rounded masses. No glacial striae were observed on these boulders.

A few sand plains occur within the map-area. The deposits are remarkably flat and generally cover less than two square miles. One such deposit is found at the northwest corner of the map-area immediately northwest of Doda lake.

Unstratified clays are scattered throughout the area but they too are rare. Some gray clay was observed less than six miles southwest of the height-of-land. Clays are also present at the following localities: south of Noel lake, on the west shore of lake Proust and along the small streams flowing from No Rock and Jay lakes into De l'Aigle river. These clay deposits are not covered by younger drift.

Eskers were noted especially in the eastern parts of the map-area but none were recognized west of Surprise lake. The eskers are composed of silt, sand and gravel, and do not show very fine sorting. The sinuous ridges trend southwards to southwestwards. Some of the eskers are 20 feet high and 30 feet wide at the base, others are as high as 60 feet and as much as 100 feet wide at the base. The slopes of these ridges are fairly steep, being around 40 to 45 degrees. The eskers like most other glacial features are best studied from aerial photographs. The longest esker occurs northeast of lake Monaco, and it measures over two miles in length. Other eskers are shorter.

Small rounded hills and depressions are common in the southeast corner of the map-area where they form kame and kettle topography. These kames and kettles and the eskers are ice-contact features, and were probably formed by a stagnant mass of ice (Flint, 1949, p. 151).

Near the northwest corner of the map-area on one of the sand plains, are three ridges that trend N40°E. These ridges were studied from aerial photos only. They are about 2000 feet apart, 200 feet wide and appear to be low. Although they trend in a direction that parallels the elongation of the drumlins they are not believed to have been produced directly by moving glaciers. These ridges are thought to represent transitional dunes. They are located between 5 to 10 miles southeast of the eastern shore of former lake Barlow-Ojibway (fig. 2, p. 92), and the sand plain on which these ridges formed may very well represent a former beach along the shores of the lake. Westerly winds blowing from the lake may have formed these ridges.

Direction of Ice Movement

The direction of movement of the last ice sheet is indicated by the trend of the drumlins, by glacial striae and glacial grooves. The long points of Caopatina lake trend S25°W, and other less reliable determinations on the rest of the drumlin-like ridges show elongation varying between S30°W and S40°W. The glacial striae and glacial grooves (Pl. I A and B) nearly all strike S35°W. Stoss and lee topography shows that the last movement of the ice sheet was southwestwards.

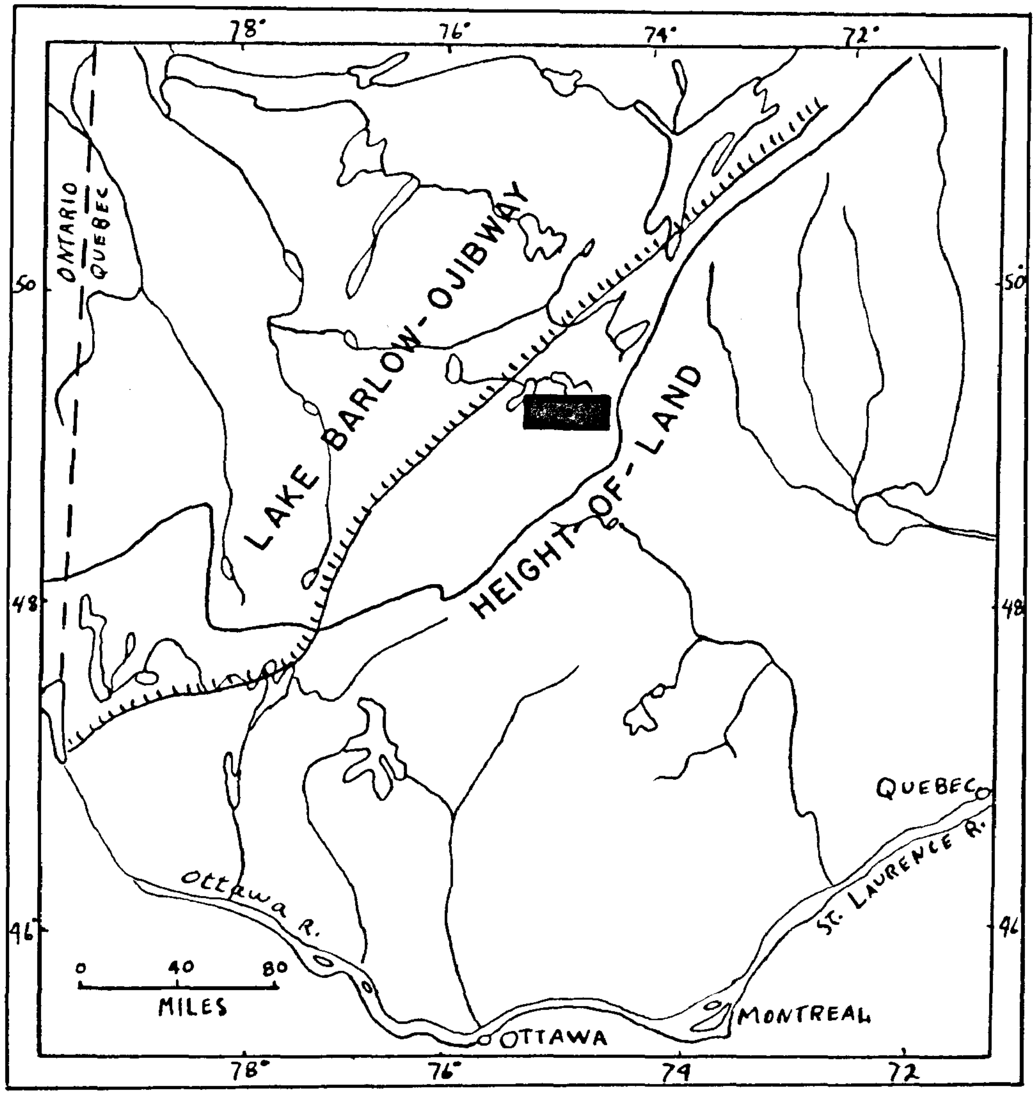

Fig. 2.—Location of area in relation to height-of-land (Antevs, 1925, fig. 27) and shore of former lake Barlow-Ojibway (Dresser and Denis, 1946, fig. 2).

ATTEMPTS AT CORRELATION

The word correlation as used in this report has no time implication but merely represents the equivalence of rock units on the basis of lithology. The distinction between the terms Keewatin and Keewatin-type and between the terms Grenville and Grenville-type should be pointed out here. The words Keewatin and Grenville imply a specific geologic age when applied to rock formations whereas the terms Keewatin-type and Grenville-type do not necessarily indicate age equivalence but rather lithologic similarities. The term Keewatin-type is applied to those rocks of the Surprise lake area that are similar to the dominantly volcanic rocks found in the three western subprovinces of the St. Lawrence province of the Canadian shield. The term Grenville-type is applied to those gneisses typical of the Grenville subprovince.

The correlation criteria are lithologic similarities, degree of metamorphism, and physical continuity. These criteria are not held in very high esteem by stratigraphers but they are nevertheless the only tools at the disposition of the geologists working in unfossiliferous and metamorphosed terrains of the Precambrian. For these reasons, the correlations are purely tentative.

In the Surprise lake area, two main difficulties hinder attempts at correlation. The first one is the paucity of outcrops. In metamorphosed terrain, one of the best ways of mapping different formations is to walk the contacts. In the area studied, however, this method of mapping is not only impracticable but almost impossible because of the lack of exposures. The second difficulty consists in the complexity of the structure and the lack of marker units. Not only have all the rocks been completely deformed but metamorphism has obliterated most of the stratigraphic and structural criteria. In the belt of Keewatin-type rocks, for instance, the volcanic, sedimentary, pyroclastic and intrusive rocks are all intermixed, nearly all metamorphosed to the same degree, and the normal sequence of deposition cannot be worked out accurately.

The problem of correlation in the Surprise lake area has three different aspects:

1) correlation of the different formations within the area
2) correlation of the different formations of the area with those of other areas and their assignment to the appropriate subprovince
3) correlation of the different formations of two geographically and geologically separate divisions of the Canadian Precambrian shield, namely the Timiskaming and the Grenville subprovinces (Wilson, 1939, p. 239)

The problem of correlation becomes increasingly difficult as larger and larger areas are considered and as the relation or stratigraphic position of the Keewatin-type and Grenville-type rocks are examined.

<u>History and Nomenclature</u>

The original meaning and subsequent expansion of each term that may be applied to the rocks of the map-area are reviewed briefly here.

Keewatin

The word Keewatin was first used by A. C. Lawson in 1885. Working in the lake of the Woods region of Ontario, Lawson recognized a thick series of closely folded lava flows and sedimentary rocks that he named Keewatin. He writes (Lawson, 1885, p. 14-15):

> "The most appropriate name for the series that suggests itself to me is 'Keewatin', the indian name for the Northwest, or the North-West wind which has been applied to the district within which the rocks occur."

According to Gunning and Ambrose (1939, p. 41), W.H. Parks in 1904 was apparently the first geologist to use the term to describe some similar rocks in western Quebec. The term was again used by Brook in 1907 and by Wilson in 1910 and kept being used more and more frequently. In 1931, (Cooke, James and Mawdsley, 1931, p. 25-53) the lava flows and sedimentary rocks of the Rouyn-Harricanaw region, Quebec were correlated with those found by Lawson. Four years later (Mawdsley and Norman, 1953) the term Keewatin (?) was tentatively applied to the greenstones of the Chibougamau lake area, Quebec. Mawdsley and Norman write (1935, p. 11):

> "The oldest rocks, the volcanic flows and minor interbedded pyroclastics and sediments form an altered assemblage that is similar to that termed Keewatin greenstones in other parts of Quebec and Ontario".

Mawdsley and Norman then refer to the Geological Survey of Canada Memoir 166 by Cooke, James and Mawdsley and write:

> "A rather full discussion of rocks of this character is given in the report on the Rouyn-Harricanaw region and the description presented there depict very well the main features of the old volcanic assemblage in the Chibougamau District".

The Chibougamau sheet, west and east halves (Mawdsley and Norman, 1938 and Retty and Norman, 1938) also refer to these lavas as Keewatin.

Timiskaming

W.G. Miller (1911, p. 648), working near lake Timiskaming, applied the term Timiskaming to a series of Archean sediments associated with but apparently younger than the Keewatin lava flows. The term Timiskaming never gained the widespread usage that Keewatin did and its stratigraphic position in relation to the Keewatin is not perfectly known. By definition, the Timiskaming sedimentary series is quite different lithologically from the assemblage of the Keewatin volcanic series, and rests unconformably upon the Keewatin lava flows. In places however, the Timiskaming-type sedimentary rocks are found intimately associated and seemingly in conformable contact with a Keewatin-type volcanic series so that in some places, the relationship between the metasediments and the volcanics is uncertain. In these places, the use of the term Timiskaming is not warranted.

Grenville

The term Grenville was first used by W.E. Logan (1863, p. 43 and 836-839) to describe a thick series of metamorphosed sedimentary rocks that he found in the Grenville township of southern Quebec. In 1910, Adams and Barlow (1910, p. 36) gave the distribution and aerial extent of the Grenville series but the western limit of the series could not be located very accurately. Geologic mapping along that western boundary has been erratic, and infrequent. In 1939, data, though still very incomplete, were sufficient to allow M. E. Wilson (1939, p. 239) to locate the western boundary of the Grenville subprovince more accurately. Among the rocks typical of the Grenville series are coarsely crystalline limestone, quartzite, and garnetiferous and sillimanite paragneisses, hornblende gneisses, and amphibolites. Anorthosite and gneissic granite form conspicuous masses within the Grenville rocks. The Grenville subprovince has been divided into four different regions (Dresser and Denis, 1946, p. 197), one of which is a border zone in the Grenville subprovince bounded on the northwest by the Timiskaming subprovince. The southeastern part of the Surprise lake area is within this border zone.

Keweenawan

The term Keweenawan was first used by Brooks (1876, p. 210) in his description of the copper bearing series of lavas and conglomerate of Keweenaw peninsula, Michigan. The term was later applied to rocks on the north shore of lake Huron and in the Sudbury district (Cooke, 1947, p. 30). The Keweenawan period occupies the upper part of the Proterozoic era and is characterized by great igneous activity that gave rise to basaltic lavas, and hypabyssal and deep-seated basic intrusives. The term Keweenawan has been applied here and there to diabase dikes that are in the upper Precambrian part of the geologic column. In most of the geologic reports covering areas in northern Quebec and Ontario, most late

Precambrian diabase dikes are termed Keweenawan without any direct evidence for the correlation other than their diabasic character and the fact that they are later than the other Precambrian rocks.

Geologic Periods Used in the Table of Formations

In the table of formations, the term Keewatin (?) is used to refer to the tightly folded sediments as well as the lavas, and the term Timiskaming has been omitted. Some of the higher grade gneisses have been referred to as Grenville-type. The granite has been classified as Grenville (?). Keweenawan (?) is applied to the late Precambrian diabase dikes.

There are two main reasons why the term Keewatin (?) is applied to the assemblage of lavas and sediments. In the first place, Mawdsley and Norman (1938) and Retty and Norman (1938) who mapped these rocks have already referred to them as Keewatin. Secondly, the rocks of the map-area correspond very closely to the descriptions of typical assemblages such as the one given by Cooke, James and Mawdsley (1931).

The term Timiskaming is not applied to the sedimentary rocks of Surprise and Caopatina lakes. Previous mapping of these sediments (Mawdsley and Norman, 1938) indicates that these rocks are:

> "in part probably younger than Keewatin but in part possibly Keewatin"....."The sedimentary rocks are possibly equivalents of the Timiskaming sediments in the Rouyn-Bell river region of western Quebec. They appear to lie in synclinal structures and to be younger than the greater part of the Keewatin lavas".

No unconformable relationship was noted between the sedimentary rocks and the adjacent volcanics, and it seems probable but far from certain that the two types of rocks are interstratified and of the same general age. Because of the close and intimate association of the sedimentary rocks and the lava flows, the writer prefers to place the two types of rocks under the term Keewatin. The rocks of the transition zone have also been grouped with the Keewatin (?) in the table of formations as they are the same rocks but have been metamorphosed.

The higher grade metamorphic rocks found east of Surprise lake were referred to by Mawdsley and Norman (1938) as "Archean and/or Proterozoic." It has been shown in a previous section of this report that the hornblende gneisses and amphibolites represent, at least in part, the metamorphosed equivalents of the lavas and related intrusive rocks and that the biotite paragneisses are metamorphosed Keewatin-type sediments. Whether or not all of these higher grade metamorphic rocks are actually metamorphosed Keewatin-type rocks cannot be ascertained, and because of this uncertainty, these Grenville-type rocks have been labelled Keewatin(?).

A major problem arose in constructing the geologic column and in trying to apply terms denoting age to the various rock units. An Archean-type rock may become by metamorphism in Proterozoic time a Proterozoic-type rock but if Archean rocks are metamorphosed in Proterozoic time they remain Archean in age. Thus, the Keewatin (?) rocks of the area do not become Grenville (?) rocks but the Keewatin-type rocks may become Grenville-type rocks. An Archean rock can give rise to a Proterozoic rock only by erosion and redeposition in Proterozoic time. There are, however, some rocks that may consist primarily of Archean material which has been modified and to which materials have been added by later metamorphic and magmatic processes. Those rocks are composite and cannot be easily placed in the geologic column.

In the Surprise lake area, the higher grade metamorphic rocks do not include the three most characteristic types of rocks found in the type locality of the Grenville namely the crystalline limestone, the quartzite and the sillimanite gneiss. However, the garnetiferous hornblende gneisses and biotite paragneisses and the amphibolites east of Surprise lake are common in the Grenville subprovince and they are considered Grenville-type rocks. Other workers who regard similar rocks of the surrounding areas as Grenville-type are Gilbert (1952, p. 2), Imbault (1951, p. 7), and Neale (1954, p. 5). In this report, the term Grenville is not applied to these Grenville-type gneisses mainly because of the strong evidences that these gneisses represent at least in part metamorphosed Keewatin (?) rocks.

Although evidences are not too reliable, it seems reasonable to assume that the granitic rocks of the area are of one age, though the intrusions may span a considerable interval of time. The granite is definitely younger than the Keewatin (?) rocks and, as shown by the Tower peninsula intrusion, it is also younger than the period of deformation that resulted in tight folding of the lavas and sediments. The granite has intrusive relation to the hornblende and biotite gneisses, and is therefore younger than the period of metamorphism that gave rise to the gneisses. It is, however, very difficult to place the time of intrusion in the geologic column. Radioactive dating is probably the only means at our disposition to date these intrusive rocks. Mawdsley and Norman (1938) have placed the granitic rocks of the map-area as Archean and "possibly not all of one age". There is a strong possibility that these granitic rocks are younger than Archean and should probably be placed in the Proterozoic. The reason for this is that the large main belt of granite has caused metamorphic effects in its western part but not in the eastern part. The eastern part of the granite therefore was intruded in hornblende gneisses and amphibolites and if these rocks were metamorphosed in the Proterozoic time (Grenville (?) time), and they probably were, then, the granite also would be Proterozoic in age. The granite is classified with the Grenville (?).

The diabase dikes are definitely the youngest consolidated rocks of the map-area as they cut the gneissic structure of the granite. Their constant composition indicates that they are co-magmatic and probably of the same age. Mawdsley and Norman (1938) have found that these dikes are later than the Chibougamau series (equivalent to the Cobalt series, Huronian (?)), though in part they may be pre-Chibougamau. Imbault (1951), Gilbert (1952) and Lyall (1953) who have mapped adjacent areas, tentatively correlated the diabase dikes with the Keweenawan (?). Although there is no evidence to show that these dikes were actually intruded in Keweenawan time, the common practice of assigning these late Precambrian rocks to that period is adopted.

Delimitation of Keewatin-type and Grenville-type Rocks

It is very difficult to place the boundary between the Keewatin-type and Grenville-type rocks of the Surprise lake area on the basis of lithology alone. The granite gneiss that spans the southern part of the area shows no noticeable change in lithology from the eastern to the western boundaries of the map-area, and therefore it cannot be used in separating the two types of rocks. As pointed out in the description of the various rock types, there is a gradation between the Keewatin-type rocks and the Grenville-type rocks, and the only realistic way to delimit the two types of rocks is to establish the transition zone shown on the accompanying map. This zone, which measures from two to three miles in width trends easterly between the eastern boundary of the map-area and the south shore of lake Caopatina. South of this lake, the belt assumes a southeasterly trend as far as Eva and Dos Claudes lakes, and it abuts against a granite intrusion south of these lakes.

A gradation between rocks of the Timiskaming subprovince and those of the Grenville subprovince has been noted by many geologists. Quirke and Collins (1930) in their famous memoir on the disappearance of the Huronian were amongst the first to conclude that the rocks of the Grenville subprovince represent metamorphosed and granitized sedimentary rocks of Huronian age. A number of Quebec Department of Mines reports show that in various places, a gradation exists between rocks of the Timiskaming subprovince and those of the Grenville subprovince. Among them the following can be mentioned:

1) Lowther, 1936, Villebon-Denain Map-Area
2) Freeman, 1943, Buteux Area
3) Wahl and Osborne, 1950, Cawatose Map-Area
4) Gillies, 1952, Caniniti River Area
5) Neale, 1954, Dollier-Charron Area

More recently W. G. Johnston (1954, p. 1072) has shown that east of lake Temagami, Ontario:

> "some of the Gneisses in the Grenville subprovince probably resulted from the metamorphism of granite of the same age as the granite in the Timiskaming subprovince".

Geologists, working near Surprise lake from the Grenville-type rocks towards the Keewatin-type rocks would tend to include the zone of transition with the Grenville-type rocks, and geologists working in the opposite direction would tend to place the zone of transition within the belt of Keewatin-type rocks.

STRUCTURAL GEOLOGY

The Surprise Lake area lies within two major structural divisions of the Canadian shield, the Superior and the Grenville provinces. These names were proposed by Gill (1949, p. 61-69), and the boundary between his Superior and Grenville provinces coincides with the boundary between Wilson's Timiskaming and Grenville subprovinces of the St. Lawrence province (Wilson, 1939, p. 237-239). Wilson's subdivisions are geologically and geographically different regions whereas Gill's provinces are based mostly on the dominant structural trends. As indicated by Gill (1949, p. 65), the generalized dominant trend of the Superior province is east-west whereas that of the Grenville province is northeast. It is also generally believed that the tectonic disturbances that took place in the Grenville province are younger than those of the Superior province.

Because the area belongs to two structurally different provinces, the structural features are treated separately in two separate sections under the headings "Folding of the Keewatin-type Rocks" and "Structure of the Grenville-type Rocks". The relationship between the structures of the two provinces is briefly discussed in a third section.

Folding of the Keewatin-type Rocks

Structural Features

As shown on the regional structure map (Fig. 3, p. 117) the Keewatin (?) lava flows and sedimentary rocks have an east-west trend, with strikes ranging between N.70°E. and

S.70°E.. The chief exceptions to this easterly trend are found near the northern part of Doda lake and south and west of Nool lake where the attitude of the flows and sedimentary rocks conforms closely to the contacts of the nearby younger granite masses.

The dips of the flows and beds are either vertical or steeply inclined. Dips generally range between 70 and 90 degrees although some dips north of the east end of Caopatina lake may be as low as 25 degrees; such low dips are very rare indeed. The lava flows along the northern boundary of the map-area from Meston lake to the western shore of Doda lake consistently dip to the north. South of this north dipping band, the sedimentary rocks and schists extending from the western shore of Caopatina lake eastward generally dip steeply to the south: west of the lake, however, the steep dips are to the north.

The Keewatin-type rocks of the area are generally schistose, and nearly everywhere the schistosity conforms to the attitude of the flows and sedimentary beds. Around the granite of the Tower peninsula, where the strata parallel the contact of the intrusion, the schistosity also conforms to the trend of the flows. Because of this parallelism, the attitude of the flows, especially where the contacts of individual flows were not recognized, have been inferred from the attitude of the schistosity. In a few places, however, as on the southern shore of Caopatina lake, the schistosity diverges as much as fifteen degrees from the attitude of the sediments.

The flows and sediments, in many places, have been very intensely deformed and drag folds and crenulations have formed (Pl. III A and B). The plunges of the axes of the drag folds range between 40 and 80 degrees to the northeast, and the axial planes generally strike east and are vertical. In some places, however, the axial planes of the drag folds strike northeasterly.

Zones of shearing are common in the belt of volcanic and sedimentary rocks, and many of them are located at the contacts of the lava flows and the sills of metagabbro-metadiorite. Most of the shear zones trend easterly paralleling the attitude of the strata and of the schistosity. One shear zone on the eastern shore of Doda lake strikes north but it also parallels the trends of the lava flows and schistosity that wrap around the intrusive of the Tower peninsula. The shear zones are from 2 to 100 feet wide, and commonly show relatively sharp contacts with the adjacent rocks. Though present throughout the belt of Keewatin-type rocks, shear zones are concentrated in two main localities. One is in the central part of Windy lake where a more or less continuous zone of shearing extends eastward from the western shore of the lake for a distance of about six miles. The other zone of shearing, traced only through widely scattered outcrops, extends from the eastern shore of Doda lake through the falls on De l'Aigle river to north of lake Jay. This zone is also about six miles long.

Jointing is not pronounced in the Keewatin-type rocks.

Basaltic flows are jointed in places (Pl. V-A), and some sediments may have a faint joint set perpendicular to the beds. All joints are steeply inclined to vertical.

No evidence of major faulting was observed in the Keewatin-type rocks. Minor faults are undoubtedly quite common, but like the shear zones, they probably generally strike parallel to the flows and sedimentary beds.

The best top determinations on lava flows were obtained from pillowed andesites exposed on the islands and shores of Windy lake. All top determinations here (about 25) show that the flows face south, and as the flows strike N.75°E. and dip 70 to 80 degrees north, they are overturned. These top determinations are spread over a width of about 8,000 feet measured at right angle to the strike of the flows. Another top determination on andesite about two miles east of No Rock lake where the flow here strikes S.70°E., and dips 80 degrees north, shows that the flow faces south and is also overturned. On the eastern shore of Doda lake about one mile south of the mouth of the Opawica river, the flow strikes N.10°E., dips 80 degrees west and also faces west.

Only three top determinations have been obtained from sedimentary rocks showing graded bedding. The sedimentary rocks on the southeastern shore of Caopatina lake strike S.80°E., dip 80 degrees south, face north, and are thus overturned. One mile southwest of Windy lake, near the survey line, easterly striking sediments are also overturned as they dip to the north and face south.

Interpretation

These top determinations on andesites and sedimentary rocks, and the other structural features represent a rather small amount of data from which to work out an interpretation of the major structure. The lack of marker beds or of an easily distinguishable rock unit also masks the structure. These factors together with the paucity of outcrops and the present scale of mapping hinder the interpretation of the structure, and make it quite speculative.

The general east-west trend of the Keewatin-type rocks suggests that the assemblage of lava flows and sediments was folded in response to north-south stresses. The steepness of the dips indicates that the strata have been tightly folded. If we accept the hypothesis that the drag folds represent on a small scale the structure of the major folds, the latter should be plunging 40 to 80 degrees to the northeast like the drag folds. The drag folds also suggest that the major folds are upright. If northeasterly plunging major folds are upright they should give rise to northeasterly trending structures; they could give rise to easterly trending structure only if the axial planes dipped to the north. A few north-dipping axial planes were recorded, but they are rare compared with the vertical ones. There is thus an apparent contradiction in the structure as indicated by the drag folds and that indicated by the trend of the formations. A possible solution to this contradiction may be that the northeasterly plunging drag folds and the major folds were formed at different periods of deformation and by stresses acting in different directions.

The structural features of the lava flows of Windy lake show that the strata strike easterly, dip steeply to the north, and face south. The top determinations are spread over a width of 8,000 feet across the strike of the strata, and no north facing flows have been observed. These structural features indicate that the individual lava flows may form a continuous sequence that is exposed over 8,000 feet. Other determinations on the attitude of these Keewatin-type volcanics north of the northern boundary of the area (Lyall, 1953), suggest that at least 3,000 feet more should be added to the top part of the Windy lake sequence. If this thickness of 11,000 feet of volcanics is in sequence without any repetition, it would then be located on an inverted northern limb of a syncline whose axial plane would be south of the lake. The strike of the axial plane of this syncline could be tentatively placed along the east-west survey line about one mile south of Windy lake. The writer thinks it more likely, however, that the exposures of Windy lake do not all belong to one limb of a major fold but rather form parts of many small isoclinal folds, but because of the lack of information a firm conclusion cannot be reached on this point.

Although sequences of sedimentary rocks and lava flows have been known to reach as much as 30,000 feet in thickness (Park, 1946, p. 307), it is doubtful that the Windy lake sequence is actually 11,000 feet thick, especially if we consider the wide distribution of the Keewatin-type volcanics. It is more likely that repetition both by bedding faults and isoclinal folding has taken place here. The evidence supporting the hypothesis of repetition is that south of the assumed axial plane, the sedimentary rocks dip steeply either to the north or to the south, and face either north or south. This arrangement suggests rather strongly that the Keewatin-type rocks are isoclinally folded. It is quite probable that more detailed mapping will reveal the presence of north facing flows in the Windy lake sequence.

Structure of the Grenville-type Rocks

The main structural feature of the higher grade metamorphic rocks is the attitude of the gneissic structure that may represent primary sedimentary and igneous structures in some places, and secondary metamorphic features in others.

Throughout most of the southeast part of the map-area, the hornblende and biotite gneisses strike east-west very regularly. The dips are to the north and generally are very steep, varying from 45 to 90 degrees. South of Vercheres lake, the dips are either vertical or to the south. The hornblende and biotite gneisses are believed to form a series of east-west trending isoclinal folds quite similar to those postulated in the belt of Keewatin-type rocks.

Structures transverse to the easterly trend occur between Vercheres and Messine lakes and more probably have been caused by the intrusion of granite. The transverse structures conform to the contacts of the granite. East and southeast of

Vercheres lake, and south of Messine lake, the easterly trend of the hornblende and biotite gneisses changes to northeast-southwest and even to north-south, and the dips are to the east. One mile southeast of Vercheres lake, the change in trend is rather abrupt whereas south of Messine lake it is more gradual. This change in the trend of the gneisses could be explained by a fault. No evidences of faulting were observed, however, and the structure is more likely to be that of a fold. Thus, the biotite paragneisses near the southeast end of Vercheres lake form an open anticline plunging southeast. The dips of the biotite paragneisses increase progressively from 45 degrees near the granite contact to 60 degrees farther eastward.

In the granite, the attitude of the gneissic structure is much less regular although general trends can still be recognized. Thus between the southwest bay of Surprise lake and lake Monaco, the gneissic structure of the granite strikes east-west. North and east of lake Monaco, it assumes a north-northeast trend that parallels the contact of the hornblende gneisses. The dips of the north-northeasterly striking granite gneiss are steep to the southeast.

Lineation in the higher grade metamorphic rocks was measured on elongated hornblende crystals and on plunges of drag folds. The number of measurements is small but all the recordings made show plunges parallel to the northeast plunges observed in the Keewatin-type rocks. Plunges as low as 15 degrees, however, were recorded in the gneisses, whereas those in the Keewatin-type rocks are much steeper.

Shearing, which is so common in the lava flows to the north, is rarely observed in the higher grade metamorphic rocks and in the granite. Only two shear zones were observed: one along Roy river in the narrow band of hornblende and biotite gneisses, and the other in the granite west of the long island in Surprise lake. Both these shear zones strike northeasterly and appear to be minor.

In only two places could evidence of transverse faulting be found. The first locality is along lake Pierre where there is cumulative evidence of a N.20°E. striking fault. The fault extends from the north end of lake Pierre to about one mile north of the southern boundary of the map-area. First, a band of hornblende gneiss is abruptly truncated at this lake; east, it is about three miles wide but to the west, it is only three quarters of a mile wide. Second, a sudden change in strike is concentrated in the vicinity of lake Pierre. The change in strike is not merely along the contact of the granite and the hornblende gneisses but also within the granite and the hornblende gneisses themselves. Third and quite significant, mylonite crops out along the shore of the lake especially near the south end. The rock is very hard and brittle, and has banded structure characteristic of many mylonites. A thin section of this rock shows strong cataclastic structure. The shape of lake Pierre which is over three miles long and about one quarter of a mile wide, and transects the east-west structure can be considered indirect evidence of faulting.

The other place where evidence of faulting has been found is along the southwest bay of Surprise lake, but evidence here is not as good as that of lake Pierre. There is no noticeable change in the trend of the structure here, and no abrupt termination or truncation of formations. Mylonite, however, is more common than at lake Pierre, and is well exposed near the southeastern part of the narrows leading into the southwest bay of Surprise lake. The outcrops of mylonite form resistant scarps. The gorge at the entrance of the bay may be considered indirect evidence of faulting parallel to the bay. The eastern side of the gorge consists of bedrock whereas outcrops are wanting on the western side.

Relationship between Folding of the Keewatin-type Rocks and the Structure of the Grenville-type Gneisses

As shown on the preceeding pages, nearly all the hornblende and biotite gneisses strike east-west, the only noticeable exception being the area between Vercheres and Messine lakes. Here, the change in trend is abrupt near the granite contact but gradual away from it, and was probably caused by the granite intrusion. North of Vercheres and Messine lakes, the belts of hornblende and biotite gneisses strike easterly and parallel the belt of Keewatin-type rocks. There is thus no sharp and continuous break in the trend of the formations as one goes from the Keewatin-type rocks into the Grenville-type rocks. East of the map-area (Gilbert, 1952), the structural trend becomes more complex, but in many places the general strike is eastward.

The change from the easterly trend of the Keewatin-type rocks to the northeasterly trend of the Grenville-type gneisses has been interpreted as a superposition of northeasterly mountain structures on the already east-west trending folds of the Superior province. Bell (1932, p. 70-73) and Norman (1940, p. 522) have found this relation between the two periods of folding in various areas of the province of Quebec. Gill who supports this hypothesis writes (1948, p. 29):

> "This (northeasterly) trend cuts directly across the east-west trend of the Keewatin and Timiskaming-type rocks along a line extending from the north shore of lake Huron to lake Mistassini. These relations strongly suggest that the Grenville subprovince marks a Late Precambrian mountain built belt with a trend later followed farther to the southeast by the Paleozoic mountain system."

In the map-area, the Grenville-type rocks trend easterly more than northeasterly. Where they trend northeasterly, they do not cut the east-west trend of the Keewatin-type rocks; instead the change in trend is gradational over a width of about two miles or more, and no age relation between the easterly and northeasterly structures can be established. If the granite responsible for the transverse structures east of Vercheres lake is related to the Grenville mountain building period, then the northeasterly trend could be interpreted as superimposed on the easterly trend. Another evidence that northeast structures have been superimposed on the east-west structure is that the youngest consolidated rocks of the map-area, the diabase dikes, trend northeasterly and cut the east-west trend. The fault along lake Pierre is also a superposition of northeasterly structure on an east-west striking formation. The Grenville structural province would thus appear to be tectonically younger than the folding of the Keewatin-type rocks.

The Grenville Front

In many places along the boundary separating the Grenville and the Superior provinces, major faults have been recognized. Such faults have been postulated in the Chibougamau region not far to the northeast, but in the vicinity of Surprise lake the relations do not indicate faulting. Norman (1936, p. 123) writes that, near Surprise lake,

> "The 'contact' between pre-Huronian rocks and the gneisses is a transition zone rather than a linear feature, though, in comparison to the extent of the pre-Huronian rocks westward and the gneisses eastward from it, the transition zone with its maximum width of two to three miles, is remarkably narrow.
>
> South of Opawica river, particularly near Surprise lake, pre-Huronian lavas and sediments apparently grade eastward into garnetiferous gneisses and schists. Further study may show that the gradation is interrupted particularly as the apparent continuity seems to be broken by faulting near a small body of intensely crushed granite at the southwest corner of Surprise lake. A few hundred feet west of the crushed granite dense massive greenstone and coarse grained metagabbro occur, whereas east of the granite, hornblende schists extend eastward in a narrow belt along the south side of Surprise lake and pass without interuption into garnetiferous amphibolites."

Evidence of faulting has been noted along the southwest bay of Surprise lake, but there is no major transverse fault. Hornblende gneisses and amphibolites are found on both sides of the bay; east of the bay hornblende gneisses increase in metamorphic grade to garnetiferous amphibolites, whereas west of the bay lower grade metamorphic rocks, such as hornblende schists are found, but the change is gradational. The same relationship between those rocks can be observed to the northeast at the outlet of Surprise lake, and there again gradational contacts instead of faults separate the rock types.

In the Surprise Lake area, the Grenville front is a zone of transition 2 to 3 miles wide that separates rocks of the Grenville-type from those of the Keewatin-type. Along the southern boundary and the central part of the map-area, intrusions of granite followed the metamorphism and the formation of the transition zone. A northeast trending fault along lake Pierre, and a northeast striking diabase dike were then superimposed on the granitic intrusives. From the northeastern end of Surprise lake eastwards, however, the metamorphism and the transition zone were not obliterated by intrusions of granite, and there are no superimposed northeast structure here. The northeast trending fault and the diabase dike along Pierre and Oriel lakes do not coincide with the zone of transition (Fig. 3, p. 117). Thus, the so-called Grenville front is a metamorphic front in this area. It is not the boundary between terrains of different time-stratigraphic rock units, nor is it a zone of strong dislocation. Here, the Grenville front is a zone in which rocks of one time-stratigraphic series pass from a lower to a higher grade of metamorphism.

Elsewhere along the Grenville front there is evidence for strong faulting or other forms of dislocation (Norman, 1940, p. 522), but the relationships in the Surprise Lake area would suggest that these are secondary tectonic features

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superimposed on, or perhaps correlative with, what is essentially a metamorphic facies change. Strong corroborative evidence for this may be drawn from the fact that all along the Grenville front the so-called Grenville-type rocks do not compare closely in lithologic variety or sequence with the assemblage of rocks identified with the Grenville series in central Ontario and southern Quebec. Along the Grenville front the rather striking crystalline limestones, quartzites, and sillimanite-bearing aluminous schists are absent or very subordinate. Amphibolite, hornblende schist and feldspathic biotite gneisses make up the bulk of the Grenville-type rocks at the Grenville front. This would suggest that the Grenville series as a time-stratigraphic entity has somewhat more restricted distribution than the Grenville subprovince as a tectonic unit. Thus, the term Grenville subprovince defines the areal extent of a metamorphic and dynamic episode that affected rocks of the Grenville series age but also affected other older rocks beyond the present limits of the Grenville series proper. The term Grenville series consequently identifies an assemblage of rocks that form a time-stratigraphic unit which is different from other time-stratigraphic units also found in the Grenville subprovince.

ECONOMIC GEOLOGY

Mineralization in the Keewatin-type Rocks

Occurrences and Distribution of Mineralized Zones

During the past several years, considerable prospecting has been carried out in the Surprise lake and nearby map-areas. In the summer of 1951, with the discovery of mineral showings in the Brogniart-Lescure area to the north (Lyall, 1953), activity in the Surprise lake region increased, and most of the northern part of the map-area from Windy lake eastward has been staked. The development work carried out so far has consisted of trenching, blasting, geophysical surveys and diamond drilling. Some encouraging gold values have been found and conditions appear favourable for the finding of deposits of interest.

Sulphide mineralization is particularly widespread throughout the lavas and to a lesser extent in the sedimentary rocks. Disseminated sulphides, mainly pyrite, are also very common in the gabbro-diorite intrusive sills. Most of the observed shear zones show at least some sign of mineralization. In many places, hydrothermal action has strongly carbonitized and silicified the country rock. Many of the most favourable shear zones occur at the contacts between gabbro-diorite bodies and the lava flows. Ten assays taken from different shear zones revealed the presence of gold in only one place, a little silver and traces of copper, nickel and zinc in the others. Some of the stronger shears and mineralized exposures are indicated on the accompanying map.

On the south shore of Caopatina lake, a few narrow beds of magnetite-rich rock occur in the sedimentary series. A grab sample of this material assayed 39.30 percent iron. The paucity of exposures in this part of the area is a hindrance to prospecting but it is of interest to note that difficulty was encountered in running traverse lines, due to the strong magnetic attraction on the needle.

Bands of talc, up to two inches wide (Pl. III-B), were found in one exposure on the west shore of Windy lake. They occupy the noses of small drag folds in schistose andesite. As the talc and magnetite occurrences are apparently small and rare, they are presently of no commercial value.

Gold-Sulphide Mineralization

The gold-sulphide mineralization in the Surprise lake region presents many of the characteristic features common in most gold producing districts of the Canadian shield. Six of these features are given below.

(a) The mining properties described in subsequent pages are all located within the belt of Keewatin-type rocks. The country rocks consist of altered volcanic flows and sills of gabbro-diorite, and minor sedimentary rocks. Alteration of these rocks gave rise to chlorite and hornblende schists.

(b) The zones of mineralization in the Surprise Lake area correspond with easterly striking shear zones. The zones do not appear to be major structural breaks, but they nevertheless represent channelways for the migrating mineralizing solutions.

(c) The country rocks have been silicified and carbonatized.
(d) All the deposits of the Surprise Lake area are located near the contacts of granite intrusions. At Moston lake, showings (1), (2), (3), and (4)[1] are within 6,000 feet of

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1. Numbers in parentheses correspond to numbers on map.

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the granite observed around the lake. The showing of Moston Lake Mines Limited (6) is within the granite itself. Similarly the showings of Mazour Chibougamau Mines Limited (5), Flamic Chibougamau Mines Limited (7), and Riverside Chibougamau Mines Limited (8) are within three and a half miles of exposures of granite. The granite contacts may very well be much closer to these prospects than indicated on the map as glacial material is thick over most of the mineralized localities. The gold values found at Des Claudes lake (9) are located within 2,500 feet measured horizontally from the granite contact.

(e) The gold occurs with quartz, calcite, pyrite, chalcopyrite and other minor sulphides. The quartz and calcite may form veinlets that follow the zones of fractures or irregular blobs. In general, the best values are found in the smaller veinlets whereas the larger masses of quartz and calcite are not mineralized. One large vein of quartz and calcite on one of the central islands of Windy lake occurs in schistose metagabbro-metadiorite. The vein is 5 feet wide and over 100 feet long, and contains no sulphides. The larger blobs of quartz on the property formerly held by the Surprise Lake

Mines Limited (9) are barren, whereas gold is found in the silicified country rock.

(f) The distribution of the gold values is erratic with very rich zones found in rocks devoid of gold.

The gold-sulphide occurrences can be classified as lode fissure hydrothermal replacement (Bateman, 1951, p. 363-364). The proximity of the mineralized zones to the intrusive rocks, the lack of crustification and cavity fillings indicate that the material was deposited in deep-seated veins. Evidences of replacement such as doubly terminated crystals, and tabular crystals intersecting the structure of the country rock are common.

The concentration of mineralized zones in the Keewatin-type lavas and schists instead of in the higher grade metamorphic gneisses affords a good example of the influence of the country rock on deposition of minerals from mineralizing solutions. The chlorite schists are much more susceptible to replacement than the gneisses and amphibolites. The smaller number of shear zones in the gneisses and amphibolites may account to a limited extent for the lack of mineralization in these higher grade metamorphic rocks.

The proximity of the mineralized shear zones to the granite may suggest, although not prove, that the vein material was introduced from an outside source and probably from the granite.

Iron-bearing Sedimentary Rocks

The two iron minerals observed in the sedimentary rocks are pyrite and magnetite. The sedimentary occurrences of both pyrite and magnetite are small and rare.

Pyritic black slate was found in only one locality on the north boundary of the map-area, 1,200 feet west of mile post VII west of Windy lake. Here, the slate is interbedded with quartzo-feldspathic beds, and intimately associated with the lava flows, and intrusive sills of metagabbro-metadiorite. The pyrite occurs as nodules and makes up 15 to 20 percent of the rock. The nodules are rounded or slightly elongated parallel to the bedding, are evenly distributed and average one quarter of an inch in diameter.

The sedimentary rocks containing magnetite are found on the south shore of Caopatina lake, and are interbedded with black slates and quartzo-feldspathic layers. They are, however, less intimately associated with the lavas than the pyritic slate. The beds rich in magnetite are thin ($\frac{1}{4}$ of an inch or less), and in sharp contacts with the adjacent beds. They are more of the "even-bedded" type than the "wavy-bedded" type (James, 1954, p. 285 and 289). The magnetite-rich beds consist of magnetite (60%), calcite (25%), and silicates (15%). The magnetite grains are equidimensional (0.5 mm), have irregular and jagged outlines. The adjacent beds are finer-grained (0.1 mm), and contain only about 25 percent magnetite and accessory calcite. The finer grains of magnetite have the same forms as those in the coarser-grained magnetite-rich beds.

The pyritic slate and the magnetite-rich beds belong respectively to the sulphide and oxide sedimentary facies of iron formation (James, 1954). The pyritic slate has very likely formed under strongly reducing and acid conditions with low pH and Eh. (Krumbein and Garrels, 1952, p. 9-13 and Huber and Garrels, 1953).

The original nature of the iron mineral in the magnetite-rich beds is less easily ascertained. The magnetite may be primary. Although experiments (Huber and Garrels, 1953) show that magnetite does not precipitate directly from solutions, James (1954, p. 257) lists a number of iron formations where magnetite is considered to be a primary mineral, but stresses that the supporting evidences are not as abundant as for primary hematite. Because of the coarser and jagged nature of the magnetite and the occurrence in slightly metamorphosed rocks, it seems more likely that the present magnetite may represent the metamorphic product of some former iron mineral. This mineral may have been hematite, as hematite easily reduces to magnetite either by diagenesis or by metamorphism.

Because of the close association of the iron-bearing sedimentary rocks, especially the pyritic slate with lava flows, it is reasonable to believe that volcanism played a major role in the formation of the iron-bearing sediments.

Mineralization in the Gneisses

Hornblende gneisses, biotite paragneisses as well as some of the less acidic granite facies are also mineralized with sulphides although less commonly than the lavas. The sulphide mineralization in the gneisses and granitic rocks consists mostly of disseminated pyrite and minor chalcopyrite. Carbonization and silicification of the gneisses is very rare. The sulphides are more concentrated near the southeastern and southwestern shores of Messine lake, and about 1,500 feet south of Vercheres lake. Analyses of samples from these localities show the presence of silver, copper and zinc but all in very small amounts. Three other occurrences of sulphides in the gneisses are indicated on the accompanying map. These are located on the south shore of Eva lake, one mile east of lake Pierre and about four miles northwest of the north end of the same lake. Traces of silver, copper, nickel and zinc are present on the south shore of Eva lake.

In the late summer of 1954, radioactive minerals were discovered by private interests in the vicinity of Yvonne lake about six miles south of Eva lake. Considerable staking followed, and by October several hundred claims had been registered. The original discovery is in the Buteux area, mapped by Freeman (1943, p. 9) who described the country rock as "red pegmatitic granite". The Barnat Mines Limited reports (unpublished information) that the pegmatite contains magnetite-ilmenite intergrowths with which very fine uraninite crystals are associated. Two samples measured by radiometric tests showed a U_3O_8 content of 0.64 percent and 0.33 percent respectively. Allanite crystals up to half an inch in length have also been identified.

Description of Properties

Adnor Mines Limited (1), (2), (3)[1]

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1. Numbers in parentheses indicate showings and/or drill holes, and correspond to those on the accompanying map.

This company holds a group of 21 claims in the northeast corner of the map-area. Due to the paucity of the exposures, the contacts have been postulated from a magnetometer survey. The survey reveals the presence of basic, intermediate and acidic lava flows striking east-west across the property and dipping steeply to the north. Bands of tuff are commonly interbanded with the lavas. These east striking rocks have been cut by a northeast striking diabase dike which shows very little evidence of shearing. Shearing zones in the flows, however, are intense especially in the Central part of the property. Three gold-bearing zones numbered (1), (2) and (3) and located on the accompanying map have received more attention. Shear zone (1) varies in width from 6 to 10 feet, and contains numerous veinlets of quartz, which rarely exceed 6 inches in width. The country rock has been carbonatized and silicified. A gold-bearing zone (2) is exposed along a trench 230 feet long that trends north-south. The rocks are altered volcanics consisting of carbonated and silicified hornblende and chlorite schists cut by four shear zones whose widths vary from 2 to 10 feet. The shear zones generally strike east-west. A grab sample taken from the second northernmost of these shears on analysis revealed 0.843 ounces of gold per ton. Diamond drill holes (3) were bored to determine the possible extension of the gold-bearing zone of Chibougamau Mines Limited, whose holdings lie to the east of the map-area. One of the holes cut a section one foot long that assayed 67 ounces of gold at a depth of 2,100 feet. All the other holes failed to encounter any gold-bearing zone. In the spring of 1953, 45 holes totalling 20,326 feet were bored. Except for the one foot section already mentioned, no values of note were found.

Wright-Hargreaves Mines Limited (4)

Immediately west of the Adnor Mines Limited, six claims belong to the Wright-Hargreaves Mines Limited. A shear zone (4) occurs in lavas associated with sills of gabbro-diorite that strikes N 70°W and dips 80°N. The country rock near the shear zone has been silicified and carbonated. Samples taken from that zone assayed 0.4 ounces of gold to the ton over a 3 foot width.

Hazeur Chibougamau Mines Limited (5)

Of the 24 claims held by this company 8 are located in the map-area, the others lie immediately north of the map-area. The company's main showing (5) lies on the northern boundary of the area about 2,000 feet east of mile post VIII north of Caopatina lake. Here, the lavas have been altered to carbonate chlorite schists whose schistosity strikes N 85°W and N 75°W, and dips between 45° and 65° to the north. Quartz veins carrying galena and pyrite parallel the schistosity, but dip only 20° to the north. This schistose zone is cut by a north-south left hand fault and by a quartz vein that strikes N 10°W. A quartz sample from the northern end of the main shear zone has assayed one ounce of gold to the ton. Gold was also reported about 200 feet southwest of the southern edge of the main showing.

Meston Lake Mines Limited (6)

The main showing of this company (6) is located on the northeast shore of Meston lake. A gold-bearing quartz vein was discovered in a granitic rock. Diamond drilling during the winter of 1952 did not give encouraging results.

Flomic Chibougamau Mines Limited (7)

The property of Flomic Chibougamau Mines Limited consists of a group of 20 claims situated west of the Meston Lake Mines property. Seventeen diamond drill holes totalling 8,429 feet were bored in the winter of 1952. Basic volcanics and gabbro were encountered in the cores but they are reported to be more massive than those found eastwards on the property of the Meston Lake Mines Limited.

Riverside Chibougamau Mines Limited (8)

The property's holdings consist of a group of 10 claims located in the extreme northern part of Mazour township on the south side of the Opawica river just east of Windy lake. An electric resistivity survey was made during June 1954. The survey indicated the presence of a possible shear zone trending N 55°E and measuring 200 feet in width and about 1,800 feet long. The conductivity was of sufficient strength to indicate the presence of sulphide mineralization. The zone of conductivity coincides with a zone of carbonate schists. The first hole (8) has penetrated only 348 feet in bedrock and has yielded two core lengths of 8 inches and 2 feet respectively that assayed over $30.00 in gold. The two-foot long core also contained 1.5 ounces of silver, 1 percent lead, and some zinc.

Lake Surprise Mines Limited (9)

At Des Claudes lake, a group of 25 claims was formerly held by the Lake Surprise Mines Limited. The company's main showing was on the large point on the south shore of the lake. Stripping, trenching and blasting were done, and in 1950, ten diamond drill holes totalling more than 3,000 feet were bored. The main showing consists of a band of diorite 7 feet wide within a black hornblende schist. Both rocks are schistose and silicified. The diorite has sharp contacts parallel to the schistosity, and includes some lenticular masses of hornblende schist. Very fine-grained disseminated pyrite, chalcopyrite, and other sulphides occur in both the diorite and the enclosing rock. The diorite shows rusty weathering and some copper colors concentrated in a zone about three feet wide. One grab sample taken by the writer assayed 0.270 ounces of gold per ton, 0.24 percent copper, and 0.24 percent zinc for a combined gross value of $14.70 per ton[1]. Similar

1. The following values were used in the calculations;
   gold-$35.00 per ounce
   copper-30 cents per pound
   zinc-12 cents per pound

values were encountered in 4 of the 10 drill holes, and in each of them, the maximum thickness of mineralization cut by the drill was four feet. The true thickness of the mineralized zones may be less than four feet as the holes probably intersected it at oblique angles. Of a total of 3,089 feet drilled, only 31 feet of mineralized rock were encountered. The average gold content of these 31 feet is 0.155 ounce of gold per ton.

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PLATE I

A.- Glacial groove, southeast shore of Windy lake.

B.- Glacial groove and striae, southeast shore of Windy lake.

PLATE II

A.- Pillowed lava with top of flow indicated by point of geologic hammer, northwest shore of Windy lake.

B.- Pillowed lava structure accentuated by differential weathering, east shore of Windy lake.

PLATE III

A.- Drag folding in highly schistose lava, east shore of Windy lake.

B.- Bands of talc along nose of drag folds in schistose lava, west shore of Windy lake.

PLATE IV

A.- Fine-grained sedimentary rocks, south shore of Caopatina lake.

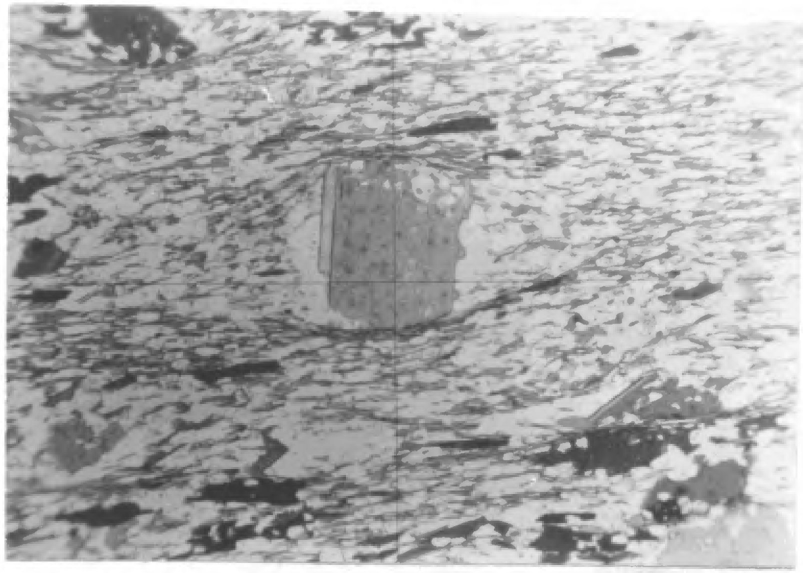
B.- Faulting and shearing in conglomerate, island south of Caopatina lake. Note quartz veinlet parallel to the fracture.

PLATE V

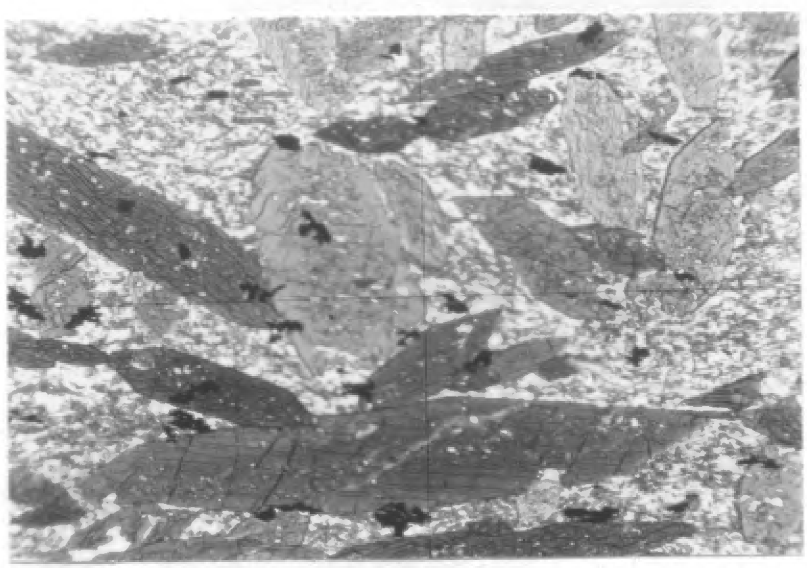
A.- Vertical joints in basaltic lava, island near western shore of Doda lake.

B.- Pebble-like plagioclase porphyroblasts in fine-grained hornblende schist, western tip of long island of Surprise lake.

PLATE VI



A.- Biotite porphyroblast perpendicular to structure of biotite paragneiss. Section is from exposure one mile southeast of lake d'Eu. Natural light, x28.



B.- Hornblende porphyroblasts in hornblende-chlorite schist. Section is from exposure north of Surprise lake. Natural light, x28.