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HAZEUR - DRUILLETTES AREA, ABITIBI-EAST DISTRICT

PROVINCE OF QUEBEC, CANADA

DEPARTMENT OF MINES

Honourable W. M. COTTINGHAM, Minister

GEOLOGICAL SURVEYS BRANCH

GEOLOGICAL REPORT 87

HAZEUR-DRUILLETTES AREA

ABITIBI-EAST ELECTORAL DISTRICT

by

A.-N. DELAND and P.-E. GRENIER

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ABITIBI-EAST ELECTORAL DISTRICT

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INTRODUCTION

General Statement

The Hazeur-Druillettes area includes somewhat more than three 15-minute map-areas in the region southwest of Lake Chibougamau. It is part of a major project, initiated in 1950 by the Quebec Department of Mines, and involving mapping at one mile to one inch scale a zone approximately 80 miles long and 35 miles wide, extending westward from the Chibougamau highway just south of Lake Chibougamau. This region parallels to the south the main "mineralized belt," as so far known, of the Chibougamau region. However, mineral deposits are present in this southern belt, and some of these are of economic importance. In the present area (1), although most of the deposits are in Keewatin-type rocks, there are deposits of considerable interest in the "Grenville gneisses" as well.

Geologically, a major objective in the present area was to study the relationship between the Keewatin-type rocks in the northwestern part of the area and the Grenville-type rocks found in the southeastern part. The relationship between the Timiskaming and the Grenville provinces of the Canadian Shield is still one of the major 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.

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(1) Unless specified the term "area" applies to the three map-areas combined.

Location and Access

The Hazeur-Druillettes area is included in Abitibi-East electoral district, some 240 miles northwest of Quebec city and 45 miles southwest of Chibougamau. It includes the townships of Druillettes and Hazeur, large parts of Gradis, Machault, Langloiserie, Pambrun and Gamache, and smaller parts of Crisafy, L'Espinay and Bressani townships. The area is bounded by longitudes 74°30' and 75°15' and, in the eastern two-thirds, by latitudes 49°15' and 49°30'. The western third extends 7 miles farther south, or to latitude 49°09' and the northern boundary of the Buteux Area (Freeman, 1943). The total area includes 646 square miles.

The area is easily accessible. The St. Félicien-Chibougamau highway passes 12 miles from the northeast corner of the area. A side road leaves the highway at Mile-post 121 (121 miles from St. Félicien) and 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 most practical way of reaching other parts of the area is by float-plane.

Lakes that afford good landing places for float-planes are numerous and provide access to all parts of the area. From des Vents, 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 des Vents lakes. A single longer portage of 6,500 feet offers a second and more direct, although more laborious, passage between these two lakes. There is but one short portage between Caopatina and Surprise lakes, as also between Caopatina and des Vents lakes. The canoe route between Surprise and Doda lakes 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.

The two main navigable rivers, Opawica and Aigle, permit easy access to the southeastern and southwestern parts of the area, respectively. The many rapids and falls on these rivers are by-passed by canoe portages. These portages, as well as those linking smaller lakes and rivers, are in good condition. The Hébert and Roy rivers permit easy access to the western and south central parts of the area, respectively.

Previous Work

The first work in the area was done in 1935 by the Geological Survey of Canada (Norman, 1936). In 1938, the Survey issued two maps on the Chibougamau region (Mawdsley and Norman, 1938; Retty and Norman, 1938). These two maps are on a scale of 4 miles to the inch and are accompanied by marginal notes. Discoveries of massive sulphides with gold values in the area south of Doda lake led to the geologic mapping of the Buteux area by the Quebec Department of Mines (Freeman, 1943).

Prior to and during the present investigation, surface prospecting was going forward especially in the northern and north-eastern parts of the area, and geophysical surveys were also made near d'Eu and Meston lakes.

The adjoining area to the east of the present area was mapped by Gilbert (1952) and the areas to the north were mapped by Lyall (1953) and by Remick (1956; 1957).

Present Work

Field work leading to the present report was carried out in the summers of 1952, 1953, and 1954. During each field season, a 15-minute area or more was mapped. Preliminary reports (Grenier, 1953; Deland, 1953; Deland, 1955) covering the three areas have been published, as well as a summary account of the three areas (Deland, 1956). The work of 1952, covering the most eastern area, was under the direction of P.-E. Grenier with A.-N. Deland being his senior assistant. A.-N. Deland was in charge of the investigation during 1953 and 1954, and it is he who has done the necessary geological laboratory work and written this final report for all three areas.

The area was explored by pace-and-compass traverses and shoreline work. The traverses were spaced 2,000 to 2,500 feet apart, and whenever possible were run north or south across the trends of the formations.

The geology was plotted on a base map with a scale of 1/2 mile to the inch. The base map was compiled by the Quebec Department of Mines from preliminary surveys and from vertical aerial photographs taken by the Royal Canadian Air Force. The aerial photographs proved very useful in the field. Aneroid barometers were used to determine the elevations of some of the higher hills.

Laboratory work included a petrographic study of about 300 thin sections aided by heavy liquids, magnetic separators, the universal stage, and the oil immersion methods. The mineral constituents of 18 rock specimens were determined by X-ray methods in the laboratories of the Quebec Department of Mines.

An attempt was made to use the National Research Council rock colour chart. The chart proved helpful in assigning colours to the less metamorphosed sedimentary rocks and some lava flows. It could not be used in describing the higher-grade metamorphic rocks.

Fourteen samples from mineralized zones were assayed in the laboratories of the Quebec Department of Mines.

Acknowledgments

Much of the information used in this report was collected by Jerome H. Remick, graduate student at the University of Michigan. Mr. Remick acted as senior assistant during the 1953 and 1954 field seasons and his valuable help is gladly acknowledged.

The junior assistants in 1952 were John Jenkins of McGill University and Pierre Crépeau of the University of Montreal; in 1953, Ken MacLeod of Mount Allison University and Claude Roberge of Ecole Polytechnique; in 1954, Jay Hodgson and Noël Chauvin of McGill and St. Lawrence universities, respectively. All performed their duties in a very satisfactory manner.

In 1954, the party received much help from J.L. Quessy and his aides of the Quebec Department of Lands and Forests station on Doda lake.

Deep appreciation is expressed to the faculty of the Geology Department of Yale University, where this study was combined with the requirements for a doctorate degree. Professors Alan M. Bateman and M.S. Walton read the manuscript and offered constructive criticism.

DESCRIPTION OF AREA

Topography

The area lies immediately west of the height-of-land separating the Hudson Bay and St. Lawrence River basins. South of Deux-Iles lake, near the east boundary of the area, the height-of-land is only 4 miles to the east. The general elevation of the area is 1,300 feet above sea level near the eastern boundary, and slightly over 1,100 feet near the western boundary. The elevations of the main lakes, listed in order from east to west, are as follows: Deux-Iles - 1,280 feet; Surprise - 1,223; Caopatina - 1,198; des Vents - 1,172; Doda - 1,109.[x] The difference in elevation between the easternmost lake and the westernmost is 171 feet; the distance between them is about 35 miles. Thus, Opawica river, which connects all these lakes has a general gradient of less than 5 feet per mile, reflecting the flatness of the area.

The topography is typical of this part of the Canadian Shield. Local relief is not marked and the land surface, in general, is remarkably flat. Tracts of land 6 miles or more long have changes in elevation of less than 50 feet. Much of the map area not covered by bodies of water consists of swamps and muskeg or low ground. Most hills have gentle slopes, and few rise more than 100 feet above the general level of the lakes. There are, however, a few hills that constitute exceptions to this low, gentle topography. Among the latter, the highest is about one mile west of the south bay of Surprise lake. This hill, on which the Quebec Department of Lands and Forest has erected an observation tower, rises 550 feet above the level of the lake within a distance of a mile. A ridge between Remick and No Rock lakes rises about 300 feet above the level of these lakes. On Tower Peninsula of Doda lake a hill rises 225 feet above lake level, 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 southeast shore of Caopatina lake.

In general, the local relief bears little or no relation to the underlying bedrock. Thus, hills and swamps overlie granitic areas, as well as Keewatin-type rocks or their metamorphosed equivalents. However, in detail, some rocks are more resistant than others and account for some of the smaller topographic features.

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[x] Elevations as given on Chibougamau-Roberval Sheet, National Topographic Series - 32SE, 1951.

Lakes and Rivers

A striking feature of the area is the abundance of lakes. More than 31 per cent of the map-area is covered by bodies of water. The major lakes, listed above, form part of the Opawica river, which drains much of the eastern part of the area. The western part is drained by 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 in any of the standard drainage patterns. Some of the larger lakes, like des Vents and Caopatina, are characterized by very intricate shorelines. There is, apparently, no structural or lithologic control over the sizes and shapes of these lakes. Des Vents lake occupies a depression in bedrock, and its shores are characterized by nearly continuous exposures. Caopatina lake, on the other hand, occupies a basin filled by glacial material, and rock exposures are very rare on its shoreline. Both these lakes are shallow, and the outcrops of des Vents and the boulders of Caopatina make traveling by canoe rather hazardous. Other lakes, such as Doda and Surprise, are deep and their shores are partly rocky and partly made of glacial material.

Although a northeasterly alignment of topographic forms, particularly of the larger lakes, is evident in the general region, this trend is not indicated by the large lakes of the present area. However, most of the smaller lakes trend northeast as well as those shores of larger lakes that are not on bedrock. Perhaps the most striking of such shores is that of the north side of Caopatina lake, which is a series of long peninsulas all trending northeast. Throughout the area this trend has been induced largely by the disposition of glacial deposits.

The channels of Opawica and Aigle rivers are 20 to 30 feet deep in most places. Where the rivers cut through bedrock or through coarser glacial material, the channels are shallower, and rapids and waterfalls are numerous. Nearly all the rapids on the Opawica and Aigle rivers are formed by coarse boulders.

Inhabitants, Climate and Resources

The area is uninhabited save for one Indian family on the east shore of Doda lake at the mouth of Aigle river. Here, also, is the main regional camp of the Quebec Department of Lands and Forests. During the summer months this Department maintains five to ten men at this camp, and operates three observation towers.

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

Owing to the climate, and the lack of good soil or clays, agricultural possibilities are slight. 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. Blueberries and raspberries are abundant in some parts of the area.

The area is well wooded. There are some beautiful stands of black spruce, the most abundant tree. Other varieties of conifers include jackpine, tamarack, white cedar and balsam fir. White birch and poplar are the deciduous trees and are much less common than the conifers.

Falls on the Aigle and Opawica rivers constitute potential sources of electrical energy.

Fish are abundant in all the lakes. Pike and pickerel are fairly common. Sturgeon, grey trout and brook trout are rare.

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

GENERAL GEOLOGY

General Statement

All the consolidated rocks of the area are of Precambrian age. The northern and northwestern parts are underlain by Keewatin-type rocks which consist mainly of altered lavas (basalts to albite rhyolites) and sedimentary rocks, with some pyroclastic and intermediate to basic intrusive rocks. This complex has been sharply folded and deformed. In general, however, the strata strike in an easterly direction and are either steeply inclined or vertical. Shear zones which also strike east are common in this northern half of the area and many of them are mineralized.

The southern and southeastern parts of the area are underlain by gneissic granites, biotite and hornblende paragneisses, hornblende gneiss and amphibolite. Some of these metamorphic rocks, being rich in garnets and highly crystalline, are of the Grenville-type. The paragneisses and hornblende gneiss also generally strike east. However, toward the southeastern corner of the area, the trend gradually becomes north-northeast. In the gneissic granite, the gneissosity is much less regular, although the easterly trend still seems to prevail.

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

Keewatin-type rocks in the northern part of the area are at the southeastern border of the Timiskaming sub-province of the Canadian Shield, and the crystalline gneisses and granites to the south are at the northwestern boundary of the Grenville sub-province. Thus, a segment of the postulated boundary between the two sub-provinces crosses the area diagonally from northeast to southwest. Lithologic and structural evidences as well as transitional phases indicate that the hornblende and biotite gneisses are metamorphosed equivalents of the Keewatin-type lavas and sedimentary rocks. Faulting has played only a very small part in the structural relationships.

Unconsolidated glacial material of Pleistocene age is widespread and masks much of the bedrock.

Table of Formations

Cenozoic	Pleistocene		clay, sand and gravel, till
Late Precambrian	Keweenawan (?)		diabase dykes
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 — Transition Zone hornblende-chlorite schist amphibolite
			Keewatin-type rocks sedimentary rocks gabbro-diorite sills basalt, andesite, rhyolite and some pyroclastic rocks

KEEWATIN(?)

The Keewatin-type rocks underlie an easterly trending belt in the northern part of the area. This belt is 3 1/2 miles wide at the eastern boundary and 8 miles wide at the western boundary. Its maximum width, northward from the western end of Surprise lake, is about ten miles. The belt occupies more than one third of the 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 include basic to acidic lava flows, sedimentary rocks, intrusive sills of meta-gabbro and meta-diorite, and small amounts of pyroclastics. These various rock types tend to form associations that are quite different from one another. Thus, the intermediate and basic lava flows are intimately associated with sills of meta-gabbro and meta-diorite. These sills, on the other hand, are not associated with the more acidic flows. Albite rhyolites and trachytes are easily distinguished from the andesites and basalts. Pyroclastics, such as volcanic breccia and agglomerate, are associated with the albite rhyolites and trachytes. The sedimentary rocks have less restricted associations. They occur in large masses such as the belt south of Caopatina lake and the one north of Surprise lake, and they also occur in smaller masses intimately associated with the andesites and basalts, or with acidic flows. They were not seen in contact with the meta-gabbro and meta-diorite.

All the Keewatin-type rocks have undergone regional metamorphism and some have been much affected by hydrothermal alteration. The acidic flows and the quartzo-feldspathic sedimentary rocks have undergone less change than the rocks of intermediate to basic composition. Metamorphic effects prohibited separation of the andesites and basalts on the present scale of work, and the two types are grouped together on the accompanying geological map. The intrusive sills of gabbro-diorite have been differentiated from the lavas wherever possible, but the separation is difficult in places, as a schistose gabbro-diorite may closely resemble a schistose andesite or basalt.

Andesites and Basalts

Distribution

Flows of andesites and basalts are widely distributed in the belt of Keewatin-type rocks. The best exposures are on the shores of des Vents lake and 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 des Vents 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	60 feet	
Andesite, schistose	25 feet	
Diorite, massive	145 feet	(lower 60 feet has disseminated sulphides)
Andesite, pillowed	25 feet	

With this section as an example, it may be said that the individual flows are from 25 to 100 feet thick. However, some of the flows might very well fall outside this range. Detailed mapping in an area northwest of Chibougamau lake (Smith, 1953, p. 5) has shown that the individual flows there are 10-20 feet thick on the average, but that some are as much as 100 feet thick. Pillows are the most striking primary feature of the intermediate type of lava; vesicles and amygdules are rare and flow structure is lacking. Although the basaltic flows are generally well-jointed (Plate V-A), columnar jointing is absent.

Pillows are best developed in the andesites and are particularly common around des Vents lake (Plate II-A). On the average they are about one foot in length but some may range up to 6 feet. Layers of darker material 1/2 inch to 1 1/2 inches thick separate the pillows. This material weathers more easily than the pillows themselves and accentuates the structure (Plate II-B). Two of the main types of pillows described by Schrock (1948, p. 364) are common: the balloon type, which is the most common, and the loaf type. These two types, however, are not easily separated in all cases. Although most of the pillows have been deformed, some of the balloon type are useful in determining the tops of flows. A few pillows are vesicular near their margins, and some of the vesicles are filled with calcite.

Petrography

The andesites and basalts are fine-grained, greenish grey to dark grey, slightly to highly schistose "greenstone". Veinlets, many of them microscopic, are common. These are of quartz, calcite, epidote and, more rarely, sulphides.

Microscopic examination of the less schistose andesite and basalt shows a mass of generally fibrous secondary minerals with a homogeneous (interwoven) texture resulting from random orientation of the minerals. In some of the sections, the original ophitic or sub-ophitic texture is still apparent. The grain size is 0.01 mm. The individual grains, whether anhedral or fibrous, lack sharp boundaries and seem to grade one into the other. Birefringence is low in general. The essential minerals are colourless amphiboles, plagioclase, epidote, chlorite and minor quartz. The accessories include biotite, magnetite, pyrite and sphene.

Colourless amphiboles, mostly actinolite, occur in fibrous or feathery grains. Although porphyroblastic, no relict primary mineral remains to indicate origins. Actinolite tends to form grains that are slightly larger than the other minerals. In some sections, the amphibole is slightly pleochroic, from light green to nearly colourless, and is believed to be tremolite.

Some of the plagioclase is in euhedral laths up to 0.5 mm. long. The laths are completely saussuritized, and the composition of the original plagioclase cannot be determined. Other, smaller, grains of feldspar are clear and anhedral. Some of these grains are twinned, have a composition of An_{10}, and are probably secondary albite resulting from the alteration of a more calcic plagioclase.

Pistacite (iron epidote) and clinozoisite (iron-free epidote) constitute the next most common minerals and, in some sections, account for thirty per cent of the rock. The clinozoisite is, in some cases, surrounded by aggregates of saussurite grains. Pistacite grows in the centres of porphyroblasts at the expense of cloudy grains of saussuritite and clear clinozoisite. The borders of the porphyroblasts still show aggregate structure but the centres do not. 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 are undoubtedly introduced.

Much of the chlorite, which is in small flakes, appears to be clinochlore, although penninite and prochlorite may also be present. Most chlorite is secondary after amphibole.

Quartz was observed in one section only, although it may be common in the aphanitic groundmass. The grains are clear and anhedral, and probably are secondary.

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

The percentage of the various mineral constituents in the andesites and basalts is highly variable as indicated in the table below:

	%
Actinolite-tremolite	20-80
Saussurite and epidote	5-45
Chlorite	0-35
Albite	0-30
Calcite	0-10
Biotite	0-10

The estimated average mineralogical composition of 14 sections is as follows:

	%
Actinolite-tremolite	50
Epidote and clinozoisite	15
Saussurite	10
Chlorite	10
Albite	5
Accessories	sphene calcite biotite quartz magnetite pyrite

The average composition indicates that these rocks belong in the biotite-chlorite subfacies of the greenschist facies (Turner and Verhoogen, 1951, pp. 466-469).

Meta-gabbro and Meta-diorite

Distribution

Widely distributed throughout the intermediate and basic lavas and intimately associated with them are sills and lens-like bodies of altered gabbro and diorite which, wherever observed, are conformable with the flows. These rocks were nowhere seen in contact with the sedimentary rocks or the rhyolites. The largest single unit, exposed along the central part of des Vents lake is about 1,500 feet wide and more than two miles long. Most bodies, however, are of much smaller size, generally between 10 and 100 feet wide, and thus too small to be indicated on the accompanying map.

Petrography

The gabbro-diorite, being altered to a largely secondary mineral assemblage, is grouped with the andesites and basalts under the term "greenstone". It is more commonly massive than schistose, and, like the lavas, is greenish-grey to dark grey in colour. The massive rock is granular and fine-to medium-grained.

Most of the thin sections examined, show remnants of a diabasic or sub-diabasic texture which, however, is subordinate to a new, crystalloblastic texture. In some sections, the crystalloblastic texture has obliterated all traces of primary texture. The former is characterized by large feathery hornblende porphyroblasts, one to four mm. in diameter, set in a mass of chlorite, plagioclase and epidote. The plagioclase is in highly altered lath-shaped crystals that are generally .5 mm. long but that may be as long as 3 mm.

In some sections pyroxene has not been completely replaced, but uralitization has proceeded far enough not to permit determination of the composition of the original mineral. Thus, uralitized pyroxene and saussuritized plagioclase make the sections very cloudy.

The thin sections show that the mineralogy is similar to that of the extrusive andesites and basalts. The minerals are nearly all secondary and consist of colourless 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 is in large, green to colourless anhedral grains. Although the amphibole is clearly secondary after pyroxene, it is difficult to determine what varieties of amphibole and of pyroxene are present.

The most common amphibole appears to be in the tremolite-actinolite range. However, some sections contain a much darker amphibole identified as hornblende. The fact that 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, possibly, that they have been differently altered.

The plagioclase is in euhedral, lath-shaped, highly saussuritized crystals. The composition is that of an albite or sodic oligoclase (An10 to An15), which normally is secondary after a more calcic plagioclase. The alteration has not destroyed the original shape of the crystals, and in many grains concentrations of epidote accentuate the zoned structure.

Pistacite, clinozoisite and saussurite commonly form zoned porphyroblasts and otherwise repeat the habits observed in the lavas.

Chlorite occurs as colourless to greenish flakes or shreds. The proportion of chlorite, as given in the tables below, is lower than in the lavas because only massive gabbro was used for thin-section studies. The schistose gabbro-diorite 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.

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

	Table I %	Table II %
Amphibole	20-75	52
Plagioclase (An10-15)	Trace -40	19
Epidote and saussurite	0-45	12
Chlorite	0-15	4
Quartz	0-35	4
Biotite	0-15	1
Magnetite-ilmenite	0-15	1
Accessories	sphene pyrite calcite	

The altered gabbro-diorites appear to be transitional between the greenschist and the albite-epidote amphibolite facies (Turner and Verhoogen, 1951, pp. 460-469), the schistose variety belonging to the first facies and the massive variety to the second. The preservation of original texture in the massive variety identifies it with the grade of metamorphism of the second 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 in view of the fact that the two facies are transitional and cannot always be easily separated. It is probable that the intimately associated sills and flows were regionally metamorphosed under the same pressure and temperature conditions. The metamorphic differences between them probably may be explained on the grounds that, during regional metamorphism, the sills acted as resistant buttresses and remained massive, whereas the flows gave way more easily. Thus, the flows were altered to chlorite schist and the sills,to amphibolites. Also, it is 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

Distribution

Rhyolites underlie about 10 square miles in the vicinity of Remick lake. Here, an oval-shaped mass is in contact with sedimentary rocks on the eastern side and bordered by andesites on all other sides. Acidic flows near the western shore of des Vents lake, in a zone 3 miles long and less than a mile wide, are the extension of a northeast trending belt mapped in the area to the north (Lyall, 1953). Other and more isolated exposures are found about 3 miles northeast of Doda lake and about half a mile east of Bernard lake. All these occurrences are in the northern part of the belt underlain by Keewatin-type rocks. Only one outcrop of acidic lava was found in the southern part of the Keewatin belt. This outcrop, located between Miles II and III on the Machault-Langloiserie line, is intimately associated with chlorite and hornblende schists.

Petrography

In contrast with the andesites and basalts, the rhyolites are light-coloured, varying from light grey or light bluish grey to greenish grey, and commonly have very light grey weathering surfaces. They are generally massive, hard to break and are resistant to weathering. However, at the falls on Opawica river about a mile east of Doda lake, well-exposed, pinkish grey rhyolite is schistose, talcose, and crenulated. Subangular grains of quartz can still be observed. The exposures northeast of des Vents lake are much brecciated.

Under the microscope, the rock is generally cataclastic, porphyritic and slightly schistose. The phenocrysts are anhedral grains of quartz or subhedral grains of plagioclase that may be as much as 7 mm. but are generally 1 to 2 mm. long. These account for as much as seventy per cent of the rock in some cases. The groundmass consists of very small (0.01 to 0.05 mm.) anhedral and equigranular grains of quartz and feldspar. In non-porphyritic varieties, there seem to be two preferred grain sizes: 0.05 mm., and 0.5 to 1 mm. Flow structure was seen in one thin section. In this section primary quartz and plagioclase grains are nearly all elongated parallel to the structure, whereas the secondary needles of sericite have a random orientation.

Quartz and feldspar are the main rock-forming minerals. Minor but varying amounts of sericite, epidote and chlorite are present. The accessory minerals include hornblende, biotite, magnetite, ilmenite, pyrite, limonite, sphene, schorlite, calcite and apatite.

The plagioclase phenocrysts are clear to very slightly altered, and have albite twinning and the composition of albite or oligoclase (An_5 to An_{12}).

Quartz is in clear anhedral grains that commonly form augen-like structures. These structures are believed to represent former quartz fragments or phenocrysts that were crushed during the periods of deformation. In one section, quartz constitutes only 5 per cent of the minerals, and the rock might be classified as a trachyte. The plagioclase of that section accounts for 70 per cent of the rock, and is a sodic oligoclase (An_{11}).

The following tables show the mineralogical composition of three representative types of this group. Table I represents a trachytic lava, and Tables II and III represent rhyolites:

	Table I	Table II	Table III
	%	%	%
Plagioclase	70	25	60
Quartz	5	55	15
Sericite	10	10	-
Epidote	15	-	10
Chlorite	Acc.	Acc.	10
Biotite	-	10	5
Hornblende	-	-	10
Accessories	-	Pyrite Limonite	Sphene Pyrite Magnetite Limonite
Composition of plagioclase	An_{11}	An_{10}	An_{10}

These assemblages indicate that the acidic flows belong to the chlorite-muscovite subfacies of the greenschist facies (Turner and Verhoogen, 1951, pp. 469-472) and are a product of the lowest grade of regional metamorphism of quartzo-feldspathic rocks with excess silica and complete lack of CO_2.

Pyroclastics

Distribution

A few, scattered exposures of tuff, agglomerate, and volcanic breccia are interstratified with the lava flows. Tuff is well-exposed on a small island in the central part of des Vents lake about 2,000 feet from the south shore. It is about two feet wide, and lies between pillowed andesite and a gabbro-diorite sill. Black-weathering agglomerate is found close to where the Druillettes-Hazeur township line meets the northern boundary of the area. Agglomerate also crops out at the tip of the long point extending from the east shore of des Vents lake. Here, a band 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 100 feet north of Mile-post VIII on the Gradis-Druillettes line. Volcanic breccia is exposed about 1 1/2 miles west of Remick lake.

Petrography

The tuffs are fine-grained and light to dark grey with a few yellowish grey beds. They are finely laminated and schistose.

A thin section from the des Vents lake exposure has grains varying from 0.05 to 0.2 mm. of sericite (50 per cent), plagioclase (30 per cent), quartz (20 per cent) and accessory pyrite and sphene. In this section, layers of coarser-grained anhedral plagioclase (An_{12}) with a little sericite alternate with layers consisting of very small flakes of sericite and minor small grains of quartz. Epigenetic cubes of pyrite have grown across the schistosity.

The agglomerate exposed at the northern boundary of the area consists of feldspathic fragments a quarter of an inch to 4 inches long that have been stretched parallel to the schistosity. The fragments are set in a dark grey groundmass. No bedding was seen in these rocks.

The matrix of the volcanic breccia exposed near Remick lake resembles a rhyolite. It is light greenish grey and contains small angular grains of quartz and feldspar. The fragments, which make up 65 per cent of the rock, are either whiter than the matrix or dark grey to black. They average 3 inches in diameter, with some up to 6 inches, and show no definite orientation. The white fragments are subangular, the black ones angular with sharp outlines. Some of the black fragments are obsidian. 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

Distribution

Two separate bands in the central part of the area are underlain by sedimentary rocks. These trend slightly south of east, and are separated by a zone of volcanic rocks 1/4 to 1 mile wide. The northern band is about 14 miles long, less than a mile wide at its western boundary near Remick lake, and broadens eastward to 3 1/2 miles at Caopatina lake. The southern band, reaching from the northeast shore of Surprise lake westward to 2 miles northeast of Jay lake, is about 2 1/2 miles wide and 7 miles long. Both bands grade eastward into biotite paragneiss. Other small exposures of sedimentary rocks are associated with the lavas, particularly on the shores of the central part of Doda lake and about 2 miles east of No Rock lake. The best exposures of sedimentary rocks are on the south shore of Caopatina lake and near the survey line 2 miles southwest of des Vents lake.

The sedimentaries on the north shore of Surprise lake are more metamorphosed than those of Caopatina lake. Only metamorphosed equivalents of the sedimentaries are found east of these lakes.

Petrography

Conglomerate, which appears to form only a small percentage of the sedimentary rocks, is well exposed on some of the islands in the southern part of Caopatina lake (Plate IV B). It coincides with a shear zone and, therefore, some of its original features may have been obliterated. This may account for the lack of recognizable bedding, for example. The matrix is fine-grained and varies from light grey and feldspathic to dark grey and hornblendic. The pebbles also are feldspathic in some cases and rich in amphiboles in others. Thus, in some places distinctions or boundaries between pebbles and groundmass are not clear. The pebbles generally make up 25 per cent of the rock, but, in one exposure, they account for 60 per cent. They are elongated parallel to the schistosity. Most are 1 inch to 2 inches long. The largest are 6 inches long and 3 inches wide.

The sedimentary rocks consist largely of interbedded, light-coloured, quartzo-feldspathic rocks and dark slates (Plate IV-A) in layers 1 inch to 7 inches thick. In addition to colour, differential weathering has further accentuated the bedding, with resistant quartzo-feldspathic layers standing as much as 5 inches higher than the adjacent softer slates.

The quartzo-feldspathic rock is generally non-laminated, very fine-grained, and similar in hand specimen to the acidic lavas. The slate is well laminated, fissile, and fine-grained. Schistosity is weak and, although generally parallel to the bedding, may diverge as much as 25 degrees. Cross-bedding is absent, and grain gradation could be used in only two places to determine the tops of beds. Locally disseminated pyrite is abundant and, where altered to limonite, it gives a pitted weathered surface. South of Caopatina lake, a few narrow interbands of magnetite-rich sedimentary rocks were found.

Most thin sections show laminae 0.1 mm. thick or more. Individual grains are anhedral, equigranular, and less than 0.05 mm. in diameter. They segregate to form bands of different composition. Thus, about half of the bands are composed entirely of sericite and quartz nearly half are composed of some epidote, and some consist of quartz (75 per cent) and sericite (25 per cent). In darker layers, the epidote (pistacite and clinozoisite) increases to 30 per cent. The essential minerals are quartz, plagioclase, sericite, epidote and chlorite; and the accessories are biotite, hornblende, magnetite, pyrite, calcite, sphene and schorlite.

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

The mineral contents of three typical sections given below indicate that the quantity of each mineral varies between wide limits.

	Table I	Table II	Table III
	%	%	%
Quartz and feldspar	50	15	35
Sericite	40	15	30
Epidote	10	60	30
Hornblende	-	10	-
Chlorite	-	-	5
Accessories	schorlite	-	sphene

The sedimentary rocks have all been slightly metamorphosed, and belong to the greenschist facies (Turner and Verhoogen, 1951, pp. 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 composition of the sedimentary rocks being quite similar to that of the volcanics indicates that these latter and adjacent rocks probably were the source rocks. Inasmuch as most of the sedimentary series is medium silt size or finer it represents, for the most part, very fine products of weathering. The grain size, the very regular bedding and the lact of crossbedding indicate that accumulation took place under quiet-water conditions and in shallow basins.

ZONE OF TRANSITION

The Keewatin-type sedimentary rocks grade eastward into the Grenville-type biotite and hornblende paragneisses, and the andesites and basalts, into Grenville-type hornblende gneisses. The transition zone shown on the map is a more accurate representation of the geology in this area than would be an arbitrary contact line between Keewatin-type and Grenville-type rocks. The transition zone occupies a westerly trending belt that extends from the eastern boundary of the area, one mile south of Meston lake to the southern shore of Caopatina. South of Caopatina lake, the belt trends southwest and reaches the northern boundary of the Surprise Lake granitic stock. Rocks characteristic of this zone also appear south of Phooey lake where hornblende schist, hornblende gneiss and amphibolite are intimately associated. The Pleistocene cover prevents the precise delimitation of this zone of transition, but it seems to change in a regular way from one mile wide at the eastern boundary of the area to two miles wide south of Caopatina lake. Although rocks of this zone are found east and southeast of Surprise lake, the limits of the zone are uncertain owing mainly to the large granitic intrusions. Small, scattered exposures of these schists are found outside the limits of the main zone. Some are indicated on the accompanying map.

The transition zone includes such highly diversified rocks as amphibolites and amphibolite schists, hornblende schists, hornblende-chlorite schists and mica schists. The amphibolites and amphibolite schists appear to have been derived from a coarse-grained intrusive rock of problematical original characteristics and composition. The hornblende schists are derived from intermediate to basic lavas, the hornblende-chlorite schists, from lavas and sedimentary rocks, and the mica schists, from sedimentary rocks.

Amphibolite and Amphibolite Schist

Distribution

The amphibolites and amphibolite schists are restricted to a rectangular area of roughly 5 by 1.5 miles southeast of Caopatina lake. The best exposures are half a mile north of d'Eu lake, on both shores of Opawica river, and on the south shore of the eastern part of Caopatina lake.

Petrography

The amphibolite is dark grey to black, heavy, and medium- to coarse-grained. It is massive to slightly schistose. The few shear zones present are generally narrow, varying from 6 inches to 4 feet in width. They strike east parallel to the shear zones in the Keewatin-type rocks. The weathered surface of the rock is rough, with hornblende crystals 1/2 to 3/4 inch in diameter standing out in strong relief. The rock is very hard and breaks in sharp-edged irregular blocks.

The amphibolite consists of secondary amphibole (60-80 per cent), minor quartz (10 per cent), epidote (5 per cent), chlorite (5 per cent), and accessory plagioclase, calcite, biotite, magnetite and sphene. The amphibole is in anhedral grains 2 to 6 mm. in diameter. The grains either form a granular mosaic or they form porphyroblasts set in a very fine-grained granoblastic groundmass. In the amphibolite schist, the amphibole porphyroblasts are elongated subparallel to the schistosity and all the minerals of the groundmass, except quartz, parallel the schistosity.

In many thin sections, the amphibole is hornblende, in large, feathery or fibrous porphyroblasts that lack sharp boundaries. Some of the hornblende grains are very dark green, but, where small opaque inclusions (magnetite ?) are concentrated, the dark colour has been bleached. In other sections, the amphibole is tremolite-actinolite. Both varieties of amphibole are partly altered to chlorite.

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

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

Small grains of zircon were observed in many sections. They are generally dark grey, cloudy and are metamict (the ordinary optical properties have been destroyed by radioactivity). They are isotropic and are surrounded by haloes if found in coloured minerals such as hornblende and biotite. Some short, tabular grains have a golden yellow colour. The smaller grains are colourless.

The estimated mineralogical compositions of five representative sections given below indicate that the amphibolite and amphibolite schist fall into the albite-epidote amphibolite facies (Turner and Verhoogen, 1951, pp. 462-463).

	Table 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	-

These rocks most probably are of igneous origin and may be the altered equivalent of pyroxenite or peridotite, as observed elsewhere in Keewatin-type rocks in the Chibougamau region (Barlow, Gwillim, and Faribault, 1911, pp. 167-174). Gabbro-diorite, such as is associated with Keewatin-type volcanic rocks, could alter to the amphibolite, but all known occurrences of such in this area are relatively very small.

Hornblende Schists

Distribution

Fine-grained hornblende schists form a narrow easterly trending belt about two miles long and half a mile wide at the outlet of Surprise lake. The belt is bounded on the south by metasedimentary rocks. Other hornblende schists are found near the granite stock on the two largest islands of Surprise lake, and another group is exposed east of Surprise lake and south of Phooey lake.

Petrography

The hornblende schists are similar in many respects to the low-grade meta-andesites and meta-basalts. They are fine-grained, dark grey to greenish black, and schistose. The dark grey colour results from the abundance of small needle-like crystals of hornblende which, in some specimens, make up 90 per cent of the rock. Aside from the hornblende, the hornblende schists are commonly characterized by stringers and small lenticular or rounded porphyroblasts of plagioclase feldspar (Pl. V-B). The porphyroblasts are white to cream-coloured, 1-3 inches long and 1 to 2 inches wide. The stringers are generally irregular and discontinuous, aligned parallel to the schistosity, and are rarely more than 1/4-inch wide. They give the exposures a bedded appearance, but the complete lack of bedding or lamination plus the irregularity of the stringers rule out the possibility that the rocks may be of sedimentary origin.

About 100 feet from the granite contact, on the islands in Surprise lake, a ten-foot-wide band is roughly 50 per cent lenticular feldspar porphyroblasts. 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 feldspar stringers and lenses. This sequence 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.

Practically all the primary structures and textures of the lavas have been obliterated at this stage of metamorphism. Vesicular and amygdaloidal structures are absent. Pillow structures were observed in only two localities, one on the south shore of Phooey lake and the other on the west shore of a small lake half a mile south of Phooey lake.

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

The mineralogical 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, pp. 462-463).

Hornblende-chlorite Schists

Distribution

Rare exposures of hornblende-chlorite schists are found in the zone of transition associated with fine-grained hornblende schists. Representative specimens were collected around d'Eu lake and north of the northern shore of Surprise lake.

Petrography

The hornblende-chlorite schists are greenish grey to greenish black and very fine-grained. They are highly schistose, with a pronounced sheen on flat surfaces, and break in thin slabs. They are characterized by long, thin, black needles of hornblende that stand out conspicuously on the weathered surface. The needles are randomly oriented, and most are 1/4 inch to 1/2 inch long. Their presence differentiates the hornblende-chlorite schists from the Keewatin-type chlorite schists (greenstones).

Under the microscope, the grains are less than 0.05 mm. except for a few porphyroblasts of hornblende and biotite and augen-like structures of granular quartz. The hornblende porphyroblasts are as much as 5 mm. long (Plate VI-B), with clear boundaries and common poikilitic inclusions of quartz. They are probably rich in aluminum and iron, as they are quite dark and strongly pleochroic.

Chlorite occurs as very small (0.05 mm.) individual flakes or as large aggregates. The paragneiss 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. 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 present in nearly all the sections examined. Garnet was observed in one section.

The dark colour 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

Distribution

Mica schists occur immediately west of the river which links the Surprise and Caopatina lakes. Here, the few exposures form an ill-defined northeasterly trending zone one to 2 1/2 miles wide and 4 miles long. (Other outcrops, northeast of d'Eu lake are associated with hornblende schists and have been grouped with them.) The best exposures are on the south shore of Caopatina lake.

The mica schists grade eastward into biotite paragneisses and westward into low-grade metasedimentaries. The exposures along the south shore of Caopatina lake show this transition very well. The sedimentary assemblage along the southwestern part of the lake is essentially lacking in biotite. 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-feldspar rich layers, and, south and southeast of d'Eu lake, the sedimentary rocks have become completely changed over to biotite paragneiss. This rock is described separately below in the section on higher-grade metamorphic rocks.

Petrography

The mica schists are light grey, fine-grained, and strongly schistose. Remnants of primary bedding structure may be seen in the outcrop and, under the microscope, the rock has compositional layering that probably represents original bedding. The schistosity and compositional layering are generally parallel to each other but, in two of the sections, they are at angles of 15 to 20 degrees. In one of these sections, an introduced veinlet of quartz is parallel to the bedding whereas, in the other, a quartz veinlet is parallel to the schistosity.

The grain size in general is very fine (0.01 mm.), although in some cases epidote forms porphyroblasts as large as 0.5 mm. in diameter. The main constituents are quartz, biotite, muscovite, plagioclase and chlorite. Accessories include calcite, epidote, schorlite, magnetite, pyrite and limonite.

Contrary to most of the rock types described above, the mineral content of the mica schists does not vary between wide limits. Three estimated compositions are given in the tables below.

	Table I %	Table II %	Table 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

Tables I and II give the compositions of two specimens taken along two adjacent bands, dark grey and light grey respectively. The two tables show a distinct variation only in the relative abundance of biotite and muscovite. Table III represents the composition of a specimen collected 3.5 miles west of d'Eu lake on the south shore of Caopatina lake.

The mineralogical 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, pp. 460-473).

HIGHER-GRADE METAMORPHIC ROCKS

The higher-grade metamorphic rocks described here include biotite paragneisses, hornblende gneisses, and amphibolites. These rocks probably represent a more advanced stage of metamorphism of, respectively, Keewatin-type sedimentary, volcanic, and intrusive rocks. The hornblende gneisses and amphibolites are not mapped separately in this area as they are intimately associated and transitional in structure and composition.

The higher-grade metamorphic rocks form two easterly-trending belts in the central part of the area. East of Verchères lake, the two belts merge and so continue eastward into the adjacent area (Gilbert, 1952).

Inclusions of gneisses and amphibolites also are present in the granitic rocks, and the larger of these are shown on the accompanying map. West of Surprise lake, between Phooey and Eva lakes, hornblende gneisses and amphibolites are intimately associated with hornblende and hornblende-chlorite schists. North of Eva lake, in a width of 1.5-2 miles, amphibolite grades outward from its contact with granite to hornblende gneiss and, farther out, to hornblende schist.

Hornblende Gneisses and Amphibolites

Distribution

Approximately 50 square miles of the area is underlain by hornblende gneisses and amphibolites. They form a more or less regular easterly trending belt which at Messine lake divides into two segments that extend to Surprise lake.

The types of rocks included in this group have a wide range of composition and a great variety of textures. They may consist almost entirely of hornblende; or of hornblende and plagioclase; or of hornblende, plagioclase and quartz. They may be fine-, medium- or coarse-grained, massive or gneissic, granoblastic or porphyroblastic. They may show indications of primary stratiform structures.

Where a gneissic structure is well developed, it is common to find lenses and veinlets of quartz parallelling the structure. Light-coloured plagioclase is segregated in parallel stringers and lenses similar to those in the hornblende schists. In general, the hornblende gneisses and amphibolites are more recrystallized than the hornblende schists and the grain is coarser. The few specimens taken from small inclusions in the granite have a granulitic texture. It is probable 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 neighbours. In most thin sections, the grains vary between 0.2 mm. to 2 mm., although there are porphyroblasts of garnet and hornblende some of which are as much as 2 cm. in diameter. As most of these porphyroblasts are not elongated parallel to the schistosity, growth under uniform pressure conditions is indicated. In some specimens, however, the hornblende porphyroblasts are all elongated parallel to the structure.

The essential minerals occur in highly variable proportions, as shown in the following table:

	%
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 in the northern part of the main belt is in anhedral to euhedral grains that are slightly larger than the other minerals. It is normally green and strongly pleochroic, but may be colourless and peppered with many minute dots of magnetite. In a few places, it is slightly chloritized.

The hornblende in the southern part of the belt is in large prophyroblasts full of small poikilitic inclusions of quartz. It is darker than the hornblende to the north and nowhere colourless.

The hornblende of the inclusions is in anhedral, rounded grains with sharp, smooth boundaries. It is darker than the hornblende in the southern part of the main belt, but does have poikilitic inclusions of quartz.

The plagioclase of all the hornblende gneisses and amphibolites is in anhedral, clear grains. Twinning, though better developed in the more crystalline rock of the inclusions, is rare and zoning is faint. The composition of the plagioclase varies unsystematically between that of a calcic oligoclase (An_{25}) to that of a sodic andesine (An_{35}).

Epidote is most common in the northern parts of the central belt, rare in the southern parts, and absent in the inclusions. In the northern part of the belt, the two varieties of epidote, pistacite and clinozoisite have grown in a porphyroblastic manner. Pistacite occurs as clear anhedral to euhedral grains which have a high birefringence.

Quartz is in clear anhedral grains. It is most abundant in hornblende gneiss of apparent sedimentary origin, whereas plagioclase predominates in rocks lacking relicts of sedimentary structures.

Garnet (probably almandite) is in anhedral porphyroblasts that may be 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 per cent of the porphyroblasts consist of these inclusions.

Mineral Assemblage and Metamorphic Facies

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

	Table I Weight % of minerals		Table II Weight % of chemical composition
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 on Table I above and on that given on page 29 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, pp. 452-454).

Origin of the Hornblende Gneisses and Amphibolites

According to other authors (Adams, 1909; Adams and Barlow, 1910; Osborne, 1936; Buddington and Sederholm, 1939) hornblende gneisses and amphibolites may be derived from at least five different kinds of rocks. These are:

(1) calcareous sedimentary rocks
(2) basic dykes
(3) volcanic rocks
(4) greywacke
(5) basic differentiates of a granitic magma.

In the present area, the hornblende gneisses and amphibolites are believed to have been 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, as indicated earlier in this report, they probably account for the greater part of the amphibolites of the area.

(2) Nearly all the gabbro-diorite sills associated with the volcanics have been metamorphosed to amphibolites. The field occurrence and

the preservation of the original ophitic texture leave little doubt of this origin.

(3) As mentioned in the description of the rocks of the transition zone, the coarse-grained amphibolite south of Caopatina lake is believed to have been an ultrabasic intrusive in view of the abundance of amphiboles (many of them light-coloured and rich in magnesium), and the very low content of plagioclase and quartz. (See particularly Williams, Turner and Gilbert, 1954, p. 243).

(4) A sedimentary origin of amphibolites in this area is not clear. First, most of the metamorphosed sedimentary rocks have changed into biotite paragneiss rather than hornblende paragneiss. However, in a few places, as on the southern shore of Surprise lake, hornblende and biotite paragneisses are interbanded. The high content of quartz (as much as 50 per cent) in some of the hornblende paragneiss is a second source of uncertainty. Such quartz-rich rock was derived from quartzo-feldspathic sandstones, but it is difficult to see how they could become freed of so much quartz and become amphibolites. It is quite probable, however, that the shaly layers interbedded with the quartz-rich beds may have given rise to quartz-poor hornblende paragneisses and amphibolites.

Tuffs of the same general composition as the intermediate and basic lavas could be transformed to amphibolites. However, the scarcity and small size of the tuff exposures prevent demonstration of this in the area.

Biotite Paragneisses

Occurrence

Biotite paragneisses underlie about 20 square miles of the area in three main easterly trending belts. The northernmost belt adjoins the southern boundary of the zone 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 Verchères lake and the western shore of Surprise lake. East of Verchères lake, the two belts join and form a U-shaped band, one mile wide, that ends north of Messine lake. Inclusions of biotite paragneisses of mappable size are found in hornblende gneisses and schists east of Deux-Iles and Pierre lakes south of Noël lake; also, in the granite areas east and west of Monaco lake and on the south shore of Eva lake. Smaller inclusions occur in the two belts of hornblende gneisses and especially where hornblende paragneiss predominates, as on the south shore of Surprise lake. The biotite and the hornblende paragneisses are gradational in many places.

Petrography

The biotite paragneiss is a light to dark grey, fine- to medium-grained rock consisting essentially of biotite, grey plagioclase and quartz. Relict bedding is indicated by the regular alternation of bands rich in biotite and others rich in lighter-coloured minerals. In a few places the rock contains red to reddish garnet (as much as 20 per cent) concentrated along certain layers, further accentuating the already pronounced banding. The exposures east of Verchères lake and around Messine lake are characterized by a greater abundance of garnet. The alternation of garnet-rich bands with garnet-poor bands is quite similar to the alternation of beds of shale and of quartzo-feldspathic rock seen on the south shore of Caopatina lake. The biotite paragneiss is friable and weathers readily, the more resistant garnet grains standing out prominently on the weathered surface. The weathered surface is rusty, which is 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 lie within the biotite-rich rocks.

Seen under the microscope, the rock is schistose and granulitic. In many sections, the granulitic texture is more strongly developed than the schistosity. Quartz and plagioclase are in anhedral grains from 0.1 mm. in diameter. The biotite flakes, mostly 0.5 mm. long, parallel the structure. These three minerals are generally segregated into biotite-rich bands and bands rich in feldspar and quartz. Epidote, garnet and tourmaline also tend to segregate into layers. Accessories include muscovite, calcite, magnetite, limonite, chlorite, sphene, sericite, zircon, saussurite and pyrite.

In both the granulitic and the schistose rocks, porphyroblasts of garnet are up to 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, porphyroblasts of mucovite and biotite are perpendicular to the gneissosity (Plate VI-A).

The plagioclase of the biotite paragneiss of the northern belt is clear, untwinned, has indices of refraction close to that of balsam, and cannot be readily differentiated from quartz grains. The plagioclase in the biotite paragneiss of Messine and Verchères 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 this is nearly the same as that of the plagioclase observed in the hornblende gneisses.

Tourmaline, (schorlite) suggestive of metasomatism and contact metamorphism, is present in about a third of the sections examined. In two sections, it accounts for 5 per cent of the rock, and forms grains that are as much as 0.5 mm. in diameter. It occurs as anhedral grains, rectangular crystals, or spherical triangles, and has a marked pleochroism from grey to light grey.

Epidote forms anhedral and euhedral grains, either in veinlets or as porphyroblasts.

Mineral Assemblage and Metamorphic Facies

Table I below gives an average estimated composition of 13 sections from the northern belt and Table II, an average of 14 sections of biotite paragneiss of the southern belt. The main differences are in the greater amount of chlorite in the northern band and the higher proportion of epidote in the southern.

	Table I %	Table 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.

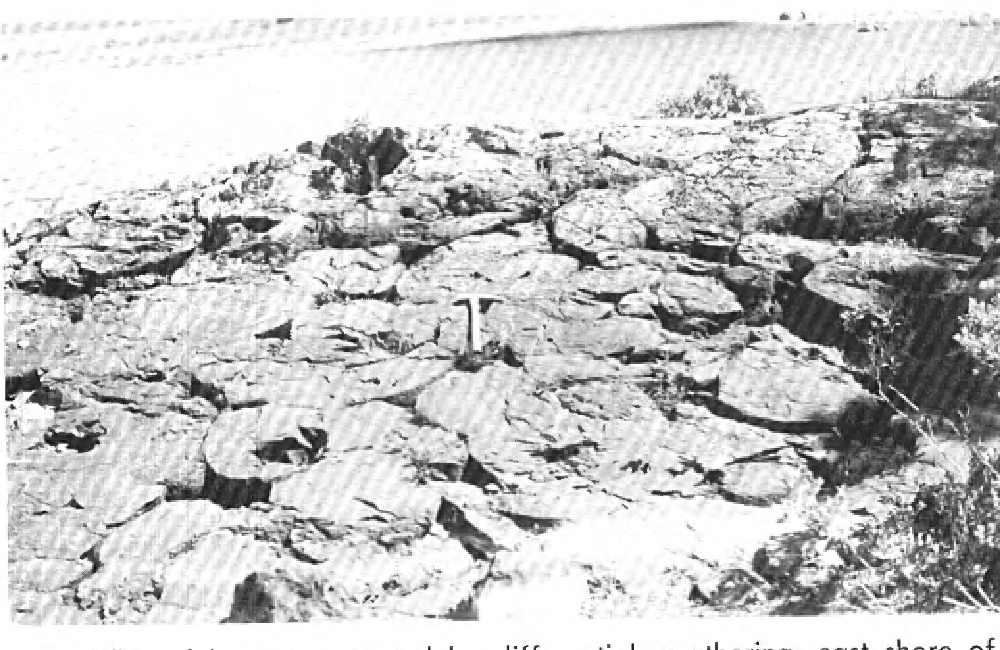
PLATE I

A. Glacial groove; southeast shore of des Vents lake.

B. Glacial groove and striae; southeast shore of des Vents lake.

PLATE II

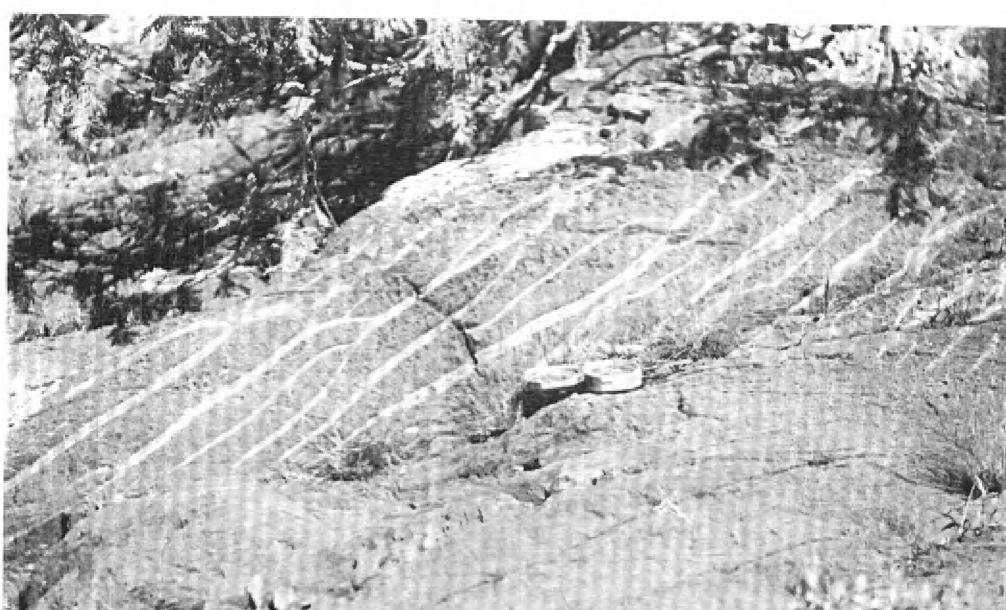
A. Pillowed lava with top of flow indicated by point of hammer; northwest shore of des Vents lake.



B. Pillowed lava accentuated by differential weathering; east shore of des Vents lake.

PLATE III

A. Drag folding in highly schistose lava; east shore of des Vents lake.



B. Bands of talc along nose of drag folds in schistose lava; west shore of des Vents lake.

PLATE IV

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

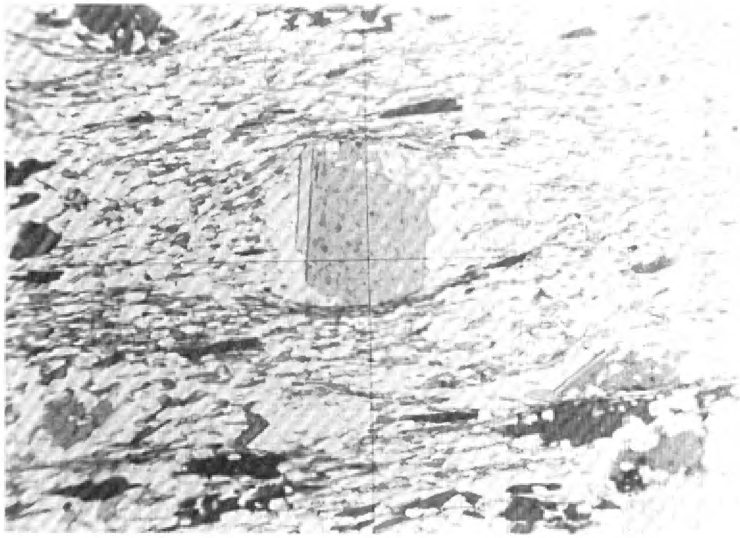
B. Faulting and shearing in conglomerate; island in southern part of Caopatina lake. Note quartz veinlet parallel to fracture.

PLATE V

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

B. Porphyroblasts of feldspar in fine-grained hornblende schist; western tip of long island of Surprise lake.

PLATE VI



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

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

Some of the garnet-biotite paragneisses belong to the amphibolite metamorphic facies equivalent to the staurolite-kyanite subfacies derived from feldspathic sandstones low in potash. (Turner and Verhoogen, 1951, pp. 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, pp. 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 is clearly shown on the south shore of Caopatina lake. Thus, the biotite paragneiss represents the metamorphosed equivalent of the sedimentary rocks found within the belt of Keewatin-type rocks.

GRANITE (1)

Distribution

Approximately 275 square miles (one-third) of the area is underlain by granite. In the southern parts of the area it forms an easterly trending belt that is 2 to 4 miles wide throughout most of its length but 16 and 8 miles respectively at the eastern and western boundaries of the area. In the centre of the area the main belt of granite is separated from a stock-like mass to the north by hornblende gneisses. This stock is about 20 miles long (east-west) and 1/2 to 3 miles wide. Smaller bodies of granite include that of Tower peninsula in Doda lake and those southeast of Noël lake, near d'Eu lake, and on a small island in the northern part of Caopatina lake. At Meston lake an outcrop of granite was submerged when the level of the lake was raised to allow landing of hydroplanes. This and the evidence of a geophysical survey suggest that granite underlies the lake and the ground immediately east of it.

(1) Unless specified, the terms "granite" and "granitic" are here used in their broader sense and include massive and gneissic alkali granite, syenite, granodiorite, and quartz diorite.

Varieties

The "granitic" rocks can be divided into two groups: an intermediate group including quartz diorite, syenite and granodiorite, and an acidic group represented by soda (1) granite, pegmatite and aplite. The pegmatite, aplite and most of the soda granite are massive. The others vary from massive to strongly gneissic. The relationship between the two groups is not simple. In places, the soda granite, pegmatite and aplite cut the rocks of the more basic group, and in others they grade into them. The more sodic varieties of granite, however, appear to be later facies of the more basic granitic rocks. The various facies will be discussed separately under the four following headings:

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

Acidic group
- 3-soda granite (1)
- 4-pegmatite and aplite

Quartz Diorite-granodiorite

More than 50 per cent of the granitic rocks consists of grey, gneissic quartz diorite and granodiorite.

These rocks are composed essentially of feldspar, quartz, biotite and hornblende with accessory epidote and chlorite. 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, especially near the contaminated borders of the intrusive masses. The rock is generally medium-grained, though some facies are coarser. In places, the gneissic structure is extremely complex and contorted with well-developed ptygmatic folding. Rarely is the rock massive, though in the finer-grained types, the gneissic structure is not everywhere obvious. The fine-grained rock weathers evenly, and the coarse-grained rock roughly or unevenly. Exfoliation is not common but is occasionally observed in the more gneissic rock.

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(1) This term is here applied to granites rich in albite but not necessarily containing sodic amphibole or pyroxene.

Under the microscope, the rock consists of anhedral grains of quartz and plagioclase feldspar arranged in a mosaic pattern, and of biotite flakes and hornblende and epidote crystals that are commonly elongated parallel or subparallel to the gneissic structure. The quartz is generally smaller than the feldspar, and some is elongated parallel to the structure. Accessory minerals are apatite, allanite and sphene.

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

Epidote (pistacite), in idioblastic grains, partly or completely surrounds most of the grains of allanite.

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

Microcline, which is not common in most of these rocks, is secondary after plagioclase. Locally, it gives the rock a slight pinkish tinge.

The estimated compositions of 5 representative sections are given below:

	Table 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

Tables I, II, III and IV represent granodiorite, and Table V, a quartz diorite.

Syenite

South of Doda lake, massive quartz diorite and granodiorite grade into syenite. Gradation from 15-20 per cent quartz to quartz free is very abrupt in places. The syenite occurs either as large masses in the quartz diorite and granodiorite or as dykes cutting hornblende gneisses. It is medium- to coarse-grained, with crystals as much as 8 mm. in diameter. Pink feldspar and hornblende are the only essential constituents, and each varies between 35 and 60 per cent; quartz and epidote are the accessories.

The hornblende syenite is well exposed one mile east of the southern end of Doda lake and in the southwest corner of the area at the falls on Aigle river. Near the river, the rock is massive with pink feldspar phenocrysts as much as 3 cm. in diameter and mottled grey and pink. The rock is porphyritic in places constituting up to 30 per cent of the rock. Epidote is common either as disseminated grains or as veinlets cutting the syenite porphyry.

A thin section from an exposure southeast of Doda lake shows plagioclase (40%), microcline (35%), hornblende (20%) and minor quartz, sphene and epidote. The average grain cross-section is about 2 mm., and the texture is hypidiomorphic. The plagioclase is strongly sericitized albite (An_{05}) partly replaced by microcline. The hornblende is in subhedral to euhedral grains with numerous poikilitic inclusions of feldspar. Sphene, the most common accessory, generally occurs as well-formed diamond-shaped crystals.

Three exposures of syenite are found at the northern contact of the granitic mass of Surprise lake near the outlet of the lake. This rock, however, is a hornblende-garnet-pyroxene syenite rather than the hornblende syenite just described. It is grey, medium-grained, and gneissic. Some of the light grey constituents have a slight pinkish tinge.

Under the microscope, this rock consists of microcline (40%), hornblende (30%), plagioclase (10%), garnet (10%) and biotite (5%). The accessories are quartz, sphene, calcite, apatite and pyroxene.

The plagioclase is present as euhedral to anhedral unaltered grains of composition An_{27}. Microcline forms clear anhedral grains. The pyroxene is diopside. The garnet as seen under the binocular microscope, is brownish and has 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 in the belt of Keewatin-type rocks is soda granite. The best exposures are on Tower peninsula, Doda lake. Here, the rock is massive, medium-grained, pink to red on the fresh surface and light pink to grey on the weathered surface. The content of dark minerals is lower than in the quartz diorite and granodiorite. Light green epidote accounts for about half of the dark minerals, and increases in quantity toward the granite contacts. Joints are common and some are 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 alternating quartz-rich and feldspar-rich bands and some bands of epidote. The grains average about 1 mm. but some are as much as 3 mm.

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 massive to slightly gneissic.

A thin section of the fine-grained variety shows 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 mineralogical composition:

	%
Quartz	32.6
Microcline	11.7
Plagioclase (An_{15})	51.2
Biotite	3.5
Sphene	0.5
Epidote	0.3

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

	Table I %	Table 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, vol. II, p. 112) listed in Table II, the rock is 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 pegmatite is in irregular lenses and blebs or irregular dykes as much as 10 feet wide. The contacts of the pegmatite masses are more generally transitional than sharp, whereas the contacts of the aplite dykes are sharp.

Pegmatite is rather sparsely distributed within the granite as well as within the country rocks near the granite contacts. The rock is pink and coarse-grained, with feldspar grains as much as 2 inches long. It consists mainly of feldspar and quartz with minor amounts of dark minerals such as ilmenite and magnetite.

One thin section of less coarse pegmatite shows 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 intergrowths giving rise to micrographic texture.

Aplite forms small dykes cutting the other granitic types or small lens-like masses making up as much as 10 per cent of some outcrops. It is massive, fine-grained, and pink with sugary texture and low percentage of dark minerals. Two specimens associated with the main mass of granite have the following mineral compositions:

	Table I	Table 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 Table I suggests the action of mineralizers. The garnet is pink to red, has an index of 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 Verchères lake to the eastern shore of Noël 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 centre 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 Verchères and Noël 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 Verchères and Noël 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 is 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 dykes have sharp boundaries; the pegmatite masses generally have gradational contacts in the granite and sharp contacts and cross-cutting relations in the country rocks. Topaz and myrmekite (micrographic texture) were formed by the action of mineralizers, and are indicative of pneumatolytic action during the later stages or after the crystallization of a magma. The occurrence and composition of the pegmatite and aplite of the area indicate that they are magmatic.

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 the 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 38 is more indicative of a composite gneiss than of purely magmatic derivation. The high percentage of mafic minerals, especially hornblende, the scarcity of quartz, the high content of potash feldspar and of garnet are features that, where found together, are more 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 caused not during magmatic crystallization, but by subsequent deformation. There is some indication in thin sections that granite has been produced during metamorphism with the introduction of potassium and the change of plagioclase to microcline. Many thin sections give evidence of a feldspathization process in the form of plagioclase grains only partly altered to microcline.

DIABASE DYKES

Distribution

Nearly all of the dozen or so diabase dykes of the area are found in the granitic or in the higher grade metamorphic rocks. Two were observed in Keewatin-type rocks. One of the latter is 60 feet wide, and cuts pillowed lavas on the north-east shore of the east point of des Vents lake. The other is 200 feet wide and cuts flows and tuffs north of Meston lake. The dyke north of Meston lake strikes northeasterly but the attitude of the dyke on the shore of des Vents lake is not known.

The other dykes generally strike about N.30°E. and seem to have a steep to vertical dip. One of the main dykes west of Grimaldi lake strikes slightly west of north. The Oriol Lake dyke, which is 4 miles long, may be continuous with the dyke east of Roy river near the southern boundary of the area. Also, the Oriol Lake dyke and that of Meston lake may be the continuation of the Dauversière dyke (Imbault, 1951). If so, this dyke, striking N.40°E. wherever exposed, would be some 25 miles long. The Oriol Lake dyke is more than 500 feet wide on the east shore of the lake, but its width generally varies between 150 and 300 feet. The other dykes are narrower. All tend to form resistant ridges but these rarely rise more than 20 feet above the surrounding country.

Petrography

The diabase is black, massive, heavy, and ophitic. Grain gradation from coarse (5 mm.) in the centre of the dyke to fine

(1 mm.) near the margin, particularly the western, is clearly shown along the southern shore of Oriol lake.

The essential mineral constituents are plagioclase with lesser pyroxene (augite). The accessories are quartz, biotite, magnetite-ilmenite and epidote. The diabasic texture is characteristic of all sections examined. The plagioclase grains are clear and the pyroxene grains clear or altered. Two stages of alteration of the pyroxene were noticed in the more altered diabase. In the first stage, the centres of the pyroxene grains are altered to tremolite, light-coloured hornblende, biotite and quartz. Most of these secondary products form needle-like grains or flakes that radiate from the centres 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. As far as could be observed, chlorite did not form directly from pyroxene. Aside from the accessories already mentioned, the altered diabase contains muscovite, chlorite, leucoxene and sphene.

The plagioclase grains are unaltered. Their composition varies from dyke to dyke between a calcic andesine (An_{48}) to a labradorite (An_{62}). The grains are mostly twinned.

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

Table	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*	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}

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

From these mineral compositions, the chemical compositions given below were calculated. The optical properties of the augite show that it consists of 42 per cent $MgSiO_3$, 40 per cent $CaSiO_3$ and 18 per cent $FeSiO_3$. The percentage of the different oxides in the augite is taken as SiO_2 = 50%, CaO = 20%, MgO = 21%, and FeO = 9%. An average of 90 analyses of diabase (Daly, 1933, p. 18) is given in Table IV for comparison. The diabase of the area has a higher CaO content but lower FeO and Fe_2O_3 contents than the average diabase.

Table	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

The diabase cuts across the gneissic structure of the granite and thus is the youngest consolidated rock of the area. It has undergone very little deformation and alteration since emplacement.

PLEISTOCENE

Distribution

The greater part of the area is mantled with unsorted glacial till; sorted fluvio-glacial deposits are present but are rare. The cover of trees and undergrowth,together with the absence of roads, makes a study of the glacial features difficult. Once recognized in the field, however, many of the glacial features are easily identified on aerial photographs.

In general, the mantle is thinner near the hill tops and thicker or more continuous in the low areas. Drilling has indicated 60 feet or more of overburden one mile west of Meston lake, and 100 feet on the south side of the Opawica river just east of des Vents lake.

Glacial Deposits

The unsorted drift forms a cover with very low relief and no particular form or pattern.

The till in places forms low drumlin-like ridges as for example the long points extending southwestward from the northeast shore of Caopatina lake. Many similar forms are distributed throughout the area but they are not as easily recognized. Most are less than one mile long, but some may extend to 3 miles in length. Widths vary between 500 and 3,000 feet, and the height rarely exceeds 50 feet.

More or less oval or rounded accumulations of boulders occur here and there in the granitic areas. The boulders average about 2 feet in diameter, are subangular and are not striated.

A few small, flat sand plains are present in the area. These generally cover less than 2 square miles. There is one such deposit at the northwest corner of the area immediately northwest of Doda lake. On this plain three low ridges about 2,000 feet apart, 200 feet wide, and trending N.40°E. may be dunes.

Rare deposits of unstratified clays are scattered throughout the area. Grey clay was seen less than 6 miles southwest of the height-of-land. Clays are also present south of Noël lake, on the west shore of Proust lake and along the small streams flowing from No Rock and Jay lakes into Aigle river. These clay deposits are not covered by younger drift.

Eskers occur mainly in the eastern parts of the area; none were observed west of Surprise lake. They trend southward to southwestward, and vary from 20 feet high and 30 feet wide at the base to 60 feet high and 100 feet wide. The sides slope at 40 to 45 degrees. The longest esker, more than 2 miles, is northeast of Monaco lake.

Small, rounded hills (kames) and depressions (kettles) are common in the southeast corner of the area.

Direction of Ice Movement

The peninsulas (drumlins) of Caopatina lake trend S.25°W. Less reliable trends on other drumlin-like ridges vary between S.30°W. and S.40°W. Glacial striae and grooves (Plate I-A and B) nearly all trend S.35^{0}W. Stoss and lee topography and the distribution of erratics show that the movement of the last ice sheet was southwestward.

CORRELATION

The problem of correlation in the Hazeur-Druillettes area has three aspects:

1) correlation of the different formations within the area;
2) correlation of the different formations of the area with those of other areas belonging to the same geologic sub-province;
3) correlation of the different formations of two geologic sub-provinces of the Canadian shield, namely, the Keewatin-Timiskaming and the Grenville sub-provinces.

Two main difficulties hinder attempts at correlation within the present area. The first is the scarcity of outcrops. The second is the combination of a complex structure and a lack of marker units. Not only have all the critical rocks been 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 nearly all metamorphosed to the same degree, and the structural confusion is such that the normal sequence of deposition cannot be worked out satisfactorily.

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.

Geologic Time Terms Used in the Table of Formations

The term "Keewatin" (?) is used in the present report because the major part of the rocks involved constitute a typical Keewatin assemblage, such as described by Cooke, James and Mawdsley (1931). Also, these rocks have already been referred to the Keewatin by Mawdsley and Norman (1938) and by Retty and Norman (1938).

The term "Timiskaming" is not applied to the sedimentary rocks of the area because these rocks and the adjacent volcanics appear to be conformable, interstratified, and, therefore, of the same general age. Previously, Mawdsley and Norman (1938) suggested that these rocks are:

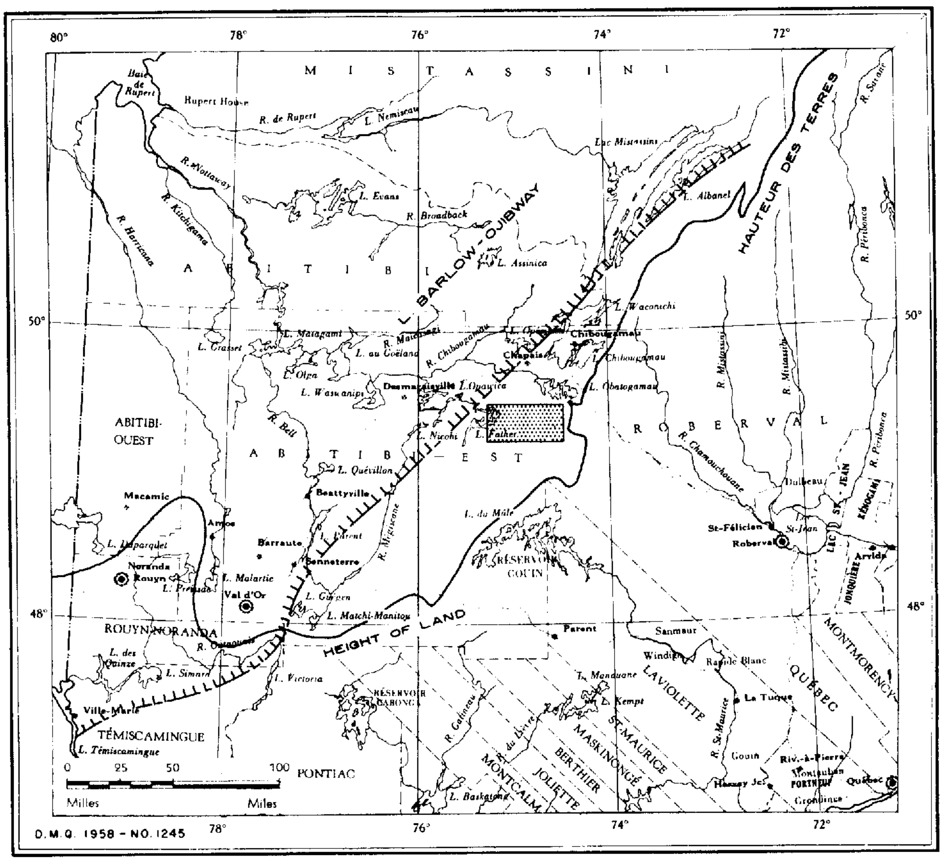

Figure I. - Location of the area in relation to the height-of-land (Antevs, 1925, Figure 27) and the shore of former Lake Barlow - Ojibway (Dresser and Denis, 1946, Fig. 2).

"In part probably younger than Keewatin but in part possibly Keewatin," and that they "are possibly equivalents of the Timiskaming sediments in the Rouyn-Bell River region of western Quebec."

The rocks of the transition zone are grouped with the Keewatin (?) in this report because they represent more highly metamorphosed volcanics and the sedimentaries of Keewatin-type.

The higher-grade metamorphic rocks (hornblende gneisses and amphibolites) found east of Surprise lake have been referred to by Mawdsley and Norman (1938) as "Archaean and/or Proterozoic." We have seen in a previous section of this report that these rocks are, at least in part, the metamorphosed equivalents of the Keewatin-type volcanic and intrusive rocks, and that the biotite paragneisses are the metamorphosed Keewatin-type sedimentary rocks. How much of these higher-grade metamorphic rocks are actually metamorphosed Keewatin-type rocks cannot be ascertained and, for that reason, these Grenville-type rocks have been labelled as possibly Keewatin (?).

In the Hazeur-Druillettes area, the higher-grade metamorphic rocks do not include the three most characteristic types of rocks found in the Grenville type locality, 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.

The granitic rocks of the area are classified into one age group even though the various intrusions may be separated by a long interval of time. They are definitely younger than the Keewatin (?) rocks and, as shown by the Tower peninsula intrusion, are also younger than the deformation that folded the Keewatin (?) rocks. The granite intrudes also the hornblende and biotite gneisses, and is therefore younger than the period of metamorphism that gave rise to the gneisses.

The time of intrusion of the granitic rocks is uncertain. Mawdsley and Norman (1938) classed these rocks as Archaean and "possibly not all of one age". However, it seems more likely that they are Proterozoic. This conclusion is based on the fact that the main belt of granite caused metamorphic effects in its western part but not in its eastern part. The eastern part of the granite intruded rocks that already had been metamorphosed to hornblende gneisses and amphibolites. If these rocks were metamorphosed in Proterozoic (Grenville?) time (and they probably were), then, the granite would be Proterozoic in age. Thus, granite is classified with the Grenville (?).

The diabase dykes cut across the gneissic structure of the granite. Thus they are the youngest consolidated rocks of the area. Their constant composition indicates that they are co-magmatic and probably of the same age. Mawdsley and Norman (1938) have found that the dykes are generally later than the Chibougamau series (equivalent to the Cobalt series), though, in part, they may be pre-Chibougamau. Although there is no evidence to show that these dykes were actually intruded in Keweenawan time, the common practice of assigning them to that late Precambrian period is followed here.

Delimitation of Keewatin-type and Grenville-type Rocks

It is very difficult to locate a boundary between Keewatin-type and Grenville-type rocks of this 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 east to west within the 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 Keewatin-type and Grenville-type rocks, and the only practical boundary between the two types would seem to be the transition zone shown on the accompanying map. This zone is from 2 to 3 miles in width. It trends westerly from the eastern boundary of the area to the south shore of Caopatina lake, and thence southerly and westerly to abut against the main granite mass.

A gradation between the rocks of the Timiskaming and Grenville sub-provinces has been noted by many geologists. Quirke and Collins (1930) were among the first to conclude that the rocks of the Grenville sub-province 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 sub-province and those of the Grenville sub-province. 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, Canimiti 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 sub-province probably resulted from the metamorphism of granite of the same age as the granite in the Timiskaming sub-province".

It seems safe to say that, in the present area, geologists working from Grenville-type rocks toward Keewatin-type rocks would tend to include the zone of transition within the Grenville rocks; if working in the opposite direction, they would tend to place the zone of transition within the Keewatin rocks.

STRUCTURAL GEOLOGY

General Statement

The Hazeur-Druillettes area straddles the boundary between two major structural divisions of the Canadian shield, the Superior and the Grenville provinces. These names were proposed by Gill (1949, p. 61-69). The boundary between his Superior and Grenville provinces coincides with the boundary of Wilson's Timiskaming and Grenville sub-provinces (Wilson, 1939, pp. 237-239). As indicated by Gill (1949, p. 65), the generalized dominant trend of the Superior province is east whereas that of the Grenville province is northeast. Further, it is generally believed that diastrophism in the Grenville province occurred later than in the Superior province.

Structure of the Keewatin-type Rocks

As shown on the regional structure map (Fig. 2) the Keewatin (?) lava flows and sedimentary rocks trend east, 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 Noël lake, where the trends conform closely to the contacts of the adjacent younger granite masses.

Dips generally range between 70 to 90 degrees. In places, as for example, north of the east end of Caopatina lake, the dips are as low as 25 degrees. The lava flows along the northern boundary of the area consistently dip to the north. South of this, from the western shore of Caopatina lake eastward, the dips are generally steeply to the south; west of the lake, however, the dips are steeply to the north.

The Keewatin-type rocks of the area are generally schistose. With only one known exception, the schistosity is parallel to the flows and to the bedding even near intrusive contacts. The exception to the rule was observed on the southern shore of Caopatina lake, where the schistosity diverges 15 degrees from the bedding.

The volcanic and sedimentary rocks, in many places, have been very intensely folded and crenulated (Plate III-A and B). The drag folds plunge 40-80 degrees to the northeast. Their axial planes strike east to northeast and are vertical.

No evidence of faulting was seen in the Keewatin-type rocks. Zones of shearing are common, many of them being at the contacts of the lava flows and the sills. Most of the shear zones trend easterly parallel to the strata and the schistosity. One shear zone on the eastern shore of Doda lake strikes north, but it also parallels the local structural trend. The shear zones are from 2 to 100 feet wide, and commonly have relatively sharp borders. Though present throughout the belt of Keewatin-type rocks, shear zones are concentrated in two main localities. One is in the central part of des Vents lake, where a more or less continuous zone of shearing extends eastward from the western shore of the lake for about 6 miles. The other zone is less continuous but appears to extend from the eastern shore of Doda lake through the falls on Aigle river to north of Jay lake. This zone also would be about 6 miles long.

Jointing is not pronounced. Basaltic flows are jointed in places (Plate V-A), and some sedimentary rocks are faintly jointed perpendicular to the beds. All joints are either steeply inclined or vertical.

About 25 reliable top determinations on lava flows were obtained from pillowed andesites on the islands and shores of des Vents lake. All the flows here face south and dip 70-80 degrees north; thus, they are overturned. The top determinations were made across a width of about 8,000 feet measured at right angles to the strike of the flows.

About 2 miles east of No Rock lake an andesite flow dips 80 degrees north but faces south. On the eastern shore of Doda lake, about one mile south of the mouth of the Opawica river, a flow strikes N.10°E., dips 80 degrees west and 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 but face north, and are thus overturned. One mile southwest of des Vents lake, near the survey line, easterly striking sedimentary rocks dip to the north but face south.

Interpretation

The general easterly trend of the Keewatin-type rocks suggests that these rocks folded in response to north-south stresses. The steepness of the dips indicates tight folding. The drag folds suggest that the major folds plunge 40-80 degrees to the northeast and that they are upright. Such major folds could give rise to easterly trending structures only if the axial planes dipped to the north. North-dipping axial planes were recorded, but they are rare compared with the vertical ones. Thus, there is an apparent contradiction between the northeasterly trend of the drag folds and the easterly trend of the formations. It is, of course, possible that the drag folds and the major folds were formed at different periods of deformation and by stresses acting in different directions.

At des Vents lake the volcanic rocks strike easterly, dip steeply to the north and face south. This attitude prevails across a width of 11,000 feet - 8,000 within the area and 3,000 farther northward (Lyall, 1953) - and suggests a thickness of 10,000 to 11,000 feet of volcanic rocks on the overturned northern limb of a syncline. However, the axis of such a syncline would have to lie about a mile south of des Vents lake, and the sequence to the south of the axis would be quite different from that to the north. Furthermore, the rocks along the required position of the axis and for a mile or more to the south not only are sedimentary but also they dip and face steeply either north or south. It seems more reasonable, therefore, to assume that the volcanic sequence has been repeated by isoclinal folding or by faulting in spite of the lack of evidence of such structures.

Structure of the Grenville-type and Granitic Rocks

The main structural feature of the higher-grade metamorphic rocks is the attitude of the gneissosity. Throughout most of the southeastern part of the area, the hornblende and biotite gneisses strike east and dip steeply north to vertical. A few dips are as low as 45 degrees. South of Verchères lake, the dips are either vertical or to the south. The hornblende and biotite gneisses, like the Keewatin-type rocks, are assumed to have been isoclinally folded.

Structures transverse to the easterly trend occur between Verchères and Messine lakes. These conform to the contacts of the granite, and probably were caused by its intrusion. The structures here include a strong fold, probably an open anticline, plunging southeast.

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 Monaco lake, the gneissic structure of the granite strikes east. North and east of Monaco lake, it trends north-northeast to parallel the contact with the hornblende gneisses, and dips steeply 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 show plunges parallel to the northeast plunges of the Keewatin-type rocks. Plunges as low as 15 degrees, however, are present in the gneisses, whereas those in the Keewatin-type rocks are much steeper.

Shear zones, so common in the lava flows to the north, were seen at only two places in the higher-grade metamorphic rocks and in the granite. They both appear to be minor. One is along Roy river on the narrow band of hornblende and biotite gneisses, and the other in the granite west of the long island of Surprise lake. Both strike northeasterly.

Two transverse faults are postulated. One strikes N.20°E. along the Lake Pierre valley. This fault is evidenced by the difference in width of a band of hornblende gneiss east and west of the lake; east of the lake, the band is about 3 miles wide but to the west it is only three-quarters of a mile wide. Also, there is a sudden change in strike near the lake, both along the contact of, and within, the granite and the hornblende gneisses. A third evidence of the fault is the presence of mylonite along the shore of the lake, especially near the south end. The rock is hard, brittle, and banded. Finally, the shape of Pierre lake can be considered indirect evidence of the fault. The lake is 3 1/2 miles long and averages less than a quarter of a mile wide.

The second postulated fault is along the southwest bay of Surprise lake. The evidence here is not as clear as at Pierre lake. The only direct evidence of a fault is the presence of mylonite. This is more common than at Pierre lake, and forms resistant scarps near the southeastern part of the narrows leading into the southwest bay. The gorge at the entrance of the bay may be considered indirect evidence of a fault parallel to the bay. The eastern side of the gorge is composed of bedrock whereas the western side is made up of unconsolidated material.

The Grenville Front

There is no sharp and continuous break in the trend of the formations between Keewatin-type and Grenville-type rocks. East of the map-area (Gilbert, 1952), the structure becomes more complex, but the general trend still appears to be 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, pp. 70-73), and Norman (1940, p. 522) have applied this interpretation in various areas of the province of Quebec. Gill, who also 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 Sub-province marks a Late Precambrian mountain-built belt with a trend later followed farther to the southeast by the Palaeozoic mountain systems."

In the present area, the Grenville-type rocks trend easterly more than northeasterly. Where they trend northeasterly, they do not cut the easterly trend of the Keewatin-type rocks; instead the change in trend is gradational through a width of two miles or more, and no age relation between the easterly and northeasterly structures can be shown directly. However, if the granite responsible for the transverse structures east of Verchères lake is related to the Grenville mountain-building period, then the northeasterly trend could be interpreted as being superimposed on the easterly trend, and the Grenville structural province would be younger than the Superior (Timiskaming).

The diabase dykes and the two postulated faults in this area may perhaps be regarded as "northeasterly" structures that have been imposed on "easterly" structures. However, the general trend of both dykes and faults is north-northeast and they transect "northeasterly" as well as "easterly" structures. Furthermore, the time factor in regard to both dykes and faults is uncertain.

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, faulting is not indicated. Norman (1936, p. 123) writes that, near Surprise lake:

> "The 'contact' between the 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 interruption 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 the hornblende gneisses increase in metamorphic grade, whereas west of the bay, lower-grade metamorphic rocks, such as hornblende schists, are found, but the change is gradational. The same relationship between these rocks is found to the northeast at the outlet of Surprise lake.

The Grenville front in this area is a zone of transition 2 to 3 miles wide that separates rocks of Grenville-type from those of Keewatin-type. Along the southern boundary and the central part of the area, intrusions of granite followed the metamorphism and the formation of the transition zone. A northeast trending fault along Pierre lake and a northeast striking diabase dyke were then superimposed on the granitic intrusives. From the northeastern end of Surprise lake eastwards, however, neither the metamorphism nor the transition zone was obliterated by the granite, and there are no superimposed northeast structures. 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 this area would suggest that these are secondary tectonic features 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 diagnostic 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 sub-province as a tectonic unit. Thus, the term Grenville sub-province defines the areal extent of a metamorphic and dynamic episode that not only affected rocks of the Grenville series age but also affected other old rocks beyond the present limits of the Grenville series proper. The term Grenville series consequently identifies an assemblage of rocks that forms a time-stratigraphic unit different from other time-stratigraphic units also found in the Grenville sub-province.

ECONOMIC GEOLOGY

Mineralization in the Keewatin-type Rocks

During the past several years, there has been considerable prospecting in the present and nearby areas. With the discovery of mineral showings in the Brogniart-Lescure area to the north in 1951 (Lyall, 1953), most of the northern part of the present area from des Vents lake eastward was staked. Development work (trenching, geophysical surveys, diamond drilling), still going forward at the end of 1954, revealed encouraging gold values.

Disseminated sulphides are common in the lavas and gabbro-diorite sills are present but less common in the sedimentary rocks. Most of the shear zones are mineralized to some extent. Many have been strongly carbonatized and silicified. A number of the most favourable shear zones are at the contacts between gabbro-diorites and lavas. Ten assays taken from different shear zones revealed gold in only one place, and traces of silver, 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, magnetite-rich beds occur in the sedimentary series. A grab sample of this material assayed 39.30 per cent iron. The fact that difficulty was encountered in running traverse lines, owing to the strong magnetic attraction on the compass needle, may point to other and larger deposits in this part of the area.

Bands of talc up to 2 inches wide (Plate III-B) were found in one exposure on the west shore of des Vents lake. They occupy the noses of small drag folds in schistose andesite.

Gold-sulphide Mineralization

The gold-sulphide deposits in this area have the following features:

(a) The deposits are all within Keewatin-type rocks, volcanic flows, gabbro-diorite sills, and minor sedimentary rocks. Alteration of these rocks gave rise to chlorite and hornblende schists.

(b) They are in 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) The deposits are located near the contacts of granite intrusions. At Meston lake, showings (1), (2), (3), and (4)[*] are within 6,000 feet of the granite observed around the lake, and those of Hazeur Chibougamau Mines, Limited (5), Flomic Chibougamau Mines, Limited (7), and Riverside Chibougamau Mines, Limited,(8) are within three and a half miles of exposures of granite. The showing of Meston Lake Mines, Limited,(6) is within the granite itself. The granite contacts may 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 prospects at Phooey lake (9) are 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 irregular masses or veinlets that follow the zones of fractures. In general, the gold is in the veinlets. A barren vein of quartz and calcite occurs in schistose gabbro-diorite, 5 feet wide, 100 feet or more long, on one of the central islands of des Vents lake. The larger blebs of quartz on the property formerly held by 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.

The gold-sulphide occurrences can be classified as lode fissure, hydrothermal replacement deposits (Bateman, 1951, pp. 363-364). The proximity of the mineralized zones to intrusive rocks, and 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 chlorite schists instead of in the higher-grade metamorphic rocks affords a good example of the influence of the country rock on deposition of minerals from mineralizing solutions: the former are much more susceptible to replacement. The scarcity of shear zones in the gneisses and amphibolites may account to some extent for their lack of mineralization.

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[*] Numbers in parentheses correspond to numbers on map.

Iron-bearing Sedimentary Rocks

A few small occurrences of pyrite and magnetite were seen in the sedimentary rocks.

Pyritic black slate was found in only one locality. This was on the Druillettes-Lescure line (north boundary of the area) 1,200 feet west of Mile-post VII. Here, the slate is interbedded with quartzo-feldspathic beds and intimately associated with lavas and sills. The pyrite is in nodules and makes up 15 to 20 per cent of the rock. The nodules are rounded or slightly elongated parallel to the bedding, evenly distributed, and average 1/4-inch in diameter.

Magnetite-rich beds are interbedded with black slates and quartzo-feldspathic layers on the south shore of Caopatina lake. They are thin (1/4-inch or less), and the contacts with adjacent beds are sharp. They are "even-bedded" rather than "wavy-bedded" (James, 1954, pp. 285 and 289). The beds consist of magnetite (60%) in grains averaging 0.5 mm., calcite (25%), and silicates (15%). The adjacent beds are finer-grained (0.1 mm.), and contain only about 25 per cent magnetite and accessory calcite. Both coarser and finer grains of magnetite have irregular and jagged outlines.

The original iron mineral in the magnetite-rich beds is not 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 in which magnetite is considered to be primary, but stresses that the supporting evidence is not as abundant as for primary hematite. The coarse and jagged nature of the magnetite grains and their occurrence in slightly metamorphosed rocks suggest that the present magnetite is 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. Further, the close association of the iron-bearing sedimentary rocks, especially the pyritic slate, with lava flows, suggests that volcanism played a mojor role in introducing the iron.

Mineralization in the Gneisses

The hornblende gneisses, biotite paragneisses and some of the less acidic granitic facies carry disseminated pyrite and minor chalcopyrite. Carbonatization and silicification of the gneisses are rare. The sulphides are somewhat concentrated near the southeastern and southwestern shores of Messine lake, and about 1,500 feet south of Verchères lake. Analyses of samples from these localities gave small amounts of silver, copper and zinc. Three other occurrences of sulphides in the gneisses are indicated on the accompanying map. These are on the south shore of Eva lake, one mile east and again about 4 miles northwest of Pierre lake. Traces of silver, copper, nickel and zinc were noted in specimens from the first locality.

In the late summer of 1954, radioactive minerals were discovered by private interests near Yvonne lake about 8 miles south of Eva lake and a mile south of the area. Considerable staking followed, and by October several hundred claims had been registered. The original discovery was in the "red pegmatite granite" (Freeman, 1943). 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 per cent and 0.33 per cent respectively. Allanite crystals up to half an inch long also are present.

Description of Properties

Adnor Mines, Limited (1), (2), (3).

This company holds a group of 21 claims in the northeast corner of the area. Exposures are scarce here, and contacts have been postulated from a magnetometer survey. Basic, intermediate and acidic lava flows with interbands of tuff strike east-west across the property and dip steeply to the north. A very slightly sheared diabase dyke cuts northeasterly across the volcanic rocks. Shear zones are pronounced in the flows, especially in the central part of the property, and most are gold-bearing. Locality or zone (1), 6 to 10 feet wide, 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 in a north-trending trench 230 feet long. The rocks consist of carbonated and silicified hornblende and chlorite schists (altered volcanics) cut by four shear zones. The shear zones are 2 to 10 feet wide, and generally strike east. A grab sample from the second northernmost zone assayed 0.843 ounce of gold per ton. In the spring of 1953, 45 diamond-drill holes totalling 20,326 feet were bored, partly in search of an extension of the gold-bearing zone of Chibougamau Mines, Limited, whose hóldings lie to the east of the area. One of the holes cut a section one foot long that assayed 67 ounces of gold at a depth of 2,100 feet. The other holes failed to encounter any values of note.

Wright-Hargreaves Mines, Limited (4)

Wright-Hargreaves Mines, Limited, has staked six claims immediately to the west of Adnor Mines, Limited. A shear zone (4) that strikes N.70°W. and dips 80°N. occurs on this property, in lavas associated with sills of gabbro-diorite. The country rock near the shear zone has been silicified and carbonatized. Samples from the zone assayed 0.4 ounce of gold to the ton over a width of 3 feet.

Hazeur Chibougamau Mines, Limited (5)

Of the 24 claims held by this company 8 are in the area and the others are immediately to the north. The main showing (5) is on the northern boundary of the area about 2,000 feet east of Mile-post VIII on the Hazeur-Rasles line. Here the lavas have been altered to carbonatized chlorite schists with average strike of N.80°W. and dip of 55° 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-striking fault and by a quartz vein that strikes N.10°W. A quartz sample from the northern end of the main shear zone 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 (6) of this company is on the northeast shore of Meston lake, where there is a gold-bearing quartz vein in granitic rock. Diamond drilling during the winter of 1952 did not give encouraging results.

Flomic Chibougamau Mines, Limited (7)

Flomic Chibougamau Mines has a group of 20 claims west of the Meston Lake Mines property. Seventeen diamond-drill holes, totaling 8,429 feet, were bored in the winter of 1952. Basic volcanics and gabbro encountered in the cores are reported to be more massive than those found on the property of Meston Lake Mines.

Riverside-Chibougamau Mines, Limited (8)

This company has a group of 10 claims in the extreme northern part of Hazeur township, on the south side of the Opawica river just east of des Vents lake. An electric resistivity survey made in June, 1954, indicated a possible shear zone 200 feet wide, about 1,800 feet long and trending N.55°E. The first diamond-drill hole (8) had penetrated only 348 feet in bedrock at the time of the writer's visit. It yielded one core length of 8 inches and another of 2 feet that assayed over $30.00 in gold. The latter core length also contained 1.5 ounces of silver, 1 per cent lead and some zinc.

Lake Surprise Mines, Limited (9)

A group of 25 claims was formerly held by the Lake Surprise Mines, Limited, at Phooey lake. The main showing here 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 totaling more than 3,000 feet were bored. The main zone is 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 the hornblende schist. Very fine-grained pyrite, chalcopyrite, and other sulphides are disseminated in both the diorite and the enclosing rock. A rusty weathering zone about 3 feet wide in the diorite shows some concentration of minerals. One grab sample taken by the writer assayed 0.270 ounce of gold per ton, 0.24 per cent copper, and 0.24 per cent zinc. Similar 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 4 feet. The true thickness of the mineralized zone may be less than 4 feet, as the holes probably intersected it at oblique angles. In a total of 3,089 feet drilled, only 31 feet of mineralized rock was encountered. The average gold content of these 31 feet is 0.155 ounce per ton.

BIBLIOGRAPHY

ADAMS, F.D., 1909 - On the origin of the amphibolites of the Laurentian area of Canada: Jour. Geology, V. 17, pp. 1-18.

ADAMS, F.D., and BARLOW, A.E., 1910 - Geology of the Haliburton and Bancroft areas, Ont.: Geol. Survey Canada, Mem. 6.

ANTEVS, Ernst, 1925 - Retreat of the last ice-sheet in eastern Canada: Geol. Survey Canada, Mem. 146.

BARLOW, A.E., GWILLIM, J.C., and FARIBAULT, E.R., 1911 - Geology and mineral resources of the Chibougamau region, Quebec: Quebec Dept. of Colonization, Mines and Fisheries, Mines Branch.

BATEMAN, A.M., 1951 - Economic mineral deposits; 2nd ed. New York, John Wiley and Sons, Inc.

BELL, A.M., 1932 - Assup River area, Quebec: Bur. Mines Ann. Rept. 1932, Pt. B, pp. 61-92.

BROOKS, T.B., 1876 - On the youngest Huronian rocks south of lake Superior and the age of the copper-bearing series: Am. Jour. Sci., 3rd ser. V. 11, art. XXVIII, pp. 206-211.

BUDDINGTON, A.F., 1939 - Adirondack igneous rocks and their metamorphism: Geol. Soc. America, Mem. 7.

COOKE, H.C., 1947 - The Canadian shield; in Geology and economic minerals of Canada; 3rd ed., pp. 11-97. Geol. Survey Canada, Eco. Geol. Ser. 1.

COOKE, H.C., JAMES, W.F., and MAWDSLEY, J.B., 1931 - Geology and ore deposits of Rouyn-Harricanaw region, Quebec: Geol. Survey Canada, Mem. 166.

DALY, R.A., 1933 - Igneous rocks and the depths of the earth: New York, McGraw-Hill Book Company, Inc.

DELAND, A.N., 1953 - Preliminary Report on Surprise Lake Area, Quebec: Quebec Dept. Mines, Prelim. Rept. 292.

1955 - Preliminary Report on Gradis-Machault Area, Quebec: Quebec Dept. Mines, Prelim. Rept. No. 312.

1956 - The Boundary Between the Timiskaming and Grenville Sub-provinces in the Surprise Lake Area, Quebec: Proc's. Geol. Ass. Canada, Vol. 8, Pt. 1, Nov., pp. 127-141.

DERRY, D.R., et al., 1950 - Tectonic map of Canada: Proc. Geol. Assoc. Canada.

DRESSER, J.A., and DENIS, T.C., 1946 - Geology of Quebec: Vol. 2., Quebec Dept. Mines, Geol. Rept. 20.

FLINT, R.F., 1949 - Glacial geology and the Pleistocene epoch: New York, John Wiley and Sons, Inc.

FREEMAN, B.C., 1943 - Buteux Area, Quebec: Quebec Dept. Mines, Geol. Rept. 15.

GILBERT, J.-E., 1952 - Preliminary Report on Rohault Area, Quebec: Quebec Dept. Mines, Prelim. Rept. 267. See also Geological Report No. 86 of the same title.

GILL, J.E., 1948 - The Canadian Precambrian shield; in Structural Geol. of Canadian Ore Deposits: pp. 20-48. Montreal, Mercury Press.

1949 - Natural divisions of the Canadian shield: Trans. Royal Soc. Canada, Ser. IV, Vol. 43, pp. 61-69.

GILLIES, N.B., 1952 - Canimiti River area, Quebec: Quebec Dept. Mines, Geol. Rept. 52.

GRENIER, P.-E., 1953 - Preliminary report on Gamache Area, Quebec: Quebec Dept. Mines, Prelim. Rept. 284.

GUNNING, H.C., and AMBROSE, J.W., 1939 - The Timiskaming-Keewatin problem in the Rouyn-Harricanaw region, Quebec; Trans. Royal Soc. Canada, Ser. IV, Vol. 33.

HOLMES, Arthur, 1920 - The nomenclature of petrology: London, Thomas Murby and Co.

HOLMES, Stanley, 1952 - Preliminary report on Fancamp-Hauy Area, Quebec: Quebec Dept. Mines, Prelim. Rept. 271. See also Geological Report No. 84 of the same title.

HUBER, N.K., and GARRELS, R.M., 1953 - Relation of pH and oxidation potential to sedimentary iron mineral formation: Econ. Geol., Vol. 48, pp. 337-357.

IMBAULT, P.-E., 1951 - Preliminary report on the Queylus Area, Quebec; Quebec Dept. Mines, Prelim. Rept. 250. See also Geological Report No. 83 of the same title.

JAMES, H.L., 1954 - Sedimentary facies of iron-formation: Econ. Geol., Vol. 49, pp. 235-293.

JOHANNSEN, Albert, 1931 - A descriptive petrography of the igneous rocks: 4 Vols., Chicago, Univ., Chicago Press.

JOHNSTON, W.G., 1954 - Geology of the Timiskaming-Grenville contact southeast of Lake Temagami, Ontario: Geol. Soc. America Bull., Bol. 65, pp. 1047-1073.

KRUMBEIN, W.C., and GARRELS, R.M., 1952 - Origin and classification of chemical sediments in terms of pH and oxidation-reduction potentials: Jour. Geol., Vol. 60, pp.1-33.

LAURIN, A.-F., 1955 - Preliminary Report on Ducharme-Bouteroue Area, Quebec: Quebec Dept. Mines, Prelim. Rept. 310.

LAWSON, A.C., 1885 - Report on the geology of the Lake of the Woods region with special reference to the Keewatin (Huronian?) belt of Archean rocks: Geol. Survey Canada, Ann. Rept., Vol. 1, Pt. C, pp. 1-155.

LOGAN, W.E., 1863 - Geology of Canada: Montreal, Dawson Brothers.

LOWTHER, G.K., 1936 - Villebon-Denain map-area, Quebec: Quebec Bur. Mines, Ann. Rept. for 1935, Pt. C, pp. 39-52.

LYALL, H.B., 1953 - Preliminary report on Brongniart-Lescure Area, Quebec: Quebec Dept. Mines, Prelim. Rept. 285. See also Geological Report No. 85 of the same title.

MAWDSLEY J.B., and NORMAN, G.W.H. 1935 - Chibougamau Lake map-area, Quebec: Geol. Survey Canada, Mem. 185.

1938 - Chibougamau sheet, east half. Geol. Survey Canada, Map 397A.

MILLER, W.G., 1911 - Notes on the Cobalt area. Eng. and Min. Jour., Vol. 96, pp. 645-649

MILLER, W.G., and KNIGHT, G.W., 1914 - The Precambrian geology of southeastern Ontario with an appendix on the correlation of the Precambrian rocks of Ontario, western Quebec and southeastern Manitoba: Ont. Bur. Mines, Rept. 22, Pt. 2.

NORMAN, G.W.H., 1936 - Preliminary report on the Opawica-Chibougamau map-area, northern Quebec: Geol. Survey Canada, Paper 36-6.

1936a - Northeast trend of late Precambrian tectonic features in the Chibougamau district: Trans. Royal Soc. Canada, Ser. IV, Vol. 30, pp. 119-128.

1938 - The Last Pleistocene ice-front in Chibougamau district, Quebec: Trans. Royal Soc. Canada, Ser. IV, Vol. 32, pp. 69-86.

1940 - Thrust faulting of Grenville gneisses northwestward against the Mistassini series of Mistassini lake, Quebec: Jour. Geol., Vol. 48, pp. 512-525.

1946 - Major faults, Abitibi region, Quebec: Canadian Institute Min. Metallurgy Trans., Vol. 49, pp. 129-144.

NEALE, E.R.W., 1954 - Preliminary report on Dollier-Charron area, Quebec: Quebec Dept. Mines, Prelim. Rept. 299. See also Geological Report No. 82 of the same title.

OSBORNE, F.F., 1934 - L'Annonciation map-area, Quebec: Quebec Bur. Mines, Ann. Rept.

1936 - Petrology of the Shawinigan Falls district: Geol. Soc. America Bull., Vol. 47, No. 1, pp. 197-227.

PARK, C.F., 1946 - The spilite and manganese problem of the Olympic peninsula, Washington: Am. Jour. Sci., Vol. 244, pp. 305-324.

QUIRKE, T.T., and COLLINS, W.H., 1930 - The disappearance of the Huronian: Geol. Survey Canada, Mem. 160.

REMICK, J.H., 1956 - Preliminary Report on the Anville-Drouet Area Abitibi-East County: Quebec Dept. of Mines, P.R. No. 322.

RETTY, J.A., and NORMAN, G.W.H., 1938 - Chibougamau sheet, west half: Geol. Survey Canada, Map 398A.

SMITH, J.R., 1953 - Preliminary report on southwest quarter of McKenzie township, Chibougamau region, Quebec: Quebec Dept. Mines, Prelim. Rept. 288.

SCHROCK, R.R., 1948 - Sequence in layered rocks: New York, McGraw-Hill Book Company Inc.

TURNER, F.J., and VERHOOGEN, Jean, 1951 - Igneous and metamorphic petrology: New York, McGraw-Hill Book Company Inc.

WAHL, W.G., and OSBORNE, F.F., 1950 - Cawatose map-area, Quebec: Quebec Dept. Mines, Geol. Rept. 44.

WALTON, Matt, 1955 - The emplacement of granite. Am. Jour. Sci., Vol. 253, pp. 1-18.

WILLIAMS, Howel, TURNER, F.J., and GILBERT, C.M., 1954 - Petrography: San Francisco, W.H. Freeman and Company.

WILSON, M.E., 1939 - The Canadian shield, in Geologie der Erde, Geology of North America 1, pp. 232-311. Berlin, Gebrüder Borntraeger.

WINCHELL, A.N., 1951 - Elements of optical mineralogy, Pt. II. New York, John Wiley and Sons, Inc.

APPENDIX to G.R. 87

ECONOMIC GEOLOGY

J.-E. Gilbert

Little exploration work has been done in the area covered by this report since 1953 except a few geophysical surveys and some prospecting.

Diamond-drilling programmes were undertaken by a few companies mainly in Hazeur township, but the results were not too encouraging.

Quebec, April 29, 1959.

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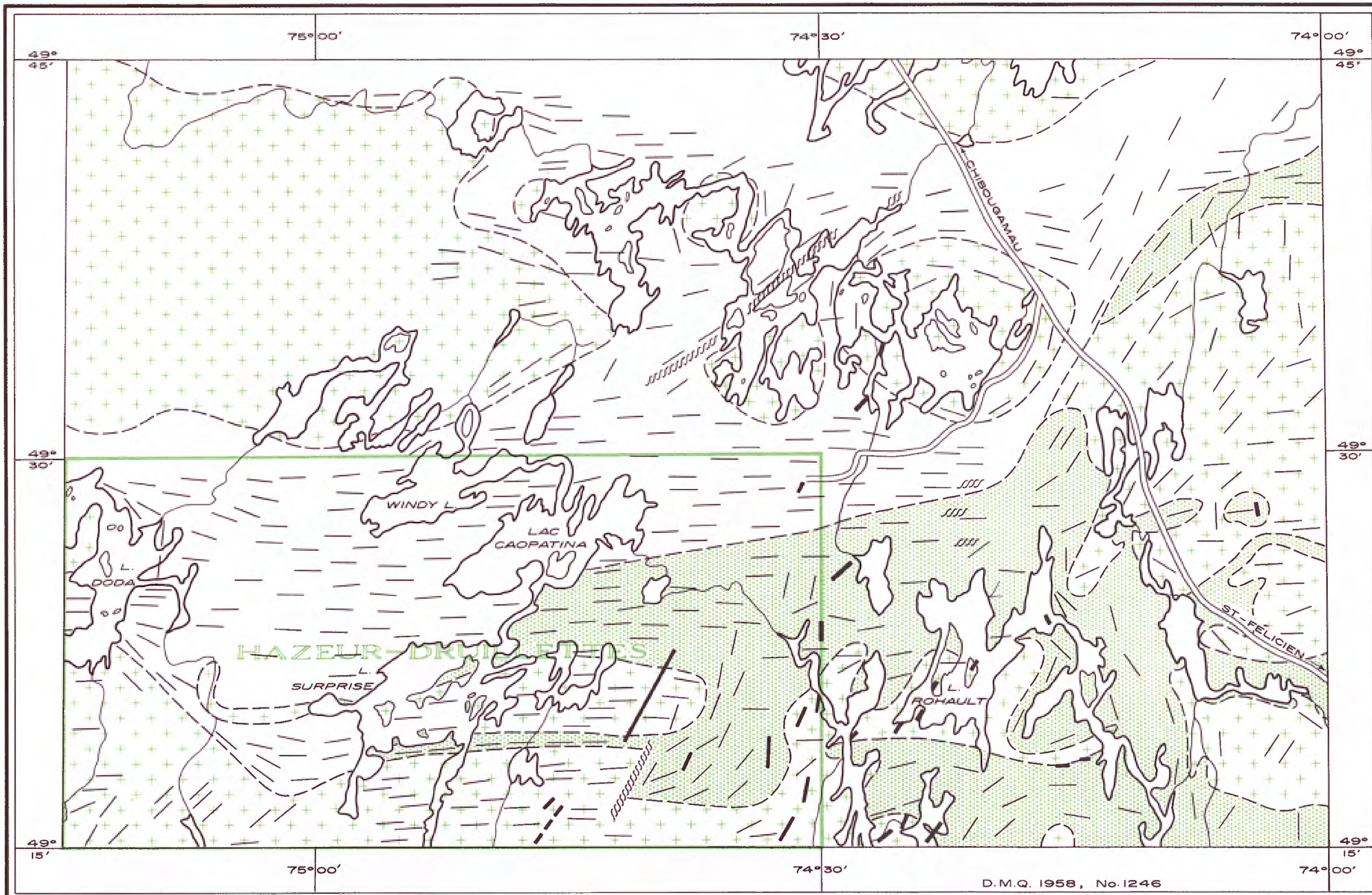

LEGEND

- Schistosity, gneissosity, bedding
- Shearing or faulting
- Diabase dikes
- Granitic rocks
- Grenville-type rocks
- Keewatin-type rocks

FIGURE 2

REGIONAL STRUCTURE

HAZEUR-DRUILLETTES AND ADJACENT AREAS

0 3 6 12 18

Scale of miles

SOURCES OF INFORMATION

Imbault, 1951
Gilbert, 1952
Holmes, 1952
Lyall, 1953
Neale, 1954
Deland, 1953-54
Laurin, 1955
Remick, 1956