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SOUTH HALF OF MCKENZIE TOWSHIP, ABITIBI-EAST ELECTORAL DISTRICT, PART I : SOUTHWEST QUARTER AND NORTH HALF OF SOUTHEAST QUARTER, PART II : SOUTH HALF OF SOUTHEAST QUARTER

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GEOLOGICAL REPORT 95

SOUTH HALF OF McKENZIE TOWNSHIP

ABITIBI-EAST ELECTORAL DISTRICT

PART I

Southwest Quarter and North Half of Southeast Quarter

by

J.R. SMITH

PART II

South Half of Southeast Quarter

by

G. ALLARD

QUEBEC

1960

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SOUTH HALF OF McKENZIE TOWNSHIP

ABITIBI-EAST ELECTORAL DISTRICT

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PART I

SOUTHWEST QUARTER AND NORTH HALF OF SOUTHEAST QUARTER

By J. R. Smith

INTRODUCTION

General Statement

An area of approximately 38 square miles, comprising the southwest quarter and the north half of the southeast quarter of McKenzie township, was mapped by the writer during the field seasons of 1951 to 1954. The south half of the southeast quarter of the township was mapped by G. Allard during the field seasons of 1953 and 1954. The two areas cover the entire south half of the township. Part I of this report covers the southwest quarter of the township and that part of the southeast quarter which lies north of a line joining the town of Chibougamau with Proulx bay.

Location and Access

The south half of McKenzie is situated approximately 300 miles north of Montreal. The town of Chibougamau, in its central part, is connected by rail with the transcontinental system of the Canadian National Railways, and by road with the highways of the Province. Access from Chibougamau to various parts of the area covered by Part I of this report is provided by the Chibougamau highway and its extension northeastward to Waconichi lake and by a secondary road to Bourbeau lake and a tractor road to Antoinette lake. Air services are available at Gilman lake within the Chibougamau townsite and at Caché lake on the east side of the highway a few miles south of Chibougamau.

Field Work

Mapping was done in the field on overlays on vertical aerial photographs enlarged to a scale of 1 inch equals 500 feet. Compilation was done on base maps at the same scale; the maps accompanying this report are at a scale of 1 inch equals 1,000 feet. The aerial photographs were unsuitable for accurate location of most outcrops, owing to heavy forest cover. Additional control was afforded in about one-third of the area by picket lines on mining properties and by surveyed claim lines. In other parts of the area picket lines were cut at intervals such that the maximum uncontrolled length of pace and compass or chain and compass traverses was one-half mile. Traverses were spaced at intervals of 300 to 500 feet, except where wide areas of drift cover were outlined by reconnaissance traverses or identified on aerial photographs.

Acknowledgments

Senior assistants were E.J. Young in 1951, T.T. Quirke and G.G. Caron in 1952, and F.D.M. Horscroft in 1954. They mapped parts of the area under the writer's supervision.

Accommodations were generously afforded the field parties by Royran Gold Field Ltd., Taché Lake Mines Ltd. and Quebec Smelting and Refining Ltd. All mining companies interested in the area offered valuable information freely.

Previous Work

The Chibougamau region was visited by Low in 1905*. Regional mapping which includes the present map-area has been done by Barlow, Gwillim and Faribault, Mawdsley, Mawdsley and Norman (1935, 1938) and Retty. The north half of Obalski township, which adjoins McKenzie township to the south, has been mapped by Graham (1956) at a scale of 1 inch equals 1,000 feet.

PHYSIOGRAPHY

The map-area is in the Hudson Bay drainage basin, about 15 miles northwest of the divide between that drainage system

* References are at the end of the report.

and the Lake St. John - St. Lawrence River drainage system. Elevations of the lakes are 1,200 to 1,300 feet above sea level.

The surface of the map-area proper is serrated by discontinuous rocky ridges which trend east-northeast and rise to a maximum of 600 feet above the intervening lakes and lowlands. The north slopes of the ridges are commonly rocky and relatively steep, whereas the south slopes are gentle and are blanketed with a discontinuous cover of glacial drift. The positions of the ridges coincide with belts of abundant rock outcrops. The widest and highest ridge is underlain by ultrabasic rocks in the northern part of the area; west of Antoinette lake the ridge is capped with relatively undisturbed Proterozoic-type sedimentary rocks at a maximum elevation of 600 feet above the lake. Ridges in the central and southern parts of the area are lower and less continuous than the northern ridge, their maximum relief being of the order of 300 feet.

The lowlands between the ridges are partly in-filled with Pleistocene glacial deposits and with recent muskeg swamps. The swamps are in various stages, including completion, of encroaching growth over lakes in the lowlands. The glacial deposits have a number of topographic expressions; they will be discussed in some detail, since they have a bearing on the Pleistocene history of the area.

Two low ridges of boulder till, each 2 miles long and one-half mile wide, occupy the western parts of Ranges II and III. The flanks of these ridges rise by sub-uniform slopes of about 2° to heights of 50 to 100 feet above the intervening depressions. On aerial photographs the surface features and outlines of the ridges, marked by differences of vegetation, present straight lines bearing N.30°E. This direction is parallel to the direction of ice movement as interpreted from glacial striations on rock surfaces. The till making up the ridges is considered to have been deposited as morainal or outwash material, or a mixture of both, near the ice-front. The elongation of the ridges is attributed to grooving action of the ice during a subsequent, probably minor, advance of the ice-front. Both of the ridges referred to terminate at their north ends against a high rock ridge, partly covering the south slopes of the ridge. The rock ridge probably diverted the ice flow, protecting the till that lay directly to the southwest from the furrowing action of the glacier. This conclusion is strengthened by the fact that, where there is a break in the ridge (at Antoinette lake), the unprotected till directly to the southwest has been scraped away to bedrock. Several smaller promontories of till extending southwestward from rock ridges are no doubt of similar origin.

One esker was recognized in the area; it is the sinuous ridge trending southwest in the centre of Range III. It can be traced beneath one mile; the upper surface, which is exposed in some places neneath the roots of fallen trees, is made up of coarse gravel containing a large proportion of well-rounded to sub-angular boulders up to 15 inches in diameter.

Some parts of the area are covered with hummocky deposits of till, which are probably of outwash origin. Most of this material is distributed over irregular, ill-defined areas, and is of little value in interpreting the movement of the ice-front. Only one till ridge was recognized as a terminal or, more probably, a recessional moraine. It is immediately east of Gwillim lake, in the extreme northwest corner of the map-area. The ridge trends southeast and rises rather steeply on its northeast slope to a height of 50 to 60 feet above the level ground to the northeast and east. The southwest slope is corrugated parallel to the ridge, and descends gently to the general level of the ground. Where it is being undercut by the waters of Gwillim lake the material forming the ridge is seem to be stratified, medium-grained sand with some interbedded gravel.

The plain on which the town of Chibougamau is located has an almost featureless surface except where it is being dissected by David river and its tributaries. In some of the ditches along the Chibougamau highway the material underlying the plain is seen to be horizontally stratified sand of fairly uniform, fine to medium grain. The sand was probably deposited in the standing water of a Pleistocene lake. The plain south and east of Gwillim lake may be of similar origin, because streams on the plain have sandy beds. According to Norman, glacial lake Barlow-Ojibway covered the lower parts of the present map-area. Since the plain south and east of Gwillim lake is only the southeastern part of a much more extensive low, level area to the northwest, it possibly represents part of the extensive deposits laid down in glacial lake Barlow-Ojibway.

The local drainage routes can be traced on the accompanying maps. Briefly, the central and southwestern parts of the area drain through David river to David lake in Scott township, the northwestern part into Gwillim lake, the northeastern part into Bourbeau lake and the extreme eastern and southern parts into Doré lake. All of these routes lead to Chibougamau river, whose waters are discharged into James bay via Waswanipi and Nottaway rivers.

GENERAL GEOLOGY

General Statement

The oldest rocks exposed are Keewatin-type volcanic rocks in which there is a distinct, but somewhat irregular, change from basic lavas (metabasalts) in the south through intermediate types (metaandesites?) in the central part to feldspathic lavas and clastic rocks in the north. Sills of metagabbro intrude the lavas and the clastic rocks. In the northern part of the area the clastic rocks are extensively intruded by ultrabasic rocks of various kinds; quartz-feldspar porphyry dykes and a body of soda granite intrude clastic rocks and ultrabasic rocks. In the southern part of the area basic dykes intrude the lavas and quartz-feldspar porphyry. Erosional remnants of relatively undisturbed bedded, unmetamorphosed arkoses, conglomerates, and graywackes of the Chibougamau series (Proterozoic?) rest unconformably on the older rocks. All of these rocks are in places strongly metasomatized.

Layers in the lavas and beds in the clastic rocks dip vertically to steeply north, and in general strike east-northeast. The igneous intrusions, especially the metagabbro bodies, are elongate parallel to the strike of the layered volcanic rocks, suggesting that they are sill-like in form. Top determinations show that the tops of flows and beds in the volcanic rocks and the tops of the metagabbro sills face north from the southern limit of the area to the south contact of the main ultrabasic intrusions. Therefore, the layered rocks of the area appear to form part of a thick, nearly vertical south limb of a major syncline.

Faults, for the most part with very minor displacements, are grouped on the basis of their general strike into an east-northeast set, a west-northwest to northwest set, and a northeast to north set.

Table of Formations

CENOZOIC	Pleistocene	Stratified and unstratified boulder till Stratified sands
Great erosional unconformity		
Faulting and hydrothermal activity		
LATE PRECAMBRIAN	Chibougamau Series	Arkose, conglomerate, graywacke
Great unconformity		
EARLY PRECAMBRIAN	Faulting, carbonatization, mineralization	
	Intrusive Rocks	Basic dykes
		Quartz-feldspar porphyry Soda granite
		Intrusive contact
		Ultrabasic complex: metapyroxenite, dunite, peridotite, minor metagabbro
		Folding and faulting
		Metagabbro sills
	Intrusive contact	
	Keewatin-type Rocks	Clastic group Feldspathic rock with interbedded laminated tuffs, minor andesitic lava, agglomerate, and very minor slate, argillite, and chert. (In part recrystallized to pseudo-dioritic rock) Lava group Feldspathic lavas) Metaandesite porphyry) Minor inter- Metaandesite ?) bedded tuff Metabasalt) and agglomerate

Keewatin-type Series

The rock-types in the Keewatin-type series are divided into two distinct groups: a group consisting predominantly of lavas, which underlies the southern part of the area, and a group consisting predominantly of bedded feldspathic clastic rocks, which underlies parts of the northern part of the area. The exact nature of the division between the two groups is not known, owing to the fact that the boundary between them is occupied for the most part by intrusive rocks. For one reason or another, structures in the bedded clastic rocks are more complex than those in the lavas; igneous textures of rocks intrusive into the clastic rocks are better preserved than those of similar rocks intrusive into the lavas. For these reasons, it is possible that the clastic rocks are not conformable with the lavas. However, feldspathic lavas very similar in composition to the feldspathic clastic rocks occur near the top of the lava group, indicating that the clastic rocks might be the products of a later, explosive stage on the same volcanic cycle which gave rise to the lavas. It is tentatively concluded that the two groups are essentially conformable, and that the structural differences between them are the result of differences in their environments during deformation.

Lava Group

The lava group underlies most of the southern three-fifths of the map-area. The general succession of rock-types is apparent on the accompanying maps: metabasalts are predominant in the lowest (southern) part of the sequence, metaandesites in the central part, and feldspathic lavas in the upper (northeastern) part. The base of the sequence has not been identified because the lavas are in contact with a complex of intrusive rocks to the south (Graham, 1956). The total stratigraphic thickness of exposed lavas is of the order of 12,000 feet, assuming no repetition by folding or faulting.

Metabasalt

Metabasalts with a minimum stratigraphic thickness of 6,000 feet make up most of the Keewatin-type section south of David river in the southwest quarter of the township. They also outcrop north and east of Gilman lake. The section is typified by thin lava flows in which pillow structure is rare, but in which amygdaloidal bands and flow-top breccia serve to identify individual flows. The flows are commonly schistose only near their margins. The rocks are dark

grey-green to greenish black on the freshly broken surface; they weather to shades of grey, black, and rusty dark brown. Mineralogically, the rocks consist essentially of a mat of minute, irregular grains of chlorite, epidote, and untwinned albite, the relative proportions of which are impossible to judge accurately, but which are named in order of abundance. Other constituents which are abundant locally, but commonly present in only minor amounts, are actinolite and calcite. Small amounts of pyrite are universally present. Leucoxene makes up about 2 per cent of most specimens. The grains of leucoxene commonly have a skeletal lamellar structure, minute lamellae of leucoxene alternating with lamellae of scraps of silicate minerals which are too small to identify. In some cases the lamellae are in three different directions in the grain, as is commonly true of ilmenite exsolution lamellae in magnetite, where the lamellae occupy tetrahedral planes, three of which are intersected by cuts through some grains. During the metamorphism of the metabasalts the magnetite lamellae of magnetite-ilmenite exsolution intergrowths were apparently replaced by silicates, and the ilmenite lamellae were leucoxenized. The original basaltic texture of the rocks is faintly preserved in the outlines of plagioclase laths now replaced by epidote, albite, and other minerals that were not identified. The outlines of the original mafic minerals are no longer visible. Amygdaloidal structure is common; the amygdule fillings are mostly chlorite and calcite, but microcrystalline quartz and pyrite are also common. The constituents commonly have a rudely concentric arrangement. The metabasalts are changed to carbonate-chlorite schist along many shear zones and interflow contacts. Their composition, texture, and structure have been changed in parts of the area by widespread metasomatism involving the growth of porphyroblasts of albite, chlorite, and quartz. The resulting rocks are coarser grained than typical metabasalt. They are discussed more fully below, in the section of the report dealing with metasomatic rocks.

Metaandesite

Metaandesites, with a stratigraphic thickness of about 6,000 feet, make up the Keewatin-type section in the central part of the area; they are also stratigraphically important south of Sauvage lake. They occur typically as thin flows, many of which are pillowed, in which respect they differ markedly from metabasalts. Metaandesites are distinctly lighter in colour than metabasalts, being light greyish green to light grey on the fresh surface and grey, green, or light rusty brown on the weathered surface. Under the microscope they are seen to consist essentially of actinolite, minerals of the

clinozoisite-epidote group, and albite. Chlorite is commonly present in only subordinate amounts; thus the greater hardness and lighter colour of metaandesite compared with the metabasalt. Titanic iron minerals are represented by leucoxene, some of which shows the relict lamellar structure described above. Carbonate and pyrite are widely distributed in small amounts. The secondary minerals are very fine grained; actinolite occurs as minute colourless shreds, commonly mixed with chlorite; originally more calcic plagioclase, the shape and twinning of which can be discerned in some thin sections, is now altered to albite containing much saussurite, which is mostly clinozoisite in such an incipient stage of crystallization as to appear semi-opaque in polarized light. The clinozoisite represents the anorthite content of the original plagioclase; in some thin sections the original crystals can be seen to have been sharply zoned, clinozoisite being more abundant in the originally more calcic zones. Metaandesite is changed to carbonate-chlorite schist along many shear zones and at interflow contacts; unlike metabasalt, it has not been affected noticeably by the metasomatism which changed the metabasalt to chlorite-albite-quartz rock. Apparently unchanged metaandesite is in contact with metabasalts so affected in many places south and east of Sauvage lake.

Metaandesite Porphyry

Metaandesite porphyry occurs in a well defined, thick, lenticular body in the metaandesites north of Gilman lake. The rock is light grey-green on the fresh surface, and weathers various shades of grey and buff. It consists of about 30 per cent milky white feldspar phenocrysts 1 to 2 mm. long in a fine-grained matrix similar in composition to metaandesite. In some places the rock also contains amygdules filled with microcrystalline quartz, the grains of which are arranged in a concentric fashion around a central core of chlorite. The lenticular body of metaandesite porphyry has a maximum thickness of 1,500 feet and a length of 2 miles. The rock within the body is for the most part massive; vaguely defined flow structures are visible on some weathered surfaces, and thin fragmental zones are fairly numerous. For these reasons the rock is thought to be of extrusive origin, but a shallow-seated intrusive origin is also possible.

Feldspathic lava

Feldspathic lavas, probably metaandesites, although no common rock name seems entirely suitable, occur near the

top of the lava sequence in the eastern part of the area and in a thick layer extending west from Proulx bay. These rocks are chalky buff to white on the weathered surface and light grey to greyish white on the fresh surface. They consist of predominant plagioclase altered to albite and clinozoisite, with minor amounts of actinolitic, amphibole, epidote, chlorite, carbonate, and sulphides. Quartz and potash feldspar are absent as identifiable primary constituents. The rocks are in many places shattered by closely spaced joints which obscure the volcanic structures. Pillow structure and amygdules are fairly common, but the northernmost occurrences shown on the map include massive, homogeneous, fine-grained feldspathic rocks which are lacking in distinctive lava structures and cannot be distinguished from some rocks interlayered with rocks of the clastic group to the north.

Tuff and Agglomerate

Tuff and agglomerate in discontinuous thin layers, the larger of which are shown on the accompanying maps, are a very small part of the lava group. Tuff commonly occurs in thin beds or very thin lamellae, but thick, massive beds also occur. Most beds are similar to metaandesite, but some contain rounded quartz grains and fragments of metaandesite and of cherty rock; in the finely laminated types some laminae consist entirely of chert. Clastic rocks in which more than 50 per cent of the fragments are larger than one inch were mapped as agglomerate. The fragments are almost invariably of metaandesite, with occasional pieces of chert. Pear-shaped bombs were found in agglomerate south of Fleury lake. The matrix of the agglomerate is commonly schistose, but in some exposures it has a distinctly clastic texture.

Clastic Group

Rocks included in the clastic group occur as remnants in intrusive rocks in the northern part of the area. Although the regional east-northeasterly strike is apparent in the attitudes of these remnants, local contortions and the almost complete lack of reliable top determinations make it impossible to estimate the stratigraphic thickness of the sequence. A well exposed section of the clastic group between Antoinette lake and North lake displays uniform strike and dip over a thickness of 900 feet; this is undoubtedly much less than the total thickness of the group.

Although the group is made up of many diverse rock-types, it is characterized by bedded and unbedded feldspathic clastic rocks very similar in composition to the feldspathic lavas described above. The feldspathic clastic rock occurs typically in thick, massive layers, between which are thinly bedded layers of the same material or of other rock-types. Even in apparently unbedded feldspathic clastic rock, occasional rock fragments or a very thin laminated bed may be found, and it is only in this way that many occurrences can be distinguished from massive feldspathic lava. The rock is buff to white on the weathered surface and white or light greyish green on the fresh surface. It is made up of a large proportion of milky white feldspar grains in a chloritic matrix, with or without small fragments of aphanitic metaandesite or of feldspathic lava. Under the microscope the feldspar is seen to be in subhedral to euhedral grains of variable size, commonly with a maximum length of 2 mm. Originally, the grains were plagioclase with sharply delimited and repeated zones of different composition — a feature characteristic of volcanic plagioclase. The original plagioclase has been altered to albite containing specks of clinozoisite and white mica in sufficient amount to render translucent to semi-opaque the albite in the originally more calcic zones of the crystals. The outermost rims of the crystals are almost free of specks. These altered plagioclase crystals make up 50 per cent of the rock in one thin section studied, and 70 to 80 per cent of the rock in three others. Two of the thin sections contain several fragments of aphanitic metaandesite, but no rock fragments were found in the other slides. The matrix is in all cases a mat of minute shreds of chlorite and epidote, with very little actinolite and leucoxenized titanic iron minerals, and a trace of quartz. Carbonate is locally abundant in the matrix, in which case it also replaces the grains of plagioclase to some extent. In some places, near bodies of ultrabasic rocks, the feldspathic clastic rock is recrystallized and it grades by an increase of mafic constituents into gabbroic and pyroxenite rocks. These hybrid rocks are described below (pp. 17, 18).

As mentioned above, feldspathic clastic rock is the predominant rock-type in most occurrences of the clastic group. Other rock-types are interbedded with the predominant type along thin, discontinuous zones. The most common of the other types is white, grey, or black, very fine-grained, thinly laminated tuff, which probably originated as falls of ash and dust in water; however, some of the black tuff beds may be related to thin beds of apparently normal sedimentary black slate and argillite which are found in a few places. The laminated tuffs commonly contain minor amounts of pyrite; the black tuffs,

slates and argillites contain traces of disseminated chalcopyrite.

Besides the rock-types described above, several others are of local importance. A flow of pillowed, porphyritic andesite 30 to 50 feet thick was traced for a length of 1,000 feet in one locality. A bed of intra-formational conglomerate 3 feet thick was found east of Antoinette lake. Fragmental felsitic lavas are interbedded with tuffs north of Antoinette lake. Carbonate-rich rock, probably of metasomatic origin, is locally the most abundant rock-type. A layer of unbedded agglomerate 500 feet wide is exposed 3,000 feet south of Gwillim lake over a length of 8,000 feet. The agglomerate is remarkably uniform throughout its length and width; it consists almost wholly of lobate to angular fragments of metaandesitic composition, ranging in size from a fraction of an inch to 15 inches, in a fine-grained clastic matrix also of metaandesitic composition. Many of the fragments have chilled margins, and a few have calcite-filled cavities at their centres. The agglomerate is different from any other rock-type so far seen in the clastic group, but because of its pyroclastic origin and its position in the section, it is included with that group. It present in the section northeast of the present area, it will be a valuable horizon marker. A lens of white, grey and black chert 600 feet wide is included in the clastic group at a point 2,000 feet south of Cran Penché bay.

The assemblage of rock-types in the clastic group, the occurrence of volcanic rock fragments and volcanic feldspars in the feldspathic rock-types, and the presence of undoubted agglomerate and lava in the section suggest that the group is largely of pyroclastic origin, although it is probable that some of the deposits have been reworked by water.

Intrusive Rocks

Intrusive rocks ranging in composition from quartz-feldspar porphyry to dunite are found in the area. The minerals of the intrusive rocks have been extensively altered to low-grade metamorphic minerals; original plagioclase is now represented by sodic plagioclase and clinozoisite and most of the primary mafic minerals are partly altered to chlorite, actinolite, or serpentine. In general, the original grain size of the igneous rocks is apparent in the hand specimen, and the rocks are only locally schistose. The details of the original igneous textures are generally better preserved in

rocks intruding the clastic rocks of the northern part of the area than in the metagabbro sills intruding the lavas of the southern part.

Metagabbro Sills

Metagabbro sills are interlayered with the lavas of the central parts of the area and with the clastic rocks and ultrabasic rocks of the northern part. The sills are made up of two or more different rock-types, the mutual relations of which are best illustrated by a thick sill which is well exposed in a high ridge north and west of Antoinette lake. The maximum width of the sill is 1,600 feet. Adjacent bedded clastic rocks and layering within the sill dip vertically, and the sill itself is assumed to be vertical; the outcrop width therefore represents the true thickness. From north to south across the sill the rock-types are hornblende-chlorite metagabbro, pyroxene-actinolite metagabbro and hornblende-chlorite metagabbro.

Hornblende-chlorite Metagabbro

The hornblende-chlorite metagabbro in the northern part of the sill is massive, medium grained, and dark greenish grey on the fresh surface. Weathered surfaces have a distinctive pepper and salt appearance, resulting from the contrast of buff-weathering feldspar with black-weathering amphibole. Amphibole is commonly present in slight excess of feldspar. In thin section the amphibole is seen to be common green hornblende partly altered to chlorite. The feldspar is albite clouded with specks of clinozoisite. Minor amounts of leucoxenized titanic iron minerals, actinolitic amphibole, and quartz are found in most specimens. In the northern parts of the layer of hornblende-chlorite metagabbro quartz is much more abundant and the hornblende is more completely altered to chlorite.

In the southern part of the sill, at the contact with bedded clastic rocks, the hornblende-chlorite metagabbro is very fine grained. Within it there is a thin lens of serpentinized ultrabasic rock which has the ovoidal texture typical of rock originally rich in olivine.

Pyroxene-actinolite Metagabbro

The pyroxene-actinolite metagabbro is massive and medium grained, with nondescript grey weathered surfaces. The fresh surface is distinctive: small, milky white feldspar grains are

homogeneously mixed with an equal proportion of equant grains of greenish black altered pyroxene. In thin section the feldspar is seen to be sodic plagioclase densely crowded with minute specks of clinozoisite, rendering it semi-opaque, and accounting for the milky white colour in the hand specimen. The amount of clinozoisite is markedly greater than in the hornblende-chlorite metagabbro, suggesting that the plagioclase was originally more calcic. The pyroxene is augite partly or wholly altered to colourless actinolite; the actinolite can be observed in all stages of growth, including completion, from the margins of and from cracks within the pyroxene grains. Minor constituents of the rock are isotropic chlorite, which makes up the cores of some altered pyroxene grains, and leucoxenized titanic iron minerals. No quartz has been found in the pyroxene-actinolite metagabbro.

The succession of rock-types in this sill is believed to be the result of differentiation during crystallization. The layer of serpentinized olivine-rich rock near the south contact probably formed by gravitative settling of early-formed olivine crystals. The presence of primary hornblende, quartz, and a less calcic plagioclase in the northern part of the sill suggests the concentration of late-crystallizing constituents in the upper part of the body as crystallization proceeded. If this hypothesis is correct, the sill must have been intruded in a nearly horizontal position, before the volcanic rocks were folded into their present steeply dipping attitude. This conclusion is supported by a similar arrangement of rock-types within several other sills in the area. In all cases hornblende-chlorite metagabbro, with or without quartz, occurs in the northern parts of the sills, and pyroxene-actinolite metagabbro in the southern parts. The inference that the tops of the sills face north is in many places supported by top determinations on the basis of pillow shapes in lavas immediately adjacent to the sills.

Sills west and south of Larone lake and at Ham lake have amphibole-rich marginal facies which are difficult to distinguish in the field from metapyroxenite. In thin section such rocks are seen to consist mostly of equant grains and shreds of an amphibole which is pleochroic in faint shades of blue and which has a large negative optic axial angle. The interstices between the amphibole grains are filled with a fine-grained mat of white mica and other minerals too small to identify. These amphibole-rich marginal facies are medium grained at the contacts with country rock, whereas sills with normal metagabbro at the contacts have very fine-

grained margins. The amphibole-rich rock is believed to have formed by assimilation of material, particularly water, from the country rock, perhaps because the sills concerned (or parts thereof) were intruded into rocks which were hot enough to allow such assimilation to take place.

The bulk composition of the metagabbro sills is probably very similar to that of the lavas mapped as metaandesite; indeed, strongly altered pyroxene-actinolite metagabbro is indistinguishable in the field from the coarser-grained parts of metaandesites; flows. This suggests either that the rocks mapped as metagabbro are actually metadiorite, or that the lavas mapped as metaandesites are actually metabasalts. The question could be resolved only by a number of chemical analyses of the rocks concerned, which are not at present available. In spite of the discrepancy in nomenclature, the metagabbro sills are considered to be intrusive equivalents of the lavas; they probably occupy parts of the conduits by which magma reached the surface during the accumulation of the volcanic pile.

Ultrabasic Complex

Ultrabasic rocks in concordant, elongate bodies are intrusive into the volcanic rocks of the northern part of the area. In some places near contacts with ultrabasic rocks the metagabbro sills described above are strongly chloritized and pyritized. Apart from this, there is no direct evidence of the age relations between the ultrabasic intrusions and the metagabbro sills. However, a body of metapyroxenite directly west of North lake occupies the axial portion of a small fold in bedded clastic rocks, and serpentinized dunite occurs along a fault 2,500 feet north of Antoinette lake; this suggests that the emplacement of these bodies was influenced by preexisting structures in the older rocks. It is therefore tentatively concluded that the ultrabasic rocks were intruded during or after the folding and faulting of the volcanic rocks, and that they are therefore younger than the metagabbro sills, which have been shown to predate the folding.

Although gabbro is associated with metapyroxenite in some localities, the volume of gabbro relative to that of the ultrabasic rock is very small. It can therefore be stated with certainty that the ultrabasic rocks did not differentiate *in situ* from a less basic magma. They may, however, be products of the same cycle of igneous activity which gave rise to the lavas and to the metagabbro sills.

The bodies of ultrabasic rocks are characterized by complex interlayering of various rock-types. The strike of the layering is for the most part parallel to the contacts of the bodies and to bedding in adjacent clastic rocks.

Metapyroxenite, Dunite and Peridotite

Within the bodies of ultrabasic rocks the marginal parts commonly consist of interlayered metapyroxenites and serpentinized dunites and peridotites. The metapyroxenites are for the most part massive, medium-grained rocks which are greenish black on the fresh surface and which weather to shades of dark grey and brownish grey. They consist predominantly of diopsidic augite which is commonly altered only slightly to actinolite, with varying proportions of serpentine and chlorite pseudomorphous after orthopyroxene and olivine. Less commonly the metapyroxenites contain clouded plagioclase and grade toward gabbro in composition, in which case the augite is much more completely altered to actinolite.

Massive serpentinized dunite and peridotite commonly make up the central parts of the bodies of ultrabasic rocks but, as may be seen on the accompanying maps, there are many exceptions to this generalization. Serpentinized dunite is a black, massive, medium-grained rock which weathers to a distinctive dark brown colour. The rock is easily recognized in the hand specimen by its ovoidal texture; under the microscope the ovoids are seen to be made up of cores of isotropic serpentine surrounded by thin zones of fibrous, birefringent serpentine. The interstices between the ovoids are occupied by ribbons of flaky serpentine with fairly high birefringence, and by minute grains of magnetite. The ovoids are from 0.5 to 2mm. in diameter; many preserve the euhedral outlines of the olivine crystals which they have replaced. Serpentinized peridotite is similar to serpentinized dunite, consisting mostly of serpentine pseudomorphous after olivine, but containing large crystals of unaltered augite and serpentinized orthopyroxene, both of which poikilitically include many grains of serpentinized olivine; the augite crystals stand out as nodular protuberances on weathered surfaces, making the rock easily recognizable in the field. Serpentinized dunite and peridotite contain many seams of soapy green serpentine and less abundant veins of brittle-fibre asbestos; occurrences of silky-fibre asbestos are described under "Economic Geology".

Metagabbro

In several places shown on the accompanying maps, metagabbro is associated with metapyroxenite. In all cases the metagabbro makes up the marginal parts of the bodies and grades by an increase of mafic constituents into metapyroxenite. The metagabbro is typically very coarse grained; it consists of elongate prisms of partly uralitized augite, large laths of plagioclase altered to albite and clinozoisite, and a minor amount of leucoxenized titanic iron minerals. Foliation resulting from a planar arrangement of the pyroxene prisms and plagioclase laths was observed in several places, but the rock is more commonly massive.

Contact Relations

As stated above, the marginal parts of the bodies of ultrabasic rocks are commonly metapyroxenites and metagabbros, which are richer in silica than serpentinized dunites and peridotites. The marginal rocks rarely show any decrease in grain size near the contacts with wall rocks, and apophyses of ultrabasic rocks were not observed in the wall rocks. In many places the contacts themselves are knife-sharp planes; in other places there is complete gradation between feldspathic rocks of the clastic group and apparently normal metapyroxenites. The rocks representing the intermediate stages of the gradation have been mapped as hybrid metadiorite and metagabbro. Such rocks are well exposed along the north margin of the body of ultrabasic rocks extending west from Trout lake.

In a typical traverse from north to south across the zone of gradation the first rock-type encountered is a feldspathic clastic rock consisting mostly of clouded sodic plagioclase with relict oscillatory zoning; the plagioclase is partly replaced by shreds of chlorite and actinolite, fine-grained mats of which occupy the interstices between plagioclase grains, resulting in a blurred, nondescript texture in the hand specimen. The next rock-type is of essentally the same composition but the feldspar is more easily distinguished from mafic constituents in the hand specimen, giving the rock the appearance of a medium-grained diorite. In thin section this appears to be the result of a very slight recrystallization of feldspathic clastic rock, involving growth of the chlorite and actinolite grains of the matrix. Next comes a mixed zone consisting of rock of similar composition with very ill-defined lenses and layers of rock richer in mafic constituents and resembling gabbro. In thin section the gabbroic rock is seen to

consist of elongate grains of a light green pleochroic amphibole containing shreddy remnants of clinopyroxene; the remainder of the rock is mostly sodic plagioclase crowded with minute specks of clinozoisite. Irregular patches of nearly isotropic chlorite occur interstitially to the major constituents and partly replace them. The next rock-type is an essentially homogeneous gabbro similar to that just described, followed by a gradation by decrease in the amount of feldspars into metapyroxenite composed almost entirely of partly altered augite with minor interstitial chlorite.

The gradation is not everywhere complete; in many places hybrid metadiorite is in sharp contact with metapyroxenite, with no intervening gradation through metagabbro. Northwest and northeast of Ham lake hybrid metadiorite and metagabbro are interlayered with feldspathic lavas some hundreds of feet from the nearest ultrabasic bodies. This suggests that the hybrid rocks were produced by reaction with hot solutions which migrated for the most part along the contacts of the ultrabasic intrusions but were not confined wholly to those channelways. That reaction can take place between ultrabasic rocks and wall rocks even a long time after crystallization of the ultrabasic rocks is demonstrated conclusively by the partial replacement by magnesian minerals of conglomerate resting unconformably on ultrabasic rocks, to be described in a later section of this report.

Soda Granite

A body of soda granite crops out between Line lake and Belle bay. The eastern part of the body is elongate parallel to the regional strike, but the western part is discordant, truncating layers of metagabbro, clastic rocks, and ultrabasic rocks; apophyses of the soda granite extend along the contacts between these rocks. South of Bourbeau lake many small dykes of soda granite cut metapyroxenite in the contact zone; the soda granite is therefore younger than the ultrabasic rocks.

The typical rock in the body is massive, medium grained, and greyish buff on the fresh surface; the weathered surface is a chalky light buff colour. It consists predominantly of greyish buff feldspar with smaller amounts of quartz and altered mafic minerals.

In thin section the feldspar is seen to be strongly clouded, markedly euhedral sodic plagioclase, which makes up more

than 50 per cent of the rock. Quartz, which makes up 10 to 25 per cent of the rock, and a small amount of chloritized hornblende are interstitial to the feldspar. No potash feldspar was found, even though two thin sections were etched and then stained with sodium cobaltinitrite.

East of Belle bay the soda granite is in places strongly sheared and carbonatized and cut by numerous barren quartz veins. In the north wall of the valley west of Belle bay it is chloritized and sheared. Near contacts with older rocks it is commonly fine grained and the feldspar is a waxy green colour, which gives the rock a more basic appearance. The soda granite is thought to be related to quartz-feldspar porphyry intrusions, which are described in the following paragraphs.

Quartz-feldspar Porphyry and Intrusive Breccia

A body of quartz-feldspar porphyry underlies the area south of Alasper lake and extends northwest of the lake. The rock consists of round to hexagonal quartz phenocrysts 1 to 2 mm. in diameter and greenish to buff-coloured altered feldspar phenocrysts in a very fine-grained, light grey-green siliceous matrix. Weathered surfaces are buff coloured and slightly rusty, suggesting that the rock contains some ankeritic carbonate. All specimens contain a few small grains of pyrite. In a number of exposures the rock contains numerous fragments of other rocks; here the matrix is chloritic, and the rock resembles the intrusive breccia described below. No chilled contacts were observed in this body of quartz-feldspar porphyry; near contacts with other rocks chlorite is markedly more abundant in the matrix. The body is massive, except east of Garth lake, where it is intensely schistose. The feldspar phenocrysts were determined in thin section to be albite with abundant minute inclusions of white mica which completely obscure the extinction in most phenocrysts, only patches of which show faint albite twinning. Quartz phenocrysts are less abundant than feldspar phenocrysts; together, the phenocrysts make up approximately 40 per cent of the rock. The matrix is an indeterminate mat of colourless minerals with refractive index close to that of Canada balsam and a minor amount of minute shreds of chlorite.

In the area southeast of Sauvage lake many dykes of similar quartz-feldspar porphyry cut metasomatized lavas. A swarm of quartz-feldspar porphyry dykes striking north and dipping vertically cut lavas, clastic rocks, metagabbro sills, and ultrabasic rocks in the vicinity of Trout lake. Some of the dykes in the Trout Lake swarm

contain a few hornblende phenocrysts as well as predominant feldspar and quartz phenocrysts; the feldspar phenocrysts are finely twinned albite with many minute inclusions of white mica and clinozoisite. Four thin sections were stained with cobaltinitrite, and it was noted that there is no potash feldspar present. The quartz-feldspar porphyry is therefore probably similar in chemical composition to the soda granite described above, and since both are younger than the ultrabasic rocks, they may be closely related to each other.

The largest dyke in the Trout Lake swarm has a sheath of brecciated wall rocks cemented by material similar to the matrix of the dykes. Several smaller dykes in this swarm and one southeast of Sauvage lake contain many fragments of assorted rock-types; these dykes are similar in composition to a less well defined rock-type mapped as intrusive breccia southeast of Sauvage lake. For the most part the intrusive breccia is made up of rounded to angular fragments of numerous different rock-types in a fine-grained chloritic matrix. The size of the fragments observed averages about 2 inches, ranging from less than 1 inch to 12 inches. Mawdsley and Norman (1935, p.36) report that the breccia contains blocks of anorthositic gabbro up to 6 feet in length. The fragments in most exposures are predominantly of basic to intermediate amygdaloidal greenstone. Rounded buff-coloured fragments, apparently single crystals of altered feldspar, are locally abundant. Other fragments resemble the matrix of the quartz-feldspar porphyry. The chloritic matrix of the breccia is commonly faintly schistose; in places it is siliceous and very fine grained. The contacts of the bodies of breccia are very ill defined, partly because the wall rocks themselves are brecciated in the contact zones, and partly because metasomatism involving albitization and silicification has affected both the matrix of the breccia and the wall rocks. The breccia is considered to be the result of diatreme-like action which probably accompanied the intrusion of the quartz-feldspar porphyry dykes. The metasomatism of the wall rocks, which is described in detail in a later section, may be related to the same cycle of igneous activity.

Basic Dykes

Basic dykes cut lavas, metasomatized rocks and quartz feldspar porphyry southeast of Sauvage lake. Most of the dykes are less than 10 feet wide; they have preferential southeast strikes and steep dips. They consist of dark green, massive, fine-grained rock which in thin section is seen to be made up of fine mats

of chlorite, actinolite, epidote and albite, in which a relict diabasic texture is faintly discernible. Many of the dykes are carbonatized, some intensely so; some are cut by veinlets of pyrite. Therefore, although the dykes are the youngest intrusive rocks in the area, their intrusion was followed by low-grade metamorphism, carbonatization and mineralization.

Metasomatic Rocks

The rock-types included here are those which have been chemically and mineralogically changed by the action of solutions permeating through them. The relative ages of such rocks are largely unknown; there may have been many different periods of metasomatic activity, in more than one of which similar rocks could have been produced. Some of the metasomatic rock-types described below are equivalent to the basalt, gabbro and quartz gabbro mapped by Graham (1956) and also equivalent to the granophyre of Part II of this report.

Albitized and Silicified Lavas

Southeast of Sauvage lake, and in the western part of Range I, rocks which are believed to have been originally metabasalts consisting of chlorite, epidote, albite and actinolite have been changed in varying degree to chlorite-albite-quartz rocks. The first stages of the change are impossible to detect in the field and consequently the limits of the metasomatism shown on the map are very ill defined. Southeast of Sauvage lake the degree of metasomatism appears to increase from north to south, but the rocks vary considerably even in single exposures. They are generally dark green to black, massive, medium-grained rocks which were thought in the field to be metagabbros; small shining grains of feldspar and quartz in a chloritic groundmass are recognized in the hand specimen. The proportions of these constituents vary erratically, and in some exposures the variations define vague layering in the rocks. In many places the rocks are sheared and carbonatized and they cannot be distinguished from sheared metabasalts. Pyrite and magnetite are common, disseminated and in veinlets, in some places making up more than 10 per cent of the rock. The texture of the rocks as seen under the microscope is entirely dissimilar to that of the metagabbros and lavas in the area. The feldspar is slightly turbid albite, occurring as irregularly lath-like, twinned grains of greatly varying size, a common range being 2 mm. to almost zero. Green pleochroic chlorite

occurs in minute grains, aggregates of which appear as one grain in polarized light. The aggregates are interstitial to the larger albite laths, but contain small scraps of albite, some of extremely minute size. Quartz occurs in grains about 1 mm. in diameter which are commonly irregularly lobate, but which have rare euhedral faces against albite; it is unstrained, and contains a few minute solid inclusions. All slides examined contain grains of leucoxene (2 to 4 per cent), many of which are distinctly lamellar, and some of which contain cores of unaltered titanic iron minerals. In 8 thin sections of albitized and silicified lavas the chlorite ranged from 30 to 60 per cent, the albite, 40 to 60 per cent and the quartz, zero to 20 per cent. No epidote or actinolite was found in any of these slides. Southeast of Sauvage lake many remnants of unmetasomatized metabasalts consisting of chlorite, epidote, albite and actinolite, with a relict basaltic texture, are apparently enclosed in albitized and silicified rocks. Because of this close spatial association, the faint layering in many exposures, and the presence of lamellar leucoxene grains, the albitized and silicified rocks are believed to have been metabasalts from which most of the lime has been leached and to which silica has been added by metasomatism.

Quartz-albite-chlorite Rock

Quartz-albite-chlorite rock of unknown origin is poorly exposed in the extreme southeast corner of the southwest quarter of the township. The rock is for the most part massive, grey-green, and medium grained; in many exposures the proportion of quartz is variable, and it is partly in ill-defined veinlike segregations. Pyrite is abundant in veinlets and disseminated grains, in places making up 10 per cent of the rock. Irregular small masses and disseminated grains of magnetite are also common. In thin section the texture of the rock is seen to be similar to that of some of the rocks mapped as albitized and silicified lavas, but chlorite is much less abundant, averaging 5 to 10 per cent of the rock. The remainder is mostly quartz and turbid albite in about equal proportions; part of the quartz has obviously replaced albite, as evidenced by isolated islands of albite with the same optical orientation enclosed in quartz. The composition of the rock is not greatly different from some igneous granites, especially the acidic differentiates of basaltic magmas; silica, however, is more abundant in this rock than in most igneous granites. For the average proportions of the constituent minerals given above, silica would be about 80 per cent. Potash is apparently absent, or present, in only minute amount in the albite and

saussurite. In view of these differences, and the secondary origin of at least part of the quartz, it is unlikely that this rock is an igneous granite. It is probably the product of extreme metasomatism of some unknown original rock.

Amphibole-magnetite-(pyrite) Rock

Amphibole-magnetite-(pyrite) rock is very poorly exposed in an irregular area between albitized and silicified lavas and quartz-albite-chlorite rock southeast of Sauvage lake. Its composition and texture are highly variable, even in small exposures. It is a dark grey to black, massive, fine to coarse grained rock containing, as the name implies, abundant dark green to black amphibole. In some places the rock contains buff-weathering altered feldspar, but feldspar is more commonly rare or absent, the rock consisting of amphibole, chlorite, magnetite and pyrite. In one locality the rock consists of rosettes and coarse grains of amphibole in a matrix of magnetite, ilmenite, pyrrhotite, pyrite and chalcopyrite, named in order of abundance. A thin section from another locality consists of randomly oriented blades of light green pleochroic amphibole 1 mm. across (40 per cent), aggregates of minutely crystalline green chlorite (35 per cent) and peculiar rings of small grains of titanic iron minerals surrounding cores of either chlorite or aggregates of amphibole blades. The titanic iron minerals make up about 25 per cent of the thin section, and were determined in polished section to be mostly magnetite mixed with a lesser amount of discrete grains of ilmenite.

This rock certainly originated as a metasomatic replacement of some unknown pre-existing rock. Because of lack of good exposures, its relations to adjacent rock-types and its exact mode of origin are unknown.

Carbonate-chlorite Rock

As indicated on the accompanying maps, carbonate-chlorite rock underlies many small parts of the area. The most common type is a schistose, grey-green, sectile rock with creamy, buff, or rusty brown weathered surfaces; when broken, a characteristic rusty orange-brown layer about one-half inch thick is seen beneath the weathered surface. The carbonate is finely crystalline, and the chlorite is in ill-defined aggregates. In many places such rock is cut by veins of more coarsely crystalline carbonate which is white, grey, flesh, or yellowish brown in colour and which weathers very

deeply to a soft reddish black or rusty brown aggregate. In a few places a little specular hematite is associated with carbonatized rocks. Pyrite and (rarely) sphalerite and chalcopyrite occur with vein-quartz in carbonate-chlorite schist east of Garth lake. Important pyrrhotite-sphalerite bodies are associated with strongly carbonatized rock near the east end of Berrigan lake. Most of the numerous smaller occurrences of metallic minerals are associated with zones of shearing and carbonatization.

Carbonate-chlorite schist is undoubtedly the result of replacement by carbonate (carbonatization) of older rocks. All rocks older than the Chibougamau series are in places so affected. In the Keewatin-type lavas circulation of the carbonatizing solutions through discontinuous channels afforded by interflow contacts, fragmental zones and thin, schistose flows resulted in mild carbonatization of the lavas in very narrow lenses. Wide, continuous zones of carbonate-chlorite schist must represent places where the solutions passed in greater quantity through channelways such as would be afforded by shear zones and faults; the presence of such zones is therefore contributory evidence of faulting. The cross-cutting nature of some of the zones confirms this conclusion.

Garnet-augite-chlorite Rock

The Chibougamau series, to be described below, rests unconformably on ultrabasic rocks south of Berrigan lake and west of Antoinette lake. The unconformity itself is well exposed for many thousands of feet. The ultrabasic rocks at the old erosion surface are as fresh as those in outcrops in the present erosion surface. However, the lower beds of the Chibougamau series in many exposures consist predominantly of very fine grained lime-magnesia silicates. In part, these rocks have formed by metasomatism of preexisting conglomerates; in some exposures the outlines of replaced boulders are faintly discernible. Other evidence suggests that the rock may in part be weathered ultrabasic rock which was reworked and deposited in depressions in the old erosion surface.

The rocks concerned present an extremely varied appearance in the field. In a typical section immediately west of the north end of Elaine lake the ultrabasic rock in and below the old erosion surface is augite pyroxenite consisting predominantly of subhedral prisms of unaltered diopsidic augite with a small amount of interstitial serpentine and magnetite. In sharp contact with the

augite pyroxenite there is a band, one foot thick, of dense, very fine-grained green rock with abundant small, black, angular fragments. In thin section the fragments are seen to be almost colourless isotropic chlorite. There are also less abundant fragments of augite partly altered to similar chlorite. The matrix is too fine grained to determine in thin section; an X-ray powder diffraction pattern showed it to be diopsidic augite. Above an ill-defined contact there follows 2 feet of dense, aphanitic to fine-grained bedded rock, mottled in shades of green, buff and purple. X-ray powder diffraction patterns of two specimens showed that they consist predominantly of garnet which, judging by the colour and by the specific gravity of the rock, is probably a variety rich in magnesia or lime. A small amount of carbonate was the only other mineral found in the specimens. Next in the sequence, above a well defined contact, is a band of arkose consisting predominantly of fresh feldspar and quartz. The arkose extends downward in cracks in the underlying rock. In thin section it can be seen that the quartz grains in the arkose are partly replaced by needles of amphibole extending profusely from the margins toward the centres of the grains. The distance over which the replacement of quartz by amphibole needles extends was not determined. A specimen of arkose taken 50 feet above the unconformity showed no sign in thin section of such replacement.

The only other occurrence of similar rocks found in the area is north of Antoinette lake, where a thick sill of metagabbro is truncated by a body of serpentine and probably by a fault. Here a layer of rocks approximately 80 feet thick consists of irregular masses of serpentine and dense, hard, aphanitic rock mottled in shades of buff, green and purple; by X-ray, the latter was found to consist mostly of diopsidic augite and garnet. The adjacent metagabbro is strongly chloritized.

As stated above, the rocks in question clearly originated at least in part by metasomatic replacement of pre-existing rocks. Since rocks of similar composition have been reported elsewhere as the products of weathering of ultrabasic rocks, some of the basal facies of the Chibougamau series, especially those containing fragments of augite, might be in part reworked products of weathering.

Chibougamau Series

Five erosional remnants of relatively undisturbed unmetamorphosed conglomerates, arkoses, and graywackes rest unconformably on older rocks between Elaine lake and Belle bay; these sedimentary rocks were called the Chibougamau series by Mawdsley and Norman (1935). The rocks of the Chibougamau series present steep cliffs, affording excellent exposures of the unconformity and of the rocks above and below it. As much as 30 feet of local relief on the old erosion surface can be seen in some exposures; the rocks in the old erosion surface are as fresh as those in present outcrops, suggesting that the weathered mantle was removed or reworked by wave, current, or ice action shortly before the deposition of the basal beds of the series took place.

The thickest section of the Chibougamau series preserved in the map-area is directly west of Antoinette lake, near the west shore of which steep cliffs rise approximately 600 feet above lake level. Here the base of the Chibougamau series dips on the average 7° south, descending to lake level at a point on the west shore. The lowest beds, which are 2 to 6 feet thick, consist of garnet-augite-chlorite rock described on page 24 . A conglomerate member ranging in thickness up to 70 feet is found near the base, but not in all cases at the base. The conglomerate is made up almost wholly of unsorted fragments of all sizes up to 3 feet, the greater part of them ranging from 1 to 12 inches in diameter. Fragments larger than one inch are commonly well rounded, whereas those smaller than one inch are more commonly angular to sub-angular. They consist of volcanic rocks similar to the Keewatin-type lavas and clastic rocks, metagabbro, pink to white granite, schists and gneisses of various compositions, and ultrabasic rocks. The ultrabasic rocks are apparently more common close to the base. The matrix, which is actually for the most part only the smaller fragments, ranges in composition from arkose to graywacke. The conglomerate is succeeded, and in some places also in part underlain by, a total of 100 to 150 feet of thickly bedded arkose and minor graywacke, commonly medium grained and containing scattered pebbles of rock-types found in the conglomerate. Sorting of the constituent grains is almost non-existent. Cross-bedding was seen in only one 5-foot bed of very fine-grained arkose. The uppermost 80 to 100 feet of the section is made up of greenish grey, fine-grained, very thickly bedded feldspathic graywacke which contains scattered pebbles and boulders, mostly of pink to white granite. Smaller fragments of phyllite were found to be fairly abundant in two thin sections.

The succession of rock-types and the thickness of the units vary considerably from place to place, but the lithology of each unit is similar. Besides the rock-types in the conglomerate described above, boulders of soda granite identical to that directly below the unconformity were found in conglomerates near the base of the erosional remnant west of Belle bay; this, together with the fact that the soda granite shows none of its usual contact features at the unconformity, leads to the conclusion that the Chibougamau series is younger than the soda granite.

The lithology of the Chibougamau series suggests that it was derived by rapid erosion, partly from local areas, and partly from more distant areas which provided the numerous boulders of pink granite found in all of the occurrences of conglomerate. Transport of the material was undoubtedly accomplished in part by fast-moving water, and perhaps in part by glaciers, for which however no conclusive evidence has been found.

Veins

Veins of epidote, quartz-epidote, and carbonate-epidote are abundant in the Keewatin-type lavas, especially in the massive parts of flows and in the sills which intrude them. They are considered to have formed during the low-grade metamorphism, at least partly by leaching and redeposition of such constituents of the rocks as lime and possibly alumina. Carbon dioxide, and possibly silica, must have been contributed by solutions from other sources. Such veins are rare in the clastic rocks and in the sills which intrude them.

Veins of barren milky white quartz are found cutting all of the rocks older than the Chibougamau series; most of them are small, discontinuous bodies, but a few are more than 10 feet wide. Some of these quartz veins contain a little crystalline carbonate and minute quantities of pyrite and chalcopyrite; important concentrations of gold have been found in a quartz vein north of the west end of Fleury lake. One stringer of pink quartz 1 inch wide and 3 feet long was found in a joint plane in conglomerate of the Chibougamau series. Mawdsley and Norman (1935, p. 58) report that the Chibougamau series east of the present area is cut by veins of quartz and specular hematite.

Veins and replacement bodies of sulphides will be described below, under "Economic Geology". A small mass of rock rich in pyrrhotite-chalcopyrite-sphalerite was found in conglomerate at the base of the remnant of the Chibougamau series immediately east of Antoinette lake; a few minute veinlets of the same sulphides occur in the altered matrix of the conglomerate. It therefore appears that at least some sulphide mineralization post-dates the Chibougamau series.

STRUCTURAL GEOLOGY

Regional Setting

The map-area is in the eastern part of the Matagami-Waconichi belt, which is the northernmost of three irregular greenstone belts constituting the northeastern extremity of the Temiscamian sub-province of southern Quebec. The rocks of the Mattagami-Waconichi belt are tightly folded into several major anticlines and synclines which strike east to northeast. The Keewatin-type series and the metagabbro sills in the map-area form part of the south limb of one of the major synclines. The anticlinal area to the south is occupied by a complex of intrusive rocks. To the north, several major folds lie between the syncline of the present area and the northern limit of the belt, which is bounded on the north by granitic rocks some 12 miles beyond the north boundary of the map-area.

Attitude of Keewatin-type Series and Metagabbro Sills

With the exception of some local contortions which can be seen on the accompanying maps, the Keewatin-type lavas strike east-northeast and dip vertically or steeply north; 60 reliable top determinations, made mostly on the basis of pillow shapes, are taken to establish definitely that the tops of the flows face north throughout the section exposed. Evidence has been presented (p. 14) to show that at least some of the metagabbro sills were intruded in a horizontal position, and that their tops also face north.

The attitude of rocks of the clastic group is in general parallel to that of the lavas, with east-northeasterly strikes and steep to vertical dips. However, bedding in the sequence of clastic rocks north of Trout lake dips 10° to 40° north, steepening to more than 70° along strike to the west; the meaning of this local contortion is not known. East and southeast of Antoinette lake minor

folds in bedded clastic rocks are clearly defined by the mapping. Bedding on the limbs and the noses of the folds dips vertically, so that the minor folding appears to have taken place about vertically plunging axes. The relation of the minor folds to regional structures is not apparent; they may have resulted from left hand movement on a major transcurrent fault.

Only 4 reliable determinations of the top of graded beds, all facing north, were made in exposures of the clastic group. As further evidence is lacking, it is assumed the clastic group conformably overlies the lava group and that the whole, with intercalated sills, constitutes part of the vertical south limb, which is at least 20,000 feet thick, of a major syncline. The axis of the syncline has not been located by the present mapping. Some determinations made by Mawdsley and Norman (1935, p. 18) indicate that the axis strikes east-northeast, plunges east, and lies near the north boundary of the present map-area. The lavas northwest of Gwillim lake strike east and dip vertically. One reliable determination indicates that the top of at least one pillowed flow faces south.

Schistosity

All of the rocks older than the Chibougamau series are in places schistose. Keewatin-type lava flows and metagabbro sills are commonly schistose near their margins, and many thin flows are schistose throughout. The schistosity is partly the result of relative movement between individual flows and sills and between smaller units within them during folding. This schistosity strikes east to east-northeast and dips vertically or very steeply north or south. Where schistosity with this attitude is intense, continuous along strike, and associated with wide zones of carbonatization, it is probably the result of faulting parallel to the strike of the flows and sills.

Vertical schistosity with a distinctly different strike, which is in general northwest, is associated with northwest faults.

Faults

Faults in the area may be grouped according to their general strike into 3 sets: a set striking east-northeast, parallel to the strike of the formations, a set striking west-northwest to northwest, and a set striking northeast to north.

Most of the east-northeast faults are inferred from topographic alignments and the occurrence of sheared or carbonatized rocks along them. These include all of the east-northeast faults in Ranges I, II, and III in the southwest quarter of the township.

A fault is assumed to underlie the valley extending east-northeast from the southeast corner of Antoinette lake to Belle bay, on the basis of the following observations: 3 remnants of the Chibougamau series in the north wall of the valley dip south toward it, but do not cross it, although the base of the series in the north wall is topographically lower than older rocks in the south wall; older rocks along the valley are in places sheared, carbonatized, and chloritized; the valley is relatively straight in plan. The remnants of the Chibougamau series are thought to be down-faulted in the north wall of the fault, the minimum vertical displacement being probably of the order of 300 feet. Since the Chibougamau series is not sheared or altered near the fault, whereas older rocks are, some movement of unknown sense and magnitude probably pre-dated the deposition of the Chibougamau series.

The inferred fault bounding the remnant of the Chibougamau series between Elaine and Antoinette lakes is probably an offset extension of the fault described above. Movement on a sub-parallel fault extending east-northeast from the north end of Elaine lake has resulted in the base of the Chibougamau series in the north wall being some 200 feet lower than the same horizon in the south wall.

Faults of the west-northwest set are inferred from intense vertical schistosity parallel to the faults from minor horizontal separations, the magnitude of which can be seen on the accompanying maps. Most of the separations are right hand, so that the faults may be minor adjustments to compressive stresses normal to the strike of the formations.

Faults of the northeast to north set are inferred from topographic lineaments and from minor right-hand and left-hand horizontal separations, the magnitude of which can be seen on the accompanying maps. Little or no schistosity is associated with the faults, suggesting that they may be normal faults resulting from release of compressive stresses.

ECONOMIC GEOLOGY

General Statement

Quartz veins, for the most part barren, but in a few places carrying coarsely crystalline carbonate, minor pyrite and chalcopyrite, and rare sphalerite, are abundant in the area. A few of the veins carry traces of gold, and at least one contains notable amounts. Veins carrying the greatest amounts of metallic minerals are in rusty-weathering carbonatized shears associated with both east-northeast and northwest faults. At Berrigan lake, sulphides are most abundant in those parts of a zone of carbonatized rock which have been silicified and veined by quartz and brecciated.

Pyrite and magnetite disseminated in metasomatic rocks southeast of Sauvage lake have not been found in important concentrations; the relative abundance of metallic minerals in the metasomatic rocks is, however, noteworthy. The mineralizing solutions were apparently localized along the same channels as the metasomating solutions, or were perhaps directly related to the same source.

Disseminated magnetite in the ultrabasic rocks, being a by-product of the serpentinization of those rocks, probably does not occur in workable concentrations. Although no chromite has been found in the ultrabasic rocks, the possibility of its occurrence should not be overlooked. Brittle-fibre asbestos occurs in unimportant quantities in the ultrabasic rocks; an interesting occurrence of silky-fibre asbestos is described on page 39. One small occurrence of graphite schist associated with ultrabasic rock was found south of Antoinette lake.

Description of Properties

Belle-Chibougamau Mines Ltd.

This company holds a group of claims in the central part of the township west and south of Belle bay. Part of the property is in the north half of the township, outside of the present map-area.

The work done by the company on this group of claims includes surveys of the claims, magnetometric and geological surveys, extensive stripping and trenching, and more than 10,000 feet

of diamond drilling. The writer visited the property during the course of mapping in the summer of 1953, at which time diamond drilling was in progress under the direction of L.S. Trenholme, consulting geologist to the company.

The claims in the northern part of the map-area are underlain by vertically dipping clastic rocks which are intruded by a thick, concordant body of metapyroxenite, serpentinized dunite, and metagabbro. The southeastern part of the property is underlain mostly by ultrabasic rocks. Near the central part of the property a partly discordant body of soda granite intrudes both the clastic rocks and the ultrabasic rocks. An erosional remnant of relatively undisturbed beds of arkoses and conglomerates of the Chibougamau series lies partly on the soda granite and partly on clastic rocks. Two faults of the northwest set were identified in the northeastern part of the group, and an east-northeast fault is inferred to underlie the valley extending west-southwest from Belle bay. Generally speaking, mineralization occurs in two different forms on the property: as veins filling steeply dipping north-northwest fractures, and as replacements of the clastic rocks, usually near contacts with ultrabasic rocks.

The main mineralized zone is exposed in a blasted rock face on the north shore of Belle bay, 600 feet west of the point where the road crosses the narrows. The rock is stripped for a distance of 150 feet northwest of the exposures nearest to the lake. The country rock is serpentinized dunite interlayered on a small scale with metapyroxenite. The layering dips vertically; within the stripped area the layers are contorted into the form of a double flexure whose axial planes dip vertically and strike north-northwest. A zone of intense shearing 5 feet in width (unmineralized), which strikes northwest and dips vertically, is exposed in the central part of the stripped area. The serpentinized dunite is irregularly slickensided in many other parts of the stripped area. The sulphides occur along a thin zone of fracturing which strikes north-northwest and dips 80° east; the zone can be traced on surface for a distance of 100 feet northward from the exposures nearest to the lake. The sulphides are in disconnected pods of broken and irregularly sheared rock, the largest of which is 6 feet thick; one of the pods exposed in the steep blasted face appears to be elongated down the dip of the zone. In order of abundance, the sulphides observed are pyrrhotite, chalcopyrite, pyrite and sphalerite, the last 3 being present in minor amounts. A sample taken by Graham (1953, p. 32) from the main lens

assayed 1.41 per cent copper and 0.366 ounce of gold per ton; samples from 2 other lenses assayed respectively 2.63 per cent copper and 0.006 ounce of gold per ton and 1.19 per cent copper, 1.74 per cent zinc and 1.004 ounces of gold per ton.

In a steep rocky slope facing south, 550 feet north-northwest on the main zone, chalcopyrite and pyrite are disseminated in small, irregular masses of rock in a joint which strikes north-northwest and dips 60° west. It is not known whether or not this is a continuation of the main zone. Pyrite and chalcopyrite were observed in minor amounts in 6 other north-northwest shear joints on the property; all of these joints cut ultrabasic rocks. In this connection, it is interesting to note that a north-northwest fault identified by the present mapping passes 700 feet east of the main zone. No sulphide mineralization was observed in the walls of the small transverse depression which the fault occupies on the high ground north of the bay, but the fault itself is not exposed, and its intersection with the body of serpentinized dunite which is the host rock of the ore in the main zone is covered by glacial drift and the water of the bay.

The clastic rocks which underlie part of the property contain nearly everywhere a small amount of disseminated pyrite. In many places, where the clastic rocks are close to ultrabasic rocks, they are replaced by pyrite, pyrrhotite and chalcopyrite along thin irregular zones parallel to the bedding and to the contacts. The largest of these occurs in the extreme northeast corner of the southwest quarter of the township. In this locality bedded clastic rocks strike northeast and dip vertically; a short distance to the east the strike of the bedding swings to east and the dip remains vertical. In the vicinity of the mineralization the clastic rocks are bounded on the northwest by a body of fine-grained, mafic-rich metagabbro which grades into medium-grained metapyroxenite; the contact between the metagabbro and the clastic rocks is sub-parallel to the bedding in the clastic rocks. The clastic rocks containing the sulphides are discontinuously exposed in strips and trenches along a zone 220 feet long which strikes northeast. Within the zone irregular, vein-like masses of chalcopyrite, pyrite, and a little pyrrhotite replace strongly altered clastic rocks over exposed widths as great as 50 feet. The distribution of sulphides within the zone is so irregular that visual or grab-sample estimates are not possible; chalcopyrite probably makes up less than 2 per cent of the total volume of the rock in the mineralized zone. According to company records 21

diamond-drill holes with an aggregate lenght of 6,500 feet, and 28 shorter holes, have been drilled to explore this zone. In addition to the main exposures, there are a few exposures which suggest that the direction of the zone may change from northeast to east as it is followed east, as does the ultrabasic-clastic rock contact and the bedding in the clastic rocks.

Sulphides occur in clastic rock in a trench 140 feet east of the northeast end of the exposures of the main zone, and in several outcrops near the north boundary of the map-area 500 to 600 feet east of the north-south centre line of the township. Exposures between these localities are too few to prove that they are extensions of the main zone; if they are, the total length of the zone is at least 1,300 feet. The sulphides in these possible extensions of the zone are pyrite, chalcopyrite and pyrrhotite, present in much smaller concentrations than in the main exposures.

Three other smaller occurrences of pyrite and chalcopyrite in clastic rocks, all close to contacts with ultrabasic rocks, were observed on the property. Whether or not this means that the sulphide mineralization is genetically related to the ultrabasic rocks is not known. There is no apparent spatial relationship between the occurrences of sulphide and the body of soda granite.

Brosnan Chibougamau Mines Ltd.

This company holds a group of claims in the southeast quarter of the township, northeast of the town of Chibougamau.

The work done on the property includes geological and geophysical surveys and some stripping and trenching. The writer visited the property during the course of mapping in the summer of 1953, at which time some trenching was being done under the direction of J. Brosnan.

The claim group is underlain by clastic rocks intruded by ultrabasic rocks and by a thick sill of metagabbro in the north, and by lava flows and metagabbro sills in the south. Minor concentrations of pyrite have been found in a few places in the clastic rocks and in the shattered rock near the south contact of the large metagabbro sill in the eastern extremity of the property. As far as the writer is aware, no gold is associated with this pyrite mineralization.

Royran Gold Fields Ltd.

Central Group

The company's central group of claims lies northwest of the Chibougamau townsite. The property was idle during the summers of 1951 and 1952, but previous to the summer of 1951 the company had done extensive stripping and trenching and had drilled more than 40 short diamond-drill holes, and former owners had sunk an exploration shaft on the Fleury Lake discovery.

The property is underlain by metagabbro sills interlayered with rocks of the clastic group in the northern part, and with rocks of the lava group in the southern part. Several zones of shearing and carbonatization extend across the property. All occurrences of metallic minerals discovered to date are in carbonatized and sheared zones, and most are associated with vein quartz.

The Fleury Lake zone is 270 feet north of the west end of Fleury lake, in an easterly-trending, rusty-weathering carbonatized shear cutting metagabbro. At the exploration shaft the shear zone is 60 feet wide, but only 25 feet of this width is carbonatized. Two milky white quartz veins 1 to 3 feet thick are exposed in the shaft, in which the water was 35 feet below the collar at the time of the examination. The shearing dips vertically, whereas the veins and probably the zone dip 55° to 70° south. Besides quartz, the veins contain a smaller amount of coarsely crystalline ankeritic carbonate, abundant euhedral pyrite, and irregular blebs and masses of chalcopyrite in small amount. A grab sample taken by the writer, and believed to be representative of the vein material, assayed 0.326 ounce of gold per ton. A channel sample across 4.3 feet at the shaft is reported by the company to have assayed 2.8 ounces of gold per ton. The rusty shear and the veins are much thinner at short distances along strike on either side of the shaft. In a trench 60 feet west of the shaft the rusty shear is 2 feet wide and no quart veins are exposed. In a trench 50 feet east of the shaft the shear is 9 feet wide and a quartz vein 4 to 8 inches wide is exposed. The company reports assays of 0.45 ounce of gold per ton over a width of 0.5 foot 30 feet east of the shaft and 0.52 ounce over a width of 0.6 foot 75 feet east of the shaft. In the shaft area 14 diamond drill holes were drilled along a 400-foot section of the zone. One assay of 0.12 ounce of gold per ton over 0.9 foot is reported 100 feet west of the shaft; other assays west of the shaft are 0.01 ounce or less.

Several other occurrences of vein quartz and sulphides have been found on the property, almost exclusively in rusty shears. Base metal content is not high enough to be important in any of the occurrences found to date and, apart from those described above, precious metal content is low or nil.

Garth Lake Group and Scott Chibougamau Option

Royran Gold Fields Ltd. holds a group of claims in the southeast corner of the southwest quarter of the township and has an option on 5 claims in the same locality which belong to Scott Chibougamau Mines Ltd.

A geophysical survey of the property has been made and some stripping, trenching and diamond drilling have been done.

The property is underlain by Keewatin-type lavas, metasomatic rocks, and quartz-feldspar porphyry, all of which are cut by basic dykes and by carbonatized shears. Metallic minerals are relatively abundant, in part in the metasomatic rocks and in part in the shears, with or without associated vein quartz. The company reports the presence of zinc, copper, silver, and gold, but no workable deposits have been found. The metasomatic rocks contain pyrite and magnetite, which constitute 15 per cent of the rock in many places, and much more than this in a few places. Laboratory studies show that ilmenite is associated with the magnetite in unimportant amounts.

In the extreme western part of Lot 29, Range I, 550 feet north of the range line, a facies of the amphibole-magnetite (pyrite) rock consists of rosettes and coarse grains of dark green amphibole in a matrix of magnetite, ilmenite, pyrrhotite, pyrite and chalcopyrite in varying proportions, chalcopyrite making up less than one per cent of two polished sections studied. Such rock is discontinuously exposed in outcrops and old trenches across a width of 150 feet in a north-south direction.

Royran Gold Fields did some trenching and diamond drilling at various places on the group of claims and reported that 2.5 feet of core from one of the holes assayed 1.05 per cent zinc, 0.24 per cent copper, 0.24 ounce of silver per ton and a trace of gold.

Taché Lake Mines Ltd.

This company holds a group of claims between Antoinette and Larobe lakes. The property was visited by the writer during the course of mapping in 1952 and 1953, at which time surface exploration work was in progress. Upwards of 30,000 feet of diamond drilling and some resistivity survey work and geological mapping have been done by present and former owners of the property.

The northern part of the property is underlain mostly by metagabbro and the central and southern parts by ultrabasic rocks, clastic rocks, and a remnant of the Chibougamau series.

Two sulphide zones have been located just north of Berrigan lake. One is 400 feet to 650 feet north of the centre of the north shore, and will be called the north zone. The other outcrops on the north shore near the east end of the lake, and will be called the Berrigan zone.

The north zone is a zone of shattering in otherwise massive serpentinized pyroxenite. The shattering resulted in some places in the formation of a three-dimensional reticulate pattern of joints, and in other places in irregular brecciation of the rock. The shattering was evidently followed by the deposition of dark grey, fine-grained vein quartz and some rusty-weathering carbonate in the fractures, each constituent replacing the wall rock to some extent. Ore minerals are concentrated in veins and masses in the vein quartz and silicified wall rock, in some places constituting the matrix of a breccia of the siliceous rock; in other places massive sulphides have completely replaced the host rock. Country rock in the ore zone is black and textureless, apparently chloritized and carbonatized; at the main surface exposure of the north zone such alteration extends only a few feet into the wall rock. At the main exposure the sulphide minerals observed are, in order of abundance, pyrrhotite, sphalerite, galena, chalcopyrite, pyrite and arsenopyrite. In other exposures galena is rare, and the relative abundance of the other minerals is variable. In the main exposure the zone is 20 feet wide.

According to company estimates, diamond drilling to date has outlined 380,000 tons of probable ore containing an average of 4.45 per cent zinc and 0.064 ounce of gold per ton. The estimate does not include some small but rich exposures of ore in the area surrounding the north zone.

The Berrigan zone outcrops along the north shore of Berrigan lake for a distance of 140 feet near the east end of the lake and extends inland in an east-northeasterly direction for a total exposed length of 1,300 feet. Two parallel zones, north and south of the main zone, have been found near the eastern extremity. It has not yet been fully established whether or not the main zone extends to the west under Berrigan lake. In one diamond drill hole beneath Berrigan lake 200 feet west of the lake shore exposures of the main zone only scattered sulphides were found, but shearing is found along the north shore west of these exposures, and there is some pyrrhotite and sphalerite in a rusty shear 350 feet west of them.

The wall rocks of the Berrigan zone are mostly serpentinized dunite and sheared serpentine, with less serpentinized pyroxenite. Within the zone the rocks are altered to carbonate-rich, rusty-weathering schists and breccias, so that it is difficult to determine their original nature; it seems likely that they were ultrabasic rocks. At the main exposure of the zone brecciation of the host rock is made apparent by differential weathering of the fragments and matrix of the breccia. Rocks of other parts of the zone are schistose, and brecciation is not apparent. Within the ore zone, parts of the carbonatized rock are replaced by dark grey, very fine-grained to cherty vein quartz, which in turn acts as host for the ore minerals. The quartz generally occurs in irregular layers separated by layers of carbonatized rock. The quartz layers have been fractured, and the ore minerals occur both in the fractures and as replacements of the quartz. In some places layers of massive sulphides have apparently entirely replaced the siliceous host rock. Ore minerals are commonly scarce in the carbonatized rock between siliceous layers. Pyrrhotite and sphalerite are by far the most abundant sulphide minerals in surface exposures of the zone. A small amount of chalcopyrite was seen in some specimens. Galena is rare or absent. The company reports one assay of 0.50 per cent nickel, and at least one other assay of a sample containing a significant amount of that metal. The richest and widest part of the Berrigan zone is the part nearest the lake. Carbonatized and brecciated rocks there are 200 feet wide, and 40 to 100 feet of that width is sulphide-bearing.

According to company estimates of 1951, diamond drilling has outlined 285,600 tons of probable ore containing 3.05 per cent zinc and 0.017 ounce of gold per ton.

Wright-Hargreaves Mines Ltd.

In 1950 this company held a group of claims covering most of Antoinette lake and areas immediately north and south of the lake and another group in Range III. At the time of the writer's examinations in the summers of 1951 and 1952 only the claims in Range III were in good standing. Both of these groups were mapped geologically by the company, and some stripping was done.

The northern part of the Antoinette lake group is underlain by metagabbro, a thin bed of clastic rocks, and ultrabasic rocks. The southern part is underlain mostly by ultrabasic rocks. In the clastic rocks 800 to 1,500 feet north of Antoinette lake minor concentrations of pyrite have selectively replaced layers of laminated tuffs over a width of 1 to 2 feet and a possible length of 1,600 feet. A little pyrrhotite and chalcopyrite accompany the pyrite in some places. A sample of the sulphide-rich material taken by the writer contained no gold.

Near the north boundary of the claim-group a layer 60 to 80 feet thick of garnet-augite rock along a contact of agglomerate and metagabbro with serpentine contains, at two places 1,800 feet apart (shown on the map), veins of silky cross-fibre chrysotile asbestos. Bedrock between these two places is for the most part covered with drift and forest debris. The asbestos veins are mostly less than one-quarter inch wide; a few are one inch wide. The eastern exposure is undoubtedly well below ore grade; the western exposure was estimated to contain about 1 per cent asbestos over a length of 150 feet and an unknown width (the exposure is a small vertical cliff-face).

The position of a small, isolated exposure of graphitic schist south of Antoinette lake is indicated on the map. The schist was probably ultrabasic rock originally, but is now chloritic and black. The average rock of the exposure probably contains less than 10 per cent graphite.

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SOUTH HALF OF McKENZIE TOWNSHIP

ABITIBI-EAST ELECTORAL DISTRICT

PART II. — SOUTH HALF OF SOUTHEAST QUARTER

by

G. Allard

SOUTH HALF OF McKENZIE TOWNSHIP

ABITIBI-EAST ELECTORAL DISTRICT

PART II

SOUTH HALF OF SOUTHEAST QUARTER

by G. Allard

INTRODUCTION

An area of approximately 13 square miles, comprising the south half of the southeast quarter of McKenzie township, was mapped by the author during the field seasons of 1953 and 1954.

Field Work

The area was mapped on a scale of 1 inch equals 500 feet using vertical aerial photographs, picket lines on mining properties and chain and compass traverses in a manner similar to that described in Part I of this report.

The area is covered by abundant timber and a thick blanket of moss. In many places the etched and weathered rock surface under the moss provides the best means of identifying the original rock. The structures and textures of the rock and the outlines of the original minerals are well displayed on such surfaces, whereas on the fresh surface a mat of fine secondary minerals blurs all original structures and textures.

Acknowledgments

The writer gratefully acknowledges the assistance of mine officials of the Chibougamau district in the gathering of information relating to geology. Campbell Chibougamau Mines Ltd. generously loaned its Cedar Bay camp for the summers of 1953 and 1954. Able

assistance was given in the field by students R. Roy, R. Weiss, R. Freedman, R. Néron, and W. Hallessey. Willing and excellent services were rendered by the cooks, F. Lavoie and B. Martineau.

PHYSIOGRAPHY

The information given under this heading in Part I of the report provides a general outline of the important physiographic features of the south half of McKenzie township, including the area here under discussion. It remains to be noted that Gouin peninsula, in the southeastern part of the map-area, is covered by a sheet of morainic gravel which locally measures 130 feet in thickness.

GENERAL GEOLOGY

General Statement

The area mapped by the writer can be divided into two parts: a smaller area to the north underlain by volcanic rocks, and a greater area to the south underlain by the plutonic rocks of the Doré Lake complex. All of the consolidated rocks of the area are Precambrian in age. The volcanic group, presumably the oldest group of the area, is here called the Keewatin-type series; the term implies a predominantly volcanic assemblage lithologically similar to the original Keewatin-type section. The southern part of the map-area is underlain by rocks of the Doré Lake complex: metaanorthosite, metagabbro, a transition member between metaanorthosite and metagabbro, metapyroxenite and granophyre. All of the rocks except a few members of the Doré Lake complex have been metamorphosed to the greenschist facies. Practically no original minerals remain intact except the magnetite and ilmenite in some layers of the Doré Lake complex.

The area is transected by two main sets of fractures: a major northeasterly-trending set, parallel to the Grenville front, and a northeasterly-trending set which is of economic importance. The latter consists of short shear zones of variable width along which veins containing chalcopyrite, sphalerite and siderite have been localized. Hydrothermal alteration and intense shearing are characteristic of these zones; carbonatization and development of chloritoid are the main types of hydrothermal alteration, but silicification, chloritization and sericitization are also common.

Table of Formations

CENOZOIC	Pleistocene	Gravel, sand	
Great erosional unconformity			
EARLY PRECAMBRIAN	Folding, faulting, hydrothermal activity		
	Intrusive Rocks	Greenstone dykes Grey fine-grained quartz diorite dykes Grey feldspar porphyry dykes Quartz-feldspar porphyry dykes	
		Intrusive contact	
		Doré Lake Complex	Granophyre Metagabbro Metapyroxenite Transition rock Metaanorthosite
		Intrusive contact	
		Folding, faulting	
		Metagabbro sills	
		Intrusive contact	
	Keewatin-type Rocks	Metaandesite Metabasalt	

Keewatin-type Volcanic Rocks

The Keewatin-type volcanic rocks underlie the northern part of the map-area and extend northward into the area covered by Part I of this report. The south boundary is the Sauvage Lake fault. A narrow band of volcanic rock underlies the north side of Gouin peninsula close to the east boundary of the township. This band is 1,000 feet wide and only 3,500 feet long within the map-area, but it is known to extend to the east across most of Portage island (Horscroft, p. 4).

That the volcanic rocks were extruded on a flat surface is shown by the regularity of flow contacts; flow junctions strike slightly north of east in a uniform and regular manner. The dip varies between 80° north and 80° south. The pillowed flows are elongated parallel to the strike of the volcanic belt. The volcanic rocks at the base of the series are of basaltic composition. Higher in the stratigraphic sequence the lavas are more andesitic, and the final outbursts of volcanic activity gave rise to rhyolite and pyroclastic deposits which are more widespread north of the map-area. Most of the flows are massive and show only minor alteration of the original structures and textures. At the base about 80 per cent of the flows are massive and the remaining 20 per cent have well developed pillow structure. Pillowed flows are more abundant north of the Grandines road. The mineralogical alteration has been profound in both kinds of lavas.

Metabasalt

The massive flows of metabasalt are uniform over wide areas. They weather to a greyish green or dark green colour. Only a few flows could be measured from top to bottom, but the thickness of individual flows appears to vary from 15 feet to 110 feet. Greater thicknesses are suspected because of the coarser grain size of some flows, but lack of outcrops commonly precludes exact measurement of thickness. The massive flows are much coarser than the pillowed flows; some approach an average grain size of one-quarter inch. Amygdaloidal layers are abundant and gradations are common in the field from a massive coarse-grained greenstone, with typical intergranular texture, through a zone exhibiting increasing amounts of amygdules, to a slaggy flow 4 or 5 feet thick. Some of the flow tops are fragmental. The massive portions of the flows resist erosion much better than the flow tops and amygdaloidal portions.

The finer-grained pillowed lavas are lighter in colour than the massive lavas and are medium to light green. The pillows range from a few inches to 15 feet in length and average 2 feet. Each pillow has a very fine-grained marginal zone one-half to one inch thick, slightly darker or lighter green in colour than the rest of the pillow. A band of amygdules or varioles 2 to 6 inches wide inside of this marginal zone of altered original glass is a very common occurrence. The amygdules become rarer toward the centre of the pillow and are absent in the centres of the larger pillows. The abundant amygdules indicate that the magma had a high volatile content.

More than 50 flow tops were observed in the metabasalts. In over 25 cases the exposures were good enough to indicate the direction of the top of the flow. Slaggy fragmental flow tops appear to have been formed when the lava was in movement; most fragments are amygdaloidal and some attain 18 inches in length. They commonly show very fine-grained chilled borders and, at times, a slight banding parallel to their borders. The lavas were erupted quietly and intermittently. They are rarely interbedded with ash. The few flow contacts observed show no evidence of weathering or soil accumulation between flows. This indicates rapid out-pouring of the lava sequence.

Flows with a uniform porphyritic texture were not observed in the metabasalts. However, at 6 different locations, indicated on the map, there are layers 9 inches to 4 feet thick that are studded with plagioclase phenocrysts in the basal portion, adjacent to the top of the lower flow. The plagioclase phenocrysts vary from one-quarter inch to 2 inches in size and on the weathered surface they stand out as white humps in a smooth fine-grained green matrix. The layered nature of the phenocrysts-bearing bands and their position close to the base of the flow indicates that the intratelluric phenocrysts settled in the still liquid lava after extrusion. In one of the flows the phenocrysts are euhedral and rhomb-shaped.

Metaandesite

The metabasalt flows are succeeded to the north by, and in places appear to be interfingered with, a much more feldspathic and lighter-coloured rock here called metaandesite. Some of these flows are porphyritic throughout. The metaandesite extends northward from a line about 1,000 feet south of the Grandines road. The best exposures are in the area covered by Part I of this report.

The rock weathers greenish white to dead white, in marked contrast to the green and dark green colour of the metabasalt. On the fresh surface the rock is fine grained to aphanitic, in places porphyritic, and light greenish grey to white in colour.

The change in specific gravity from a maximum of 3.02 for the metabasalts (average around 2.90) to a minimum of 2.64 for the rocks farther north (average around 2.75) is indicative of a progressive change in original and actual composition of the lavas. This change in density is reflected in the modal analyses of the rocks by a very marked decrease in the amount of magnetite, leucoxene, epidote and actinolite, and a gradual increase in the amount of albite.

Petrography of the Volcanic Rocks

The volcanic rocks of the map-area are metamorphosed to the greenschist facies. Field geologists call these rocks green schists or greenstones. The latter term is preferred because of the preponderance of massive, unfoliated rocks. The massive portions of the flows still show the original textures and structures, and the author believes that very little has been added or lost during the metamorphism of these rocks. Along flow tops and shear zones the rock is commonly schistose and could be called chlorite schist or carbonate-chlorite (in places chloritoid) schist. The introduction of the carbonates ankerite or siderite modifies the colour of the rock to light brown. The chlorite schists and carbonate-chlorite schists are very fine grained and cannot be positively identified as volcanic in origin unless they contain amygdules or have the typical intergranular texture of basalts. The textures of the metavolcanic rocks are remarkably uniform. The grains of these rocks, not including the porphyritic ones, vary between 4 mm. by 0.7 mm. for the microphenocrysts to very small grains of the order of 0.03 mm.

The massive metabasalts consist of albite, chlorite, actinolite, epidote, opaque minerals (magnetite, ilmenite, pyrite), leucoxene, calcite, and minor quartz. Albite occurs in long lath-shaped grains or more rarely as equant euhedral to subhedral grains. In a few cases the larger grains or microphenocrysts are grouped together, producing a typical glomeroporphyritic texture. The albite is twinned following the albite, Carlsbad and albite-Carlsbad laws; untwinned grains are rare. Chlorite, sericite, carbonate, magnetite and epidote are disseminated throughout the albite in submicroscopic grains. The equant albite grains have a chloritic core. This chlorite

is apparently the alteration product of original glass or magnetite grains. In the large lath-shaped albite grains tiny inclusions of chlorite form a vague zoning. The albite in the light-coloured rocks north of the metabasalts is generally much finer grained. This albite retains the predominant lath shape but it appears to have a larger length to width ratio than the albite in the coarse metabasalts. The texture is intergranular; glomeroporphyritic texture was not noted, but a plumose arrangement of the albite laths is common.

Actinolite is commonly present in the metabasalts of the area, especially in the coarse-grained darker flows close to the base of the volcanic series. It occurs either as small individual grains between plagioclase laths or as large poikiloblastic grains enclosing many grains of albite and iron oxides. Small individual grains of pyroxene, all in optical continuity, were observed in the core of actinolite grains in two thin sections. Small individual grains of actinolite are markedly acicular and have ragged ends with long fibrous projections into the adjacent plagioclase grains. This indicates that the actinolite, unlike the albite, is not a perfect pseudomorph of the original pyroxene; it has grown outward into the plagioclase, using up some of the calcium released by the change from calcic plagioclase to albite. The local preservation of ophitic texture indicates that in places the actinolite is pseudomorphic after pyroxene. The actinolite is well intergrown with chlorite. The chlorite occurs in narrow bands parallel to the cleavage directions of actinolite, in patches throughout, and especially in the cores of actinolite grains. It is difficult in many cases to decide the age relations of the chlorite and actinolite. In places the actinolite seems to grow into chlorite. In others it may be that the first stage of metamorphism caused a development of actinolite around cores of pyroxene; this is exemplified in the area to the north, where a pyroxenite sill contains grains of pyroxene surrounded by a zone of actinolite. Later changes in conditions, combined with an access to sufficient water, would cause the alteration of the remaining pyroxene to chlorite. The pre-existing actinolite around the grains and along cleavage planes and cracks remains unaltered as separate islands, all in optical continuity, in the patches of chlorite. Progressing northward, actinolite gives place to chlorite in the metavolcanics, although it was found in sills intruding the metavolcanics and in basic flows interleaved with more andesitic ones.

Chlorite is the most conspicuous mineral in these rocks. It is conspicuous not by its quantity as much as by its green colour,

which imparts to the whole rock a marked green colouration: hence the term greenstone for these rocks. Except in some feldspathic lavas to the north, chlorite is ubiquitous in the greenstones. It occurs in small grains between the plagioclase laths. Patches of chlorite with irregular outlines are common in the coarse-grained metabasalts. In some sections the chlorite has a fibrous habit and a radial arrangement. Chlorite also occurs as aggregates of coarse grains in amygdule fillings. The metabasalt commonly contains chlorite in the form of elongated, spindle-shaped smears; these are shown to be made up of many large grains, commonly curved and twisted, or of many very small unoriented flakes. Chlorite and calcite are very mobile minerals in these rocks, in that they are commonly found cutting across plagioclase laths, even in fresh massive rocks which have undergone no deformation and had no apparent addition of material. This differs from the late veins of chlorite, calcite, quartz and epidote which transect the whole rock and are certainly later than the very minor veinlets of chlorite which transect individual albite grains.

Epidote is not common in these rocks, being restricted to the dark metabasalts at the base of the series and to basic sills intruded into the volcanic rocks. Epidote occurs as small granules disseminated through the rock. Large euhedral crystals are occasionally found in chlorite-filled amygdules. Optical data indicate that the epidote is an iron-rich variety of pistacite. Veinlets of epidote and quartz are very common in the more basic flows, where they occur as filling of tensional fractures. They range in composition from pure quartz to pure epidote. Some of them measure 15 feet in length and 18 inches in width.

There is a large difference in the quantity of opaque minerals in the dark-coloured flows (metabasalt), which contain up to 24 per cent combined iron oxides and leucoxene, as compared with the light-coloured flows, which contain only 5 per cent opaque minerals. In the field some dark lavas attract a hand magnet and cause a slight deviation of the compass needle. In general, the opaque minerals consist of magnetite, ilmenite and minor pyrite. The grains of ilmenite in some sections have a marginal zone of leucoxene and a core of opaque unaltered ilmenite, whereas in other sections the ilmenite is completely altered to leucoxene. The leucoxene is evidently made up largely of submicroscopic grains of sphene.

Intrusive Rocks

Metagabbro Sills

Three sills of metagabbro are intrusive into the metavolcanics. These sills are part of the group of metagabbro sills in the area to the north and west, described in Part I of this report. In order to avoid repetition, only particular features will be discussed here. The sills consist of a narrow mafic-rich layer at the base, a central layer of normal feldspathic metagabbro and a quartz and chlorite-rich layer at the top. Strike and top determinations on the sills accord with strike and top direction of the volcanic rocks. The petrography and field relations suggest that the gabbro sills were intruded and differentiated in relatively undisturbed volcanic rocks and were later folded with them.

The bulk composition of the sills, or the composition of the original magma, may have been very close to the composition of the volcanic rocks. The sills may be part of a system of dykes which acted as feeders for the flows. The sills appear only above a certain horizon in the volcanic series. Possibly the force of intrusion could pry apart the volcanic flows above this horizon, but below it the load exceeded the force of intrusion of the magma and no sills were formed.

Doré Lake Complex

The Doré Lake complex is a layered intrusive made up of many different rock types varying from ultrabasic to very silicic in composition and including a large body of anorthosite. The metamorphism of these rocks varies depending on location with respect to later intrusives, original chemical composition, grain size, texture and structure. The present mineral composition has also been influenced by the type and intensity of hydrothermal alteration along mineralized shear zones.

Metaanorthosite

Metaanorthosite, the most common rock type in the Doré Lake area, underlies the southern part of the map-area. In the field a rock was called metaanorthosite if it contained more than 80 per cent altered plagioclase. The rock is white with light yellowish green and dark green interstitial areas. It weathers greyish white and buff and the texture is brought out on the weathered surface by

differential weathering of the interstitial chlorite and the large crystals of altered plagioclase. No stratification was observed in the metaanorthosite, but a crude layering must be present to account for the different textural varieties observed in adjacent outcrops.

The predominant minerals are albite, zoisite, clinozoisite and chlorite. Ilmenite partly altered to leucoxene, shpene and rutile are very minor accessories. The plagioclase (albite) crystals, in spite of intense zoisitization, commonly have sharp grain boundaries. Cleavage faces and twinning plane traces are readily identified in the hand specimen. The crystals measure, for the most part, one-half inch to two inches; however, some larger crystals measuring up to 18 inches were observed. Chlorite, which is possibly pseudomorphic after original pyroxene, occurs in the interstices between the albite grains. Zoisite and clinozoisite, the predominant minerals in the metaanorthosite, occur principally as a partial or complete replacement of plagioclase. A fine-grained, nearly pure zoisite rock is a common contact phase of metaanorthosite adjacent to granitic rocks. The accessory minerals in metaanorthosite are ilmenite and titaniferous magnetite. The ilmenite is altered to leucoxene and the magnetite to chlorite.

Transition Rock

The metaanorthosite, by a decrease in the amount of plagioclase and an increase in mafic minerals, grades into what has been called transition rock. The description given for metaanorthosite applies equally well for the rock in the transition zone. The plagioclase is heavily saussuritized and the mafic minerals are altered to chlorite. The ilmenite is partially altered to leucoxene. Thin lenses of metaanorthosite, which have very limited lateral extent, occur within this member. There are also zones rich in magnetite and titaniferous magnetite. A general characteristic of the transition zone is the very large size of the grains of plagioclase.

Metagabbro

The metagabbro is a coarse- to medium-grained gabbro now metamorphosed to a granitoid textured rock composed of saussuritized plagioclase, actinolitic hornblende and relict pyroxene, magnetite and titaniferous magnetite, chlorite, apatite and other minor accessories. The rock weathers light greyish white. On the fresh surface white plagioclase and dark hornblende appear in equal proportions.

Primary foliation is commonly well developed; it is defined by a distinct alignment of plagioclase tablets and elongated hornblende grains. There is no lineation within the foliation plane. Banding or layering is also well exemplified in the metagabbro; it results from an alteration of bands of feldspathic metagabbro and metapyroxenite or magnetite-rich metapyroxenite.

The original labradorite is altered to albite containing clinozoisite, carbonate and shreds of chlorite. Light green actinolitic hornblende occurs as large plates pseudomorphic after pyroxene. Relict pyroxene within the hornblende was found in two thin sections. Clinozoisite is most frequently associated with the alteration of the original plagioclase, whereas epidote occurs in the matrix or in cross-cutting veinlets with associated quartz. Magnetite and titaniferous magnetite are commonly present.

Metapyroxenite

Layers of coarse-grained amphibole-rich rocks are interlayered with anorthositic gabbro and gabbroic anorthosite on the south side of Gouin peninsula and on the north shore of Doré lake. This rock is dark green to brownish red in colour and coarse grained. The weathered surface of the metapyroxenite is very jagged and rough with grains of amphibole and magnetite-ilmenite standing in relief.

The rock consists of large crystals of amphibole and patches of chlorite set in a green to yellowish matrix. In thin section the coarse amphibole is seen to be calciferous hornblende, apparently pseudomorphic after pyroxene. These crystals are zoned, twinned and also bent and fractured. The matrix is made up of fine needles of tremolitic amphibole. Some rock sections contain anhedral grains of serpentine with released magnetite which likely are derived from olivine. Ilmenite, in fractured grains, is a very common accessory. These rocks correspond to metapyroxenite and metaperidotite.

Granophyre

A body of granophyre underlies the large hill north of Kokko Creek bay, close to the centre line of the township. This rock type has been termed quartz gabbro by Graham (1956, p. 4) and is mapped as part of a metasomatic complex in Part I of this report. The size of the mass is quite small compared to the extent of the anorthosite and gabbro masses. The granophyre mass has a low dip to

the northwest and is found in an area of high ground; it is thought to represent an erosional remnant of an originally larger mass. In a few places the granophyre was found to grade into metagabbro and transition rock. The essential minerals of the granophyre are quartz, chlorite and turbid plagioclase.

In thin section this rock is seen to be a true granophyre; the granophyric texture is well preserved in spite of the intense alteration of the original plagioclase and mafic minerals. The clear quartz grains, which appear to be single grains or eyes in the hand specimen, consist of many irregularly-shaped fragments having identical optical orientations; the interstices between the fragments are filled with chlorite and highly sericitized and chloritized plagioclase. Minor actinolite and apatite and accessory pyrite, sphene, calcite, magnetite and ilmenite are also present.

Field relationships and microscopic features of this rock suggest that it is one of the youngest members of the Doré Lake complex. The differentiation of the original basic magma of the complex gave rise to an acidic rest liquid which produced the granophyre.

Dykes

The southern part of the map-area contains a great number of dykes of greenstone, quartz-feldspar porphyry, grey feldspar porphyry and grey fine-grained quartz diorite. All have excellent chilled contacts and they vary from a few inches to 55 feet in width. Most of the dykes are parallel to the northwesterly-trending and steeply-dipping shear zones; there is a close connection between the shearing in the northwest direction and the fracturing associated with dyke emplacement. The dykes may be massive or sheared.

Greenstone Dykes

The greenstone of these dykes resembles the metabasalt of the map-area. The dykes show chilled contacts, with a gradual increase in grain size toward the interior of the dyke. These dykes consist of chlorite, albite, epidote, and opaque minerals. The albite laths are pseudomorphic after labradorite; epidote and clinozoisite are by-products of the plagioclase alteration. Hydrothermal carbonates tend to replace the plagioclase, whereas chlorite and chloritoid substitute for the original mafic minerals. Along the Siderite Hill zone (p. 63) some of these dykes are completely altered

to a mixture of quartz, carbonate, sericite and chloritoid. In spite of the total mineralogical change in these rocks, the original intergranular texture can still be distinguished in thin section.

Quartz-feldspar Porphyry Dykes

Dykes and irregular masses of quartz-feldspar porphyry cut the granophyre and metabasalts south of Little Gilman lake. They are probably offshoots from a larger body mapped farther west (Part I of this report). Quartz-feldspar porphyry dykes are also numerous in the area around Cedar bay and along the belt of anorthosite north of Doré lake.

These dykes are massive; they weather light grey to buffish white and have good chilled contacts. The phenocrysts are plagioclase and (less abundant) quartz; they stand out in relief on the weathered surface. The plagioclase (albite) phenocrysts are euhedral to subhedral, well twinned, and commonly sericitized and carbonatized. In general the quartz phenocrysts are rounded and partially resorbed. The matrix is made up of very fine grains of quartz, chlorite and carbonate, and minor magnetite, pyrite and leucoxene. Some thin sections were stained with cobaltinitrite to detect potash feldspar, but the reaction was negative.

Grey Feldspar Porphyry Dykes and Grey Fine-grained Quartz Diorite Dykes

These dykes are found only in the Doré Lake complex, mainly in the metaanorthosite member. They are massive, fine grained to nearly aphanitic where narrow, and show chilled contacts. In some cases the contacts are sheared and in others the whole dyke may be sheared; in the latter case they resemble silicified shear zones in anorthosite.

Microscopically, the rock consists of a fine-grained aggregate of plagioclase, quartz, chlorite, white mica, epidote, clinozoisite, carbonate and leucoxene. The alteration and the fine grain size make an accurate study of these dykes nearly impossible.

STRUCTURAL GEOLOGY

General Statement

The northern part of the area mapped by the writer is underlain by volcanic rocks and basic to ultrabasic sills. These rocks form the south limb of a large syncline whose axis lies 3 miles north of Gilman lake. The southern part of the area is underlain by members of the Doré Lake complex, a stratiform sheet which has been arched up by the intrusion of the Chibougamau Lake granite mass (Mawdsley and Norman, p. 38).

The volcanic rocks strike east to slightly north of east and dip 80° to 90° north. The strike of the flows is regular and uniform. Some 50 evenly distributed flow-top determinations indicate a normal succession of volcanic rocks with tops facing north.

Two layers of variolitic metabasalt show a marked lineation. The best exposures are in the east flank of the high hill 6,200 feet north of Kokko Creek bay. The varioles average 1.5 cm. in diameter where undeformed. In the deformed layers the varioles are represented by lenticular bodies 5 cm. long at their maximum by 1.6 cm. wide and 2.5 mm. thick. The variolitic layers, as well as the flows, are nearly vertical in attitude. The long axes of the stretched varioles are also vertical. The plane of stretching is vertical and is limited to a layer about 2 feet thick. On either side of this layer there is a gradual decrease in flattening and the varioles retain the original spherical shape. No drag folds were noted along these planes.

The metabasalts in the lower part of the volcanic group commonly contain elongated spindle-shaped dark green chlorite smears. These invariably plunge 80° north to 80° south. The origin and exact significance of these smears are not clear. They may represent original phenocrysts of augite altered to chlorite or amygdule-fillings of original chlorophaeite. The long axis of the spindles is vertical, the intermediate axis is horizontal in the east-west direction and the short axis is horizontal in the north-south direction. This orientation indicates movement in a vertical direction which corresponds to the long axes of the stretched varioles described above.

The Doré Lake complex is intrusive into the Keewatin-type metavolcanic rocks. In the area mapped by the writer, the north

contact is marked by the Sauvage Lake fault zone. No well exposed contacts were observed between the metagabbro and the lens of metabasalt on Gouin peninsula. There is evidence pointing to the original horizontality of the Doré Lake complex; the original mass could have been a sill, laccolith or lopolith. It has been arched into a northeasterly-plunging anticlinal structure and part of its core has been obliterated by the intrusion of the Chibougamau Lake granite mass (Mawdsley and Norman, p. 38). In the area to the south mapped by Graham (1956) and in the area under discussion, the primary foliation and layering in the northwest limb dip northwest. Very little is known about the southeast limb.

Shear Zones

The area is transected by two important sets of shear zones, one striking northeast and the other northwest. Both sets may be complementary in origin, but each has had a different history since inception. A third set of minor shears strikes north-northeast. All of the shear zones are marked by extensive development of carbonate (siderite, ankerite and calcite), quartz, chlorite, chloritoid, and sericite.

Northeast Shear Zones

Sauvage Lake Fault

The Sauvage Lake fault zone has been mapped in detail over a length of 16 miles, extending both east and west of the area under discussion. In the area mapped by the writer this fault zone separates the Keewatin-type volcanic rocks to the north from the Doré Lake complex to the south. It is marked by a wide zone of shearing with extensive development of iron carbonates and chloritoid. The drag folding observed in a few places indicates a displacement of the north block to the east with respect to the south block. Since there are no available horizon markers, the direction and amount of movement cannot be established. In many localities the rock is massive but extremely well banded, especially where alternate layers of carbonate and chloritoid make up most of the rock. Bedded tuffs are present in some localities and there is a strong suggestion that the faulting took place along a tuffaceous horizon.

In the volcanic rocks north of Cedar bay there are two zones of shearing parallel to the Sauvage Lake fault zone.

Doré Lake (McKenzie Narrows?) Fault

The McKenzie Narrows fault was named after McKenzie Narrows at the northeast corner of Chibougamau lake (Mawdsley and Norman, p. 51). In that area nearly horizontal (Huronian) sediments are in contact with steeply-dipping Keewatin-type volcanic rocks. Graham (1956, p. 17) mentions that the extension of this fault is found in the creek between Caché and Doré lakes and is also indicated by diamond drilling west of Merrill island. This brings the fault to the boundaries of the area under discussion where, however, the probable trace of the fault is everywhere concealed by the waters of Doré lake.

The presence of a major shear zone along the axis of Doré lake may be a controlling factor in the development of the present topography; an inclined diamond drill hole directed under Doré lake from Machin point intersected 175 feet of very highly sheared chlorite-sericite schist. This shear zone cannot be positively identified as the extension of the McKenzie Narrows fault and, until further work clarifies this point, the name Doré Lake fault should be applied to the fault along the axis of Doré lake.

Northwest Shear Zones

The shear zones belonging to the northwesterly-trending set are of economic importance in that they are copper-bearing. These zones are characterized by intensive shearing and hydrothermal alteration leading to complete replacement of the host rock by iron carbonates, chlorite, chloritoid, sericite and quartz. Sparse drag folding indicates that the movement, at least in the last stage of the deformation, took place in a horizontal direction. The northwest shears are much shorter than the northeast set. Northwesterly-trending dykes are very common and a great number of them have been introduced along shear zones. Most of the commercial orebodies are found along dykes in shear zones. The dykes may or may not be sheared but they are commonly heavily altered.

The mineralogy of these shear zones is variable and depends on the degree of shearing, the chemical composition of the host rock, and the presence or absence of sulphide bodies. Sheared anorthosite is altered to a sericite schist with minor calcite and chlorite; if the shear is mineralized, the rock becomes quite chloritic. Chlorite, ankerite and minor sericite are the most common

minerals in sheared metagabbro and transition rock; if the shear is mineralized, siderite and chloritoid are present. These generalizations have a wide range of application in prospecting for copper-bearing shear zones.

North-northeast Shear Zones

This third set of shears is only poorly known. The north-northeast shearing is not indicated in surface mapping but recent aeromagnetic surveys, diamond drilling and mine development work point to shearing in this direction.

ECONOMIC GEOLOGY

General Statement

Many sulphide zones have been discovered in this area. The main sulphide mineral is chalcopyrite; pyrite, pyrrhotite and sphalerite are present in variable amounts, generally less than the chalcopyrite. All of the mineralized zones found to date are located along dykes in northwesterly-trending shear zones having dips steeper than 45°. The dykes are generally highly altered and are either sheared or massive. The sulphides replace a sericite-chlorite schist. The localization of the sulphide bodies is thought to be related to dilational openings formed between the brittle dykes and incompetent schist during movement along the northwesterly-trending shear zones. The relation of the sulphide zones to the northeast and north-northeast shears is not clear, but these zones bear a close spatial relationship to the Doré Lake and Sauvage Lake faults.

Hydrothermal Alteration

The predominant alteration in the shear zones is carbonatization. Besides carbonates, other important minerals along these zones are sericite, chlorite, quartz and chloritoid. In the zones of carbonate the rock is reduced to a paper schist. Away from the centre of the shear zones the shearing gradually decreases in intensity and the content of carbonate decreases to 15 or 20 per cent. In the massive adjacent wall rock the original textures and structures of the rock remain, but large carbonate rhombs are present. Unmineralized shear zones in anorthosite are marked by an abundance of sericite and minor calcite and quartz; in ferromagnesian-rich rocks like metagabbro and metabasalt, chlorite and ankerite or siderite

predominate and chloritoid is of common occurrence. Where sheared metaanorthosite is mineralized, chlorite is the chief alteration mineral. In sheared and mineralized transition rock, metagabbro or metabasalt, siderite and chloritoid are the most common alteration minerals.

Chloritoid

Chloritoid occurs in shear zones in metaanorthosite, metagabbro, transition rock, metabasalts, and in all types of dykes previously described. The chloritoid in shear zones occurs with siderite, ankerite, chlorite, sericite and quartz. Typical localities are the small island at the mouth of a bay in the southwest corner of Gilman lake. Some of the best specimens of chloritoid come from the footwall of the siderite-chalcopyrite vein of the Siderite Hill zone (p. 63) and from both walls of the Jaculet (p. 62) and Machin Point (pp.64,65) zones. The last two occurrences are in metaanorthosite and transition rock. Chloritoid is also present in the dykes along these shear zones. The Sauvage Lake fault zone is also chloritoid-bearing.

The chloritoid in the Chibougamau area occurs as single grains or as radiating sheaves of twinned crystals. Chloritoid is dark green to black in colour and can be distinguished from chlorite by its superior hardness and good cleavage. The size of the grains varies from 0.3 mm. to 3 mm. In the muscovite schists chloritoid attains its maximum dimensions and in the altered greenstone dykes it is evenly distributed throughout the rock in grains averaging 0.4 mm. in size. In places, a strong foliated structure is brought out by the alternation of bands rich in chloritoid with chloritoid-free bands.

In thin section the chloritoid shows no preferred orientation. The crystals are neither broken nor deformed; this shows that it grew after the final phase of deformation in a static medium. The chloritoid porphyroblasts contain opaque grains and some quartz grains as helicitic inclusions parallel to the foliation, indicating that it could not absorb all of the quartz and opaque minerals during growth. On the other hand, muscovite abuts into the side of chloritoid crystals and is not preserved as inclusions; this implies that it has been taken up by the chloritoid during growth. In a few thin sections narrow veinlets of carbonate cut the chloritoid-rich bands, indicating that solutions were present after the growth of chloritoid.

The hydrothermal origin of the chloritoid is evident from its mineralogical associations, its spatial relations to shear zones and ore zones, and by the fact that it is found in shear zones cutting such diverse rocks as metabasalt, metagabbro, metaanorthosite and altered dyke rocks along shear zones.

Description of Properties

Bateman Bay Mining Company

Bateman Bay Mining Company holds a group of claims which straddle the McKenzie-Roy township line; 7 of the claims are in the southeast quarter of McKenzie township. The Company was incorporated in May, 1955. Diamond drilling was started in the fall of 1955.

The property is underlain by metagabbro, transition rock, metapyroxenite, and metaanorthosite. The north shore of Gouin peninsula is underlain by a narrow band of metabasalt, succeeded to the north by metaanorthosite. The members of the Doré Lake complex strike slightly north of east and dip north.

Recent drilling indicated northwesterly-trending shear zones containing copper mineralization, some sections of which are of ore grade.

Campbell Chibougamau Mines Ltd.

Cedar Bay Property

Campbell Chibougamau Mines Ltd. owns 7 claims at the southwest corner of Cedar Bay. The property formerly belonged to Consolidated Chibougamau Goldfields Ltd. Consolidated Mining and Smelting Company of Canada Ltd. optioned the property in September, 1934, and sank a shaft to a depth of 522 feet and did 4,732 feet of lateral work on the 250-foot and 500-foot levels.

Campbell Chibougamau Mines Ltd. acquired the property in March, 1950, and did 13,623 feet of surface diamond drilling in the winter of 1951. During the summer of 1956 the company started unwatering the old workings in order to do detailed exploration work.

The company reports indicated reserves of 135,000 tons with an average grade of 0.25 ounce of gold per ton and 1.70

per cent copper above the 500-foot level and 35,000 tons averaging 0.18 ounce of gold per ton and 2.90 per cent copper between the 500-foot and 750-foot levels. The orebodies occur in a series of shear zones in anorthosite mineralized with quartz, chalcopyrite and pyrite. The shear zones and a series of parallel greenstone and quartz-feldspar porphyry dykes strike in a southeast direction.

Kokko Creek Property

The Kokko Creek property was leased by Campbell Chibougamau Mines Ltd. from Merrill Island Mining Corporation Ltd. in 1953 for a period of 99 years and is to be worked by the lessee on an equal profit sharing basis with the leaser.

Merrill Island Mining Corporation Ltd. drilled 16 diamond drill holes in 1951 and 1952 for a total of 5,709 feet. Campbell Chibougamau Mines Ltd. drilled 16 additional holes between January and June, 1956.

The property is underlain by metaanorthosite. The mineralized zone occurs along a northwesterly-striking shear zone on one side, or possibly both sides, of a quartz-feldspar porphyry dyke. The mineralized zone is 2,000 feet long and has a known width of 40 feet. The sulphide minerals, in order of abundance, are chalcopyrite, pyrrhotite, pyrite and sphalerite. Carbonatization, silicification, and chloritization are the most common types of alteration.

Copper Cliff Consolidated Mining Corporation

Jaculet Zone

This zone is located on the west shore of Cedar bay; it extends underneath the waters of the bay. This part of the company's property is underlain by anorthosite and transition rock with gabbroic layers occurring towards the north. The property is crossed by a series of northwesterly-striking shear zones marked by intense development of siderite, sericite and chloritoid. The main shear zone is steep and is intruded by a swarm of dykes of altered greenstone, grey feldspar porphyry and grey fine-grained quartz diorite. The ore occurs in the shear zone between the dykes. Locally, the chalcopyrite has replaced altered dyke rock, but in general the best sulphide material is found adjacent to the dykes.

The company is sinking a 5-compartment shaft in this part of its property.

Quebec Smelting Siderite Zone

This zone is on property formerly owned by Quebec Smelting and Refining Ltd. It was explored by that company over a strike length of 460 feet by diamond-drill holes totalling 7,000 feet; 17 of the holes intersected copper mineralization. The zone strikes in a northwesterly direction. The mineralization consists of chalcopyrite and siderite in a host rock of gabbro and transition rock. No outcrops of the mineralized zone were found on surface. Indicated reserves are estimated at 178,602 tons averaging 2.1 per cent copper.

Siderite Hill Zone

This zone is located 1,000 feet southwest of Towle lake. Essentially, it is a zone of massive siderite with disseminated coarse blebs and small veinlets of chalcopyrite and minor pyrite. A small amount of chalcopyrite is also found in the wall rock, especially in the massive chloritoid. The siderite occurs along a dyke in a broad northwesterly-trending shear zone which abuts against the pyrite-carbonate zone which is parallel to the Sauvage Lake fault. At the east end the zone splits into two branches and is concealed by a thick cover of overburden. The siderite vein varies between 10 feet and 125 feet in width; the maximum width may correspond to a large body of siderite at the nose of a drag fold within the shear. The original host anorthosite and transition rock is completely altered to a sericite-carbonate schist containing abundant chloritoid. Chloritoid is present in all of the rock types, constituting up to 60 per cent of the wall rock of the siderite vein. Silicification is intense in many parts of the mineralized zone.

A series of dykes lie parallel to the mineralized zone. In general, the dykes are fine grained and massive; they consist of carbonate, quartz, sericite, very minor chlorite, and abundant small grains of chloritoid which give a peppered appearance to the rock. The original nature of the dyke rock is difficult to establish, but a transition from the completely altered dyke to a rock which is evidently greenstone was noted.

Some 8,000 feet of diamond drilling in 29 holes was completed to explore this vein. Company officials report reserves

of 520,000 tons averaging 1.46 per cent copper or 2,000,000 tons carrying 31.1 per cent iron and manganese and approximately 1 per cent copper.

Zinc Zone

This zone is located 200 feet south of Towle lake. The main part of the zone has been trenched for approximately 700 feet and tested by one diamond drill hole located at the west end of the zone. The main shear zone strikes in a northwesterly direction. The rocks are intensely sheared and carbonatized. In places the shear zone is drag-folded and contorted. A quartz-feldspar porphyry dyke is found along the south wall of the zone. The country rock is gabbro containing patches of magnetite-rich gabbro and metapyroxenite. The mineralization consists of sphalerite and minor chalcopyrite and pyrite. The sphalerite in this zone differs from the sphalerite in the other parts of the Doré Lake area in that it is silvery white in colour rather than dark brown.

Company officials report that 4 channel samples assayed 24.7 per cent zinc over 3.0 feet, 24.85 per cent over 7.0 feet, 8.79 per cent over 27 feet and 6.80 per cent over 15 feet.

Zinc mineralization also occurs in a shear zone in anorthosite on the south tip of the tongue of land east of Cedar bay. The mineralization consists of dark brown sphalerite and calcite in a sericite-chlorite schist which is exposed on the side of a small cliff surrounded by drift-covered areas. No work has been done here.

New Royran Copper Mines Ltd.

This property is on Gouin peninsula. It is underlain by transition rock and is crossed by a broad northwesterly-trending shear zone. Greenstone dykes are intruded within the shear zone.

Some of the mineralized zones have already been described by Graham (1953, p. 12). The main shear zone is exposed on Machin point and along the shore to the southeast. It is a heavily sheared zone containing chloritoid, sericite, chlorite and carbonate. Diamond drilling results indicate that its width exceeds 650 feet. Another northwesterly-trending zone 400 feet northeast of Machin point was explored by trenching and drilling along a strike length of 1,200 feet. It is essentially a siderite-chloritoid zone in a sericite-chlorite schist. Chalcopyrite in veinlets and splashes are found in the better-grade siderite lenses.

During the summer of 1955 the company drilled a series of diamond drill holes to intersect the Machin Point zone at a deeper level than the former drilling. An important sulphide body was located immediately west of Eaton bay. Shaft sinking was started in the fall of 1955.

Quebec Chibougamau Goldfields Ltd.

This company's property is located between the Cedar Bay and Kokko Creek properties of Campbell Chibougamau Mines Ltd.

The area is underlain by metaanorthosite and transition rock and is crossed by northwesterly-trending shear zones. A large shear zone in the southern part of the property was drilled in 1955 and a copper-gold ore zone was located. Shaft sinking started in the spring of 1956.

Bouzan Mines Ltd.

This company holds a group of claims in the southeast corner of the township. The bedrock is composed of a medium to coarse grained anorthosite which is massive except in the vicinity of the ore zone where it is sheared and altered to a talc-sericite, chlorite and carbonate schist. The Bouzan ore zone lies along the dip extension of the Copper Rand-Eaton Bay ore zone.

A resistivity survey has been conducted on the property, and from 1955 to 1957, the company drilled 60 diamond drill holes for a total of 77,263 feet. The ore found consists of pyrite and chalcopyrite associated with chlorite, quartz and some carbonate.

REFERENCES

Graham, R.B., Mining Properties and Development in the Chibougamau Region, Abitibi-East and Roberval Counties during 1952; Que. Dept. Mines, P.R. No. 287 (1953).
North Half of Obalski Township, Electoral District of Abitibi-East; Que. Dept. Mines, G.R. 71 (1956).

Horscroft, F.D.M., Preliminary Report on the Southwest Quarter of Roy Township, Abitibi-East Electoral District; Que. Dept. Mines, P.R. No. 370 (1958).

Mawdsley, J.B. and Norman, G.W.H., Chibougamau Lake Map-area, Quebec; Geol. Surv. Can., Mem. 185 (1935).

APPENDIX

(South Half of McKenzie Township)

Economic Geology 1954-1959

by J.-E. Gilbert

A considerable amount of exploration and development work has been carried out in the south half of McKenzie township since 1954 and most of the work that was done prior to 1958 has been described in the following reports published by the Quebec Department of Mines.

1. Description of Mining Properties visited during 1956 in the Chibougamau Region, P.R. No. 352, pp. 11-16;

2. Description of Mining Properties visited during 1957 in the Chibougamau, Bachelor Lake, and Waswanipi Regions, P.R. No. 388, pp. 8-11;

3. Mining Industry of the Province of Quebec in 1955, pp. 94, 95;

4. Mining Industry of the Province of Quebec in 1956, pp. 94-96;

5. Mining Industry of the Province of Quebec in 1957, pp. 105-107;

Reports deposited in the Department's archives and information gathered by the Department's geologists indicate that exploration and development work was especially concentrated in 1958 and during the first half of 1959 in the southeast quarter of the township.

Campbell Chibougamau Mines Ltd. rehabilitated the former Consolidated Chibougamau Goldfields Cedar Bay three-compartment shaft and, after considerable surface and underground exploration work, the company sank a four-compartment production shaft to

a depth of 1,021 feet. Production began in March 1958 and the present rate is 550 tons per day. A considerable amount of surface drilling was also carried out on the company's Kokko Creek property and a 3,200-foot drive was conducted from the 400-foot level of the company's main mine across the lake. A two-compartment service shaft is being presently put down on the property to intersect the drive. Ore reserves are estimated on the Cedar Bay property at 927,000 tons grading 2.06 per cent copper and 0.125 ounce of gold per ton to a depth of 650 feet, and at 467,000 tons averaging 3.29 per cent copper and 0.029 ounce of gold per ton to a depth of 406 feet on the company's Kokko Creek property.

Amongst the other companies which performed some exploration and development work in the area, Bateman Bay Mining Co. completed, in May of 1959, a shaft-deepening programme to a depth of 526 feet on its property and opened two new levels at 375 and 500 feet. After completion of a large surface diamond-drilling programme in 1956-1957, the company announced the discovery of two chalcopyrite-bearing structures containing an estimated 565,000 tons averaging 1.8 per cent copper, 0.115 ounce of gold and 0.47 ounce of silver per ton to a vertical depth of 600 feet, and 183,200 tons grading 1.65 per cent copper, 0.048 ounce of gold and 0.187 ounce of silver per ton to a depth of 670 feet.

Ground geophysical surveys, geological studies and diamond drilling were also carried out during the last few years in the southern half of McKenzie township by Brosnan Chibougamau Mines Ltd. and Copper Rand Chibougamau Mines Ltd. The properties of Chibougamau Mining and Smelting Co. Inc., Chib-Kayrand Copper Mines Ltd., Quebec Smelting and Refining Ltd., and Copper Rand Chibougamau Mines Ltd. were covered by airborne geophysical surveys.

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