CANADA

DEPARTMENT OF MINES

HON. W. A. GORDON, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

GEOLOGICAL SURVEY

W. H. COLLINS, DIRECTOR

Summary Report 1933, Part D

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OTTAWA

J. O. PATENAUDE

PRINTER TO THE KING'S MOST EXCELLENT MAJESTY

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HYDROUS SILICA DEPOSIT NORTH OF MINAKI, ONTARIO

By J. F. Wright and C. H. Stockwell

INTRODUCTION

In 1918 Mr. Findlay McCallum noticed rusty and decomposed materials on the hillside at the northwest corner of Vermilion Lake and nearly one-half mile southeast of the east end of a bay on the east side of Winnipeg River, about 8 miles north of Minaki. As the surface rocks elsewhere in the district are fresh, this unusual material was investigated. A white, earthy powder and fragments of dark quartz were found on the surface at the entrance to a few of the burrows in the hillside, and when at these localities pits were dug through the thin mantle of glacial drift and rusty materials they entered honeycombed material consisting of dark quartz and a white, earthy powder, and also a more compact grey and white, but porous, light-coloured rock containing the same white powder. Specimens of it were collected and submitted for study, but, as no definite information was available regarding the character and uses of such material, no attempt was made to develop the deposit.

In 1931 Mr. McCallum and Mr. W. J. Dickson, 270 Fort Street, Winnipeg, the present owners, again became interested in the deposit. Additional work was undertaken and in all ten trenches and pits, one to a depth of 27 feet, were made, and in May, 1932, the ground was staked. In August, 1932, Mr. V. L. Eardley-Wilmot visited the deposit and collected representative samples for laboratory tests to determine possible uses of the material. The present writers visited the deposit early in June, 1933, and spent two days in company with Mr. McCallum, who kindly made arrangements for the trip and cleaned out some of the trenches for examination.

GENERAL GEOLOGY

The deposit is in an area of Precambrian sediments and lavas penetrated by bodies of granite and pegmatite. The area is about one-half mile wide and lies between the northwest bay of Vermilion Lake and a bay of Winnipeg River to the northwest. The lava is black and dense with pillows in some outcrops. It probably is hornblende basalt. The sediments are grey, bedded rocks and are tuffs, impure quartzite, and sillimanite gneiss. The bedding and the schistosity both strike about north 70 degrees east, magnetic, and dip steeply north. The extent of this body of lavas and sediments along the strike is unknown, but to the west it does not cross Winnipeg River about a mile distant from the deposit. The body of lavas and sediments is bounded by intrusive granite on both its north and south sides. The granite is a grey and pinkish grey, massive, or only slightly foliated, microcline-bearing variety that outcrops extensively along Winnipeg River both north and south of the deposit. Pegmatite cuts the lavas and sediments as discontinuous dykes and some bodies are rich in quartz and others in microcline. The deposit is in basalt, sillimanite gneiss, and pegmatite at the south side of the area of lavas and sediments.

CHARACTER AND OCCURRENCE OF HYDROUS SILICA

The hydrous silica is a white powder with an index of 1·432. This suggests that it carries from 8 to 10 per cent water. It is non-crystalline.[1] It occurs in pegmatite, sillimanite gneiss, and lava. In these rocks the minerals, except quartz, tourmaline, sillimanite, and garnet in part, have been leached and hydrous silica occupies their place. If the original mineral was mica, the hydrous silica is in thin layers of the shape of the mica crystal; if after feldspar or hornblende the outline of the particles of hydrous silica is characteristic of these minerals. Where quartz was not abundant in the rock the material is friable. The sillimanite gneiss is leached to a light, porous rock, carrying quartz and sillimanite needles intermixed with hydrous silica. Black lava, probably basalt, is gone to friable almost pure hydrous silica. A few small fragments of the lava remain, however, and outward from them the hydrous silica becomes more plentiful until no trace remains of the texture and minerals of the rock. In the zone between unleached lava and friable hydrous silica, the feldspar and hornblende are crossed by veinlets of hydrous silica. In some crystals of feldspar only a few fragments with their original orientation remain, and these are surrounded by hydrous silica. The hydrous silica thus clearly is a residual mineral formed by leaching of lime, soda, potash, iron, and other constituents of the minerals of the country rocks.

EXTENT AND CHARACTER OF THE DEPOSIT

The zone carrying the white, hydrous silica is exposed 450 feet along its strike of north 70 degrees east, magnetic, by ten pits and shallow trenches from 25 to 70 feet apart. The workings are from 70 to 110 feet up the hillside from the shore of Vermilion Lake and from 20 feet at the east end to 60 feet at the west end above the water-level. The decomposed, rusty material ends on the hillside just above the line connecting the highest trenches, and back of this bedrock rises rather steeply to form an irregular trending escarpment up to 15 feet high. The surface is nearly flat behind this escarpment and the rock is fresh at the surface. Glacial deposits are thin and confined to small depressions between rock ridges. The rock surfaces are not polished or striated as they are at nearby localities along Winnipeg River, although poor striæ were found on one rock surface just behind the escarpment. These trend south 50 degrees west, magnetic, or at an angle of about 30 degrees to the general trend of the top of the escarpment and also the strike of the zone of hydrous silica.

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[1] X-ray analysis, Department of Geology, Univ. of Wisconsin.

In the east or No. 1 pit, which is 3 feet deep, the upper 6 to 12 inches are of limonite-stained glacial drift carrying fragments of fresh rock. This is followed downward with sharp contact by 2 feet of intermixed friable and non-friable pegmatite, quartz, and hydrous silica. Some of the fragments of pegmatite are coated by an orange to yellowish coloured mineral, which is also intermixed with the hydrous silica and crosses it in veinlets. This orange-coloured, powdery mineral is considered by Mr. Poitevin probably as jarosite. It is soluble in dilute hydrochloric acid and has the following chemical composition as determined by Mr. R. J. C. Fabry.

	Per cent
Fe_2O_3	48·09
K_2O	11·82
Na_2O	3·61
SO_3	33·13
H_2O	3·35[1]
	100·00

This mineral apparently is a variety of jarosite as the analysis in respect to Fe_2O_3 and SO_3 agrees closely with that of jarosite. Jarosite, however, should have no Na_2O, although many of the analyses of minerals classed as jarosite do show Na_2O[2]. The jarosite is so intermixed with flaky hydrous silica that it is difficult to collect a pure sample, and the Na_2O and excess K_2O may be due to impurities in the material, although this seems hardly possible for only that part of the sample soluble in dilute hydrochloric acid was analysed.

The hydrous silica carrying jarosite is underlain by white, porous, and friable hydrous silica, and it extends to the bottom of the pit. The powdery hydrous silica contains compact pieces with the texture of pegmatite in which both the feldspar and mica are changed to hydrous silica. The hydrous silica retains the outline of the crystals of the feldspar and mica and the quartz is unchanged. The hydrous silica here is derived from pegmatite with andesite on the north wall. The hydrous silica-bearing pegmatite is separated from the andesite by a thin seam of jarosite and sulphur. The south wall of the deposit is not exposed in the pit.

At pit No. 2, 75 feet west of No. 1, the glacial drift is about 3 feet thick. Under this is porous quartz pegmatite in which the feldspar and mica are changed to hydrous silica. The porous pegmatite is mixed with yellowish jarosite for 4 inches below the drift. As the pegmatite here has only a small proportion of feldspar, mica, and other minerals from which the hydrous silica could form, this part of the deposit is low in hydrous silica but high in pegmatitic quartz.

The No. 3 or main pit is about 50 feet west of No. 2 pit and was 27 feet deep in 1932, but owing to the friable character of the material the walls had caved, so that in 1933 it was filled to about 15 feet below the surface. At the bottom the hydrous silica is reported to be more abundant than at 15 feet below the surface; also the material is reported to be so

[1]Water by difference.
[2]Hintze, Carl: Handbuch der Mineralogie, 1929, p. 4200.

friable that a 6-foot bar could be driven through it without difficulty and with a hollow sound, suggesting that the material was of the same general character for another 10 feet in depth.

Here the rusty glacial drift is about 1½ feet thick. On the west face of the pit, jarosite-stained material extends a foot below the drift with veinlets of jarosite extending across the white, hydrous silica for another 2 feet in depth. On the north or hanging-wall side, a block of quartz pegmatite, about 3 feet across, lies in a friable mass of hydrous silica and fragments of quartz. Under this large block, pieces of quartz pegmatite up to 6 inches across are scattered throughout the mixture. The blocks of quartz are angular and have sharp contacts against their porous friable matrix. They probably are remnants of a quartz-rich phase of pegmatite that has been broken into fragments.

Pieces of pegmatite are intermixed with the friable material in the central part of the east wall of the pit. This pegmatite, in addition to abundant quartz in small grains, contains microcline, microcline-perthite, biotite, white mica, and tourmaline. In some specimens the microcline and biotite are crossed by veinlets and the biotite flakes are surrounded by a film of a yellow, crystalline mineral, probably jarosite. In other specimens the feldspar and mica are in part or completely changed to hydrous silica, although the original texture of the rock is preserved. The pegmatitic quartz and the microcline pegmatite probably are phases of the same dyke. The fragments in the south wall of the pit are grey, light, porous, non-friable rock consisting of small, round, and subangular grains of quartz, needles of sillimanite, a few crystals of tourmaline and garnet, and irregularly outlined areas of hydrous silica. In a few specimens, bits of feldspar and mica are not completely altered to hydrous silica. The walls of the deposit are not exposed in the pit which is about 6 feet wide. The distribution of the fragments of partly leached rock in the friable matrix suggest that here the hydrous silica developed both in the quartz-sillimanite rock and pegmatite in a brecciated zone along the contact between these two rocks.

The remaining pits along the strike of the deposit west of No. 3 pit are shallow and narrow. They expose friable material of the same general character as that in the three east pits already described, and also some hydrous silica. A few of the pits are in quartz-sillimanite gneiss, others in pegmatite, and two in black lava. They are not distributed in a straight line along the strike, but at different points across an area 25 feet wide and extending 450 feet west from the No. 3 or main pit. Not enough work has been completed to indicate the width and character of the body. It would appear, however, that the part of the mass carrying the most hydrous silica will be in the high feldspar and mica-bearing pegmatite. This appears to form a number of disconnected, narrow bodies along the contact between a narrow body of quartz-sillimanite gneiss on the south and black basalt on the north, and close to a large body of granite on the south. The quartz-sillimanite gneiss, basalt, and pegmatite appear to have been brecciated across widths of at least 7 feet to form a channel, or perhaps two or more parallel and closely spaced channels, for the migration of the solutions that leached all the constituents but silica from the minerals of these rocks, excepting quartz, sillimanite, tourmaline, and most of the garnet, which were unattacked.

ORIGIN

The deposit is covered by glacial drift carrying fragments of various kinds of unleached rock, hence the body of porous, leached material carrying the hydrous silica formed before the last glaciation. The drift over the deposit and down the hillside from it, however, is stained yellowish and reddish and this suggests that solutions laden with iron and perhaps other constituents entered the glacial drift from along the zone of porous materials occupied by the hydrous silica. At a depth of 5 feet or less below the drift the hydrous silica is not stained by limonite, jarosite, and sulphur.

The hydrous silica clearly resulted from the leaching of the constituents, except silica, of certain of the rock-forming minerals. Of these feldspar and mica are the most important. Quartz, sillimanite, tourmaline, and most of the garnet were not attacked by the solutions. Sulphur and jarosite are the only minerals known to have been deposited and their presence suggests hot waters, probably containing hydrogen sulphide, and sulphuric and other acids. Sulphur forms under a number of conditions, and, according to Lindgren[1], ". . . . . . . sulphur is found at active or extinct hot springs in the tufas or other adjoining porous rocks like volcanic tuffs." Ransome[2] describes a mineral that probably is jarosite in association with alunite in the gold ores at one locality at Goldfield, Nevada. These ores are considered by Ransome (page 196) to have been deposited from ascending " hot waters carrying abundant hydrogen sulphide with some carbon dioxide and the various metallic constituents of the ores. . . ." These hot waters are believed by this author (page 198) to have been volcanic emanations. In discussing the character and reactions of the hot solutions at Goldfield, Ransome (page 194) remarks that " Sulphuric waters. . . . . . must have exerted a strong leaching action on the superficial rock similar to that observable at Sulphur Bank, Cal., at the present day, where basalt has been altered to spongy masses of snowy white silica by the removal of its basic constituents." This snowy white silica derived from the leaching of basalt apparently is very similar to the hydrous silica in the Minaki deposit. The leaching action of waters on rocks is described as follows by Clarke[3]: "When we remember that even pure and cold water exerts a solvent action upon many silicates, we can see how violently corrosive a hot, acid, volcanic water must be. Wherever waters of this class occur the surrounding rocks are more or less decomposed, calcium, magnesium, alkalis, and iron being dissolved out, while silica and hydrous aluminium silicates remain behind." The deposit of hydrous silica at Minaki thus exhibits the characters ascribed to the effects of leaching hot waters. The source of these hot waters is not

[1]Mineral Deposits, 3rd ed., 1928, p. 422.
[2]U.S. Geol. Surv., Prof. Paper 66, 1909, p. 133.
[3]"Data of Geochemistry"; U.S.G.S. Bull. 770, 1924, 5th ed., p. 210.

known, for no period of vulcanism except that of the Keweenawan to the east about Lake Superior is known in this region to be younger than the granite and pegmatite, which the deposit cuts. Although the hot spring existed before the last glaciation, the deposit probably is not ancient for it is not modified by processes of cementation or the effects of deep burial. In conclusion, it is believed that hot waters, most likely from a magma source, ascended here along a fissure and flowed out at the surface as a hot spring. The deposits formed at the surface by these waters were eroded by the ice-sheet. The body of porous friable material carrying hydrous silica resulted from the leaching action of the waters in ascending along the fissure.

USES

No uses are at present known for the hydrous silica. It may, however, have properties that will make it useful for particular industries and thereby command a higher price than the ordinary varieties of silica. Some industries require very finely ground silica and perhaps this material can be prepared for such uses cheaper than some other materials. The mixture of hydrous silica and pegmatitic quartz apparently cannot be used as ganister or in the manufacture of silica brick. The hydrous silica may have a sharp fusion point and the fused material a low coefficient of expansion. It will have to be separated from the quartz and this probably can be done cheaply by a washing process. The material thus will have to be crushed to a certain mesh, washed, and the hydrous silica product dried and classified into several sizes. This pure product might be specially valuable in the manufacture of sodium silicate and other chemicals; as a special filter in liquor manufacture or other industries; in tooth powders and pastes; as a special abrasive; as an inert filler in certain paints; as an ingredient to mix with certain ceramic raw materials and in glazes; and perhaps other uses. The hydrous silica should be thoroughly tested to determine its outstanding qualities and if they are such that it is likely to be in demand commercially, the deposit next should be explored to prove that it extends at least 200 feet in depth.

BLOCK CREEK MAP-AREA, THUNDER BAY DISTRICT, ONTARIO

By F. Jolliffe

CONTENTS

INTRODUCTION

The field season of 1933 was spent investigating the geology and economic possibilities of an area lying on either side of Block Creek (Muskrat Brook) north of Dog Lake in Thunder Bay district. W. C. Güssow rendered efficient service during the summer as field assistant and materially aided the solution of problems of age relationships and correlation by a petrographic study of the granites of the area and the granite pebbles within the conglomerate.

The Lake Shebandowan Sheet of McInnes includes the southern part of the Block Creek area.[1] McInnes' explorations did not take him up the Block, but he noted that the character of the rocks somewhat to the east suggested a belt of schist in the vicinity. In 1922, T. L. Tanton of the Geological Survey, Canada, made an exploratory trip up Block Creek, and established the existence in the area of an extensive belt of schists and sediments, the latter including a conglomerate carrying granite pebbles.

The canoe route into Block Creek area, followed during the summer of 1933, lies up Kaministikwia River from Kaministikwia Station (18 miles west of Port Arthur on the Canadian Pacific Railway), across Dog Lake, up Dog River, and thence up the Block. Kaministikwia River is reached by a road 1 mile long and extending north from the railway station. Four portages are necessary, the last being nearly 2 miles long between Little Dog and Dog Lakes. The other three are around short rapids some of which may be run or lined during periods of high water. Due to the dam at the outlet of Dog Lake, parts of Dog River, Block Creek, and Rivière des Isles are drowned and their mouths and channels are recognized only with difficulty. Apparently this flooding extends up the Block as far as the 2-chain portage, since this part of the brook has little current and throughout the summer is readily navigable for even

[1] Geol. Surv., Canada, Ann. Rept., vol. X, pt. H (1899).

large canoes. Above this point, however, rapidly diminishing water flow after about July 1 renders travel nearly impossible for even a small canoe, and there are log jams and like obstructions, the number of which rapidly increases during the summer with the falling water. Sheltered harbours suitable for aircraft anchorage are found in many of the larger lakes throughout the area, and it would seem that this method of transportation is by far the most efficient for the area. Other canoe routes into the area are reported to lie along Poshkokagan River draining into Lake Nipigon, along the string of lakes and rivers extending southeast from Dog Lake, and via an 8-mile portage from Raith Station of the Canadian Pacific Railway into Dog River a few miles above the mouth of Rivière des Isles.

The topography developed in various parts of Block Creek area is dependent upon the nature of the underlying formations. The southeastern part possesses the uneven surface of low relief characteristic of most of the Precambrian terrain. Along the southern stretches of the Block this topography is even more subdued due to extensive, flat-lying, post-glacial lacustrine clays. Towards the east and north, however, the horizontal diabase intrusions have resulted in a markedly different topography. Here the local relief rises to as much as 400 feet, the scenery being dominated by the flat-topped, scarp-bounded, diabase mesas.

GENERAL GEOLOGY

All the consolidated rocks of the Block Creek map-area are of Precambrian age.

Table of Formations

Keweenawan	Diabase dykes and sills Sediments
Algoman	Granite Diorite Injection gneiss
Windigokan	Sediments and some lavas
Laurentian (?)	Granite and gneiss
Schist Complex	Lava, pyroclastics, and banded mica schists

SCHIST COMPLEX

The oldest geological unit is a sedimentary-volcanic complex extending southwesterly 11 miles from Poshkokagan Lake. The greater part of this complex consists of highly altered extrusives. Within these extrusives, however, is a belt up to 2 miles wide of predominately sedimentary material. These two members are lithologically similar to rocks found in adjacent areas and referred to as Keewatin and Couchiching respectively. However, in this case, the age relations are obscure and the two members are considered together on the basis of their structural unity.

The volcanic member of the schist complex consists dominantly of andesitic flows, now largely chloritic schists. Where not too highly metamorphosed the lavas show the amygdaloidal and ellipsoidal structures characteristic of flows. Locally some of this complex is coarsely crystalline, due, presumably, to recrystallization and granitization. Minor amounts of tuffaceous and cherty sediments occur between the flows. The occurrence of iron formation among these is inferred from the presence of a few banded magnetite and silica boulders in the overlying Windigokan conglomerate. Near the contact with the northern granite the green chlorite schists pass gradationally into black hornblende schists and amphibolites. To the northeast of the intrusive body at the southwest end of the area of schists, feldspar metacrysts up to $\frac{1}{8}$ inch across are developed in recrystallized chlorite schists, the resulting rock simulating a diorite.

Within the schist complex serpentine rock occurs for a distance of at least 700 feet along the south shore of the small lake slightly less than 2 miles north of Block Lake. The boundaries of the mass were not defined nor its geological relations determined. Under the microscope the rock appears to consist entirely of secondary minerals, chiefly serpentine, and a black opaque mineral, probably magnetite. This serpentine rock may be an alteration product of basic material in the schist complex or of an ultrabasic rock intrusive into the schist complex.

The sedimentary member of the schist complex consists predominately of light grey to dark green, thinly banded schists recognizable in most instances as altered sediments. In places in the light grey sediments a few, rounded, milky quartz " eyes " up to $\frac{1}{8}$ inch in diameter occur. The dark green sediments consist of quartz and fine-grained chlorite, hornblende, and other secondary minerals, and may be of pyroclastic origin. The lighter coloured rocks are quartz-carbonate-sericite assemblages. No rocks showing extrusive characters were found in this belt. Certain massive hornblende and chlorite rocks occurring in these sediments may represent feeders for the overlying extrusives.

LAURENTIAN (?) BATHOLITHIC INTRUSIVES

The existence or former existence in this region of batholithic intrusion of at least two periods is indicated by the presence of granite pebbles in a conglomerate itself cut by granite. This conglomerate is believed to be of pre-Huronian age and the granites that supplied the pebbles are, therefore, called Laurentian. A petrographical study of the granites of Block Creek area and of the granite pebbles in the conglomerate indicates that these pebbles may have been derived from the batholith lying along the northern edge of the area.

The northern granite is in contact with the members of the schist complex only, and has caused considerable metamorphism in these. Sparsely disseminated pyrite in the adjacent schists indicates some mineralization due to the granite. The study of thin sections from the southern margins of this batholith reveals two distinct phases. In one the essential constituents are quartz (35 per cent to 45 per cent), orthoclase (25 per cent to 45 per cent), and albite (5 per cent to 20 per cent). Hornblende and biotite are present in amounts rarely in excess of 5 per cent. Titanite, magnetite, and apatite occur as accessory constituents. The other phase of the northern granite shows a few, scattered, rounded grains of quartz and feldspar up to $\frac{1}{10}$ inch in diameter set in a fine-grained, foliated groundmass of quartz, feldspar, and a little biotite. This phase may represent a recrystallized and granitized paragneiss or it may be a contaminated part of the granite. All the feldspars in northern granite are highly altered.

WINDIGOKAN

The major part of the non-granite belt in Block Creek area is made up of a sedimentary group containing minor amounts of flow material near the base. The pebbles in the conglomerate member indicate that the series is younger than the schist complex and perhaps younger than the northern granite. The rocks of this group are closely folded and show varying degrees of metamorphism depending on the proximity of intrusive bodies. Attitude determinations based on grain gradations within the limits of single strata indicate that the structure consists of nearly isoclinal folds, the axes of adjacent anticlines and synclines lying parallel to each other at intervals of about a mile. These plunge at moderate angles to the northeast, as is evidenced by the consistent plunge of all the minor drag-folds in this direction. The general trend of these folds is about 55 degrees east of north and more or less parallels the regional foliation in the schist complex to the north. The projection of this strike across Lake Nipigon intersects the type area of the Windigokan sediments. Since the strata of the two areas are lithologically similar, occupy a similar place in the local geological time scale, and are equivalent in degree of metamorphism, the Block Creek sedimentary series may be classed as Windigokan.

The lowest member of the series is a thick conglomerate lying with an erosional unconformity upon the rocks of the schist complex. Except in one case, attitude determinations were not possible due to the sheared character of the conglomerate matrix. If folded the conglomerate probably lies in a syncline followed to the south by an anticline, and the thickness of the conglomerate where thickest must approach 3,000 feet. South of the western part of the main belt of conglomerate and separated from it by greywacke, andesite, and tuff, further conglomerates were found and apparently form detached lenses up to 3 miles in length and $\frac{1}{4}$ of a mile in width. Due to the scarcity of outcrops in the vicinity of these lenses, their boundaries are imperfectly known and it is not certain whether they occur at a higher stratigraphic horizon than the conglomerate of the main belt, or at the same horizon brought into position by folding or faulting. The pebbles in the conglomerates are well rounded, in general are closely packed, and are predominantly granite. These latter may be divided into two types which are identical with the two granitic types found in the northern granite. The same minerals are present in about the same percentages and the alteration of the feldspars has proceeded to approximately the same high degree. These granite boulders are up to 20 inches in diameter and are considerably larger than the pebbles of schist complex, quartz, and iron formation. The matrix varies from a coarse, sandy grit to a rusty-weathering greywacke largely transformed into chloritic schists as a result of shearing. Accordingly, bedding is obscure and attitude determinations difficult. The pebbles are apparently unsheared except where they consist of soft schist complex material.

Within the conglomerate, and apparently stratigraphically below most or all of the Windigokan andesite flows, are small masses of igneous rock showing no extrusive characters and approximating a hornblende diorite or gabbro in composition. These are probably intrusive dykes and sills of which the andesite is the surface expression. Immediately above the conglomerate a number of amygdaloidal and ellipsoidal andesites are intercalated with the sediments. Silicified tuffs are common near these horizons, but no coarse pyroclastics were observed. The position of the iron formation with reference to these volcanics is suggestive of a genetic connexion. The iron formation was seen in only two places, its extension being traced by compass variation. In each case it consists of magnetite and jasper or argillite in alternate bands up to $\frac{1}{2}$ inch across. The remainder of the Windigokan series is made up of sediments which vary considerably in thickness of bedding and in character of material. Thinly and well bedded sections alternate with massive portions in which the bedding is rude or entirely obscure. Crossbedding was not observed. Rapid variations from slate to arkose to greywacke were observed within the limits of single outcrops. Away from the intrusives the sediments are least metamorphosed and in places show small, biotite metacrysts in a quartz-feldspar matrix in which the original, well-rounded, clastic quartz grains are quite apparent, surrounded by a secondary growth of the same mineral in optical continuity. Towards the southern granite these sediments change gradationally into biotite schists and paragneisses locally containing a few, minute garnets.

ALGOMAN BATHOLITHIC INTRUSIVES

The Windigokan sediments in the south are intruded by granite and in the west, along their northern edge, by diorite. Sills of porphyry occur within the sediments and are tentatively placed in this same general intrusive period which is correlated with the Algoman of Rainy Lake area. It is evidently older than the Keweenawan sediments found near the east side of the area, which are not folded, have suffered little metamorphism, and are not cut by granitic intrusives.

The south side of the belt of sediments is bounded by an area of granites and migmatites which extends southward beyond Dog Lake. Within this area the rocks vary transitionally from sediments intruded by granite sills, through granites contaminated by many sedimentary inclusions, to relatively pure granites. Even as far south as Dog Lake little uncontaminated granite having appreciable areal extent was observed. Most of it contains shred-like inclusions of the sedimentary gneiss. The constancy of strike of these (paralleling the strike of the unintruded sediments to the north) suggests that they represent unreplaced remnants and that the granite has been intruded in a passive, pervasive manner. Both the inclusions and the sedimentary bands between the granite sills are of quartz-biotite gneiss and appear to be granitized equivalents of the Windigokan sediments. At certain places within these migmatites, traverses crossed apparently uncontaminated granite for appreciable distances. It is possible that such patches represent sills lying along the crests of folds. A pronounced horizontal jointing in the central part of one of these bodies lends support to this view. The larger, pure granite mass in the west may represent a part of the more purely magmatic portion of the intrusive. Microscopically the southern granite shows some differences from the northern granite. The essential minerals are quartz and feldspar (orthoclase predominating, with microcline and albite) in proportions varying from 30 per cent to 40 per cent, and from 60 per cent to 70 per cent, respectively. Biotite showing many pleochroic haloes is present in amounts up to about 5 per cent. Apatite, magnetite, and sphene are common accessories. The feldspars show but slight alteration to sericite and chlorite. Pegmatites are most common in the lit-par-lit injection gneisses. In these feldspar and quartz, frequently in graphic intergrowth, are essential constituents. Muscovite in plates up to 3 inches across, garnet, and in one place beryl, are accessories.

Cutting into the Windigokan conglomerate from the west is an intrusive salient. The form of this body appears to be due to a plunge to the northeast. This is supported by the fact that a belt of highly metamorphosed schists lies along the extension of the salient in this direction, and by the fact that a stock-like intrusive of the same rock type occurs to the northeast within the pre-Windigokan schists. The intrusive character of the salient with respect to the conglomerate is indicated by the presence of intrusion breccias, and by the complete absence of diorite boulders in the conglomerate. The rock varies from a hornblendite to a quartz diorite, the latter being the most common type. Quartz is present in all but the most basic phases and in some sections makes up as much as 30 per cent of the rock volume. Feldspar (oligoclase) varies from 40 per cent to 60 per cent, hornblende from 30 per cent to 45 per cent, and biotite up to 5 per cent. Apatite, titanite, and in places pyroxene, are present in minor amounts. The alteration of the feldspars has proceeded to approximately the same extent as in the case of the southern granite feldspars, and is markedly less than the similar alteration in the northern granite. Only the borders of this intrusive mass were examined and it is possible that the interior is more acidic. Pyritic mineralization in shear zones, quartz veins, and disseminations in the adjacent country rocks is probably connected. Small aggregates of pyrite and chalcopyrite occur in the diorite near its southern border on Rivière des Isles.

Within the folded sediments of the Windigokan series are sills of feldspar porphyry. These are rarely more than 100 feet across and are traceable for distances up to $\frac{1}{4}$ of a mile along the strike. They consist of albite phenocrysts up to $\frac{3}{8}$ inch across in a grey to pink, felsitic matrix. Lean, pyritic mineralization occurs within and adjacent to the sills.

Near the southern edge of the Windigokan sediments certain beds have been felsitized. In places this has resulted in the development of nodular felsitic bodies up to 3 inches long with indefinite boundaries within the felsitized sediments. Such rocks simulate conglomerate on the weathered surface. The development of these rocks is related to post-Windigokan igneous intrusion, hence they are considered here as a phase of the Algoman. Their occurrence along a fairly definite horizon within the Windigokan sediments suggests a selective action by the felsitizing solutions.

KEWEENAWAN

The Keweenawan is represented in Block Creek area by sediments and diabase.

Towards the eastern edge of the area mapped, two exposures of flat-lying sediments similar to those of the Sibley series were found. Probably a considerable portion of the drift-covered area to the east of Turtle and Starnes Lakes is underlain by these sediments. The exposures seen were of buff sandstone, and a 4-foot thickness of thinly bedded, red-brown to purple argillite partly changed to a hornfels by an overlying diabase sill.

The diabase intrusions occur in two distinct forms. Numerous, small, vertical dykes, generally porphyritic, intrude all the other consolidated rocks of the region. In places these about follow the bedding planes of the nearly vertical Windigokan sediments, and hence may be termed sills. The porphyritic diabase dykes are up to a few hundred feet in width and can be traced along their strike for distances up to 2 miles. Apart from being vertical they seem to favour no general orientation. They are composed of labradorite-andesine feldspar, augite, and small amounts of micropegmatite, iron oxides, and quartz. In the chilled zones along the contacts the porphyritic character is more apparent, although even well within the dykes fresh, light-green feldspar phenocrysts up to $\frac{3}{4}$ inch across occur. The largest diabase intrusions occur in the form of nearly horizontal masses of limited thickness. Horizontal diabase intrusions up to 150 feet in thickness occur vestigially in the northeastern part of the map-area. They probably represent remnants of a once-continuous intrusive sheet, an extension of the Nipigon diabase. In no place is this horizontal diabase found overlain by other rocks, but the medium-grained texture and absence of all extrusive characters indicate that it is not a flow. Its attitude and its position with respect to the Keweenawan sediments suggest that it represents an interformational sheet intruded along the unconformity below the Keweenawan. The rock is made up of apparently the same minerals as the porphyritic dykes, except that more alteration has taken place. As a general rule the ophitic texture is observable only in the finer grained contact phase. Locally the diabase contains indefinitely bounded patches of pink-weathering granophyre. The geological relations between the porphyritic diabase intrusions and the nearly horizontal sheet were not observed in the field.

PLEISTOCENE AND RECENT

Drift boulders occur everywhere in the district, and gravel ridges are particularly common in the vicinity of the head of Block Creek. Towards the east where the horizontal Keweenawan rocks predominate, these are largely masked by soil and drift covered by the heavy timber of the Nipigon Forest Reserve. The direction of the glacial striæ is similar to that noted on Lake Nipigon to the northeast (about 45 degrees west of south) and unlike that noted in the areas lying to the north and south (about due south). In general the striæ in Block Creek area follow the trend of the underlying rocks. Varved lacustrine clays are exposed along the banks of Block Creek and probably represent deposits formed in a fairly extensive post-glacial lake.

ECONOMIC GEOLOGY

An area of about 200 square miles is underlain by early Precambrian schists such as elsewhere in northern Ontario are generally regarded as suitable prospecting ground for deposits of gold, copper, iron, chromium, and other metals. In this area there are also diabase dykes and remnants of a thick diabase sill believed to be of the same age as the intrusives that are generally credited with the bringing in of the silver, lead, and zinc deposits in the nearby area around Thunder Bay. In Block Creek area no prospecting has been in progress, so far as known, in recent years; and in 1933 there was no mining claim held in the area. A search of the scanty records of previous work done reveals that by 1914 a group of twenty claims had been staked for iron ore west of Little Pine Lake, together with a further group of twenty-seven claims 4 miles to the northwest. "From the best information obtainable it appears that the iron showings in this locality consist of bands of iron formation composed of interbanded jasper, magnetite, and hematite, similar to that occurring in many other parts of Thunder Bay district."[1] No iron ore was developed on these properties and the title reverted to the Crown.

The principal occurrences of iron formation were traced in 1933, as indicated on Figure 1, about 6 miles southwest from near the head of Block Creek. Within this belt the iron-bearing beds were observed at only two places, the maximum width being about 10 feet. However, on the old Elkstrom workings east of Block Creek, widths up to 300 feet measured across highly contorted jaspilite were seen by Tanton in 1922. This latter occurrence of iron formation, like both of those observed during 1933, consists of layers up to ½ inch wide of magnetite (locally hematite) alternating with jasper, or argillite, or mixtures of these. Within this 300-foot width it was estimated that no considerable part of the jaspilite had an iron content exceeding 35 per cent, and that most of it contains about 25 per cent or less of iron. The beds are steeply folded and highly contorted, but as a whole they maintain a regular course parallel to the strike of the adjacent sediments. The greater part of the iron formation belt as traced lies in a topographic depression now occupied by muskeg.

Within the salient of diorite bounding the Windigokan sediments on the west, at a point one-half mile south of the larger lake along the north edge of the diorite body, Tanton[2] states there is a zone approximately 100 feet wide which consists almost entirely of magnetite and hornblende. It grades into normal diorite.

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[1]Report of the Ontario Iron Ore Committee, 1923, p. 182.
[2]Personal communication.

The pegmatite bodies in the southern migmatites contain minerals that may be of economic importance. In a few places they consist almost entirely of white to grey feldspar. Beryl was noted at one locality (locality 1, Figure 1) in an albite pegmatite.

Two pyritized zones were observed. One lies along the contact of the Windigokan conglomerate with the schist complex to the north. The locality (locality 2, Figure 1) is almost due south of the southern extremity of Poshkokagan Lake and is close to the southern shore of the upper part of a small lake on the river that in this area flows northeasterly and close to the contact. This contact is marked by a shear zone (observed across a width of only 2 feet) in which there is extensive pyritic mineralization. The material when crushed and panned failed to yield any gold. The second zone of this type occurs at the southwest end of a lake (locality 3, Figure 1) lying a little more than 2 miles northwest of the first-mentioned locality and within the sedimentary band of the schist complex. Here a heavily rusted outcrop of a pyritic replacement body up to 25 feet wide extends for at least 300 feet in a southwesterly direction. Within this zone probably 40 per cent of the rock by weight consists of pyrite. A rough channel sample on assay gave traces of both gold and silver, and negative results for copper, nickel, and platinum.

Tanton[1] states that in 1922 C. Lalonde had staked claims at a place (locality 4, Figure 1) just northeast of the locality where, on the map (Figure 1) accompanying this report, indications of iron formation are represented as ending. Tanton states that at this place there was visible a stockwork of quartz veins up to 10 feet in total width and exposed by trenching for 100 feet along the strike. The vein material is quartz with small amounts of ankerite and sericite, and carries some pyrite. The country rock is a sheared, silicified andesite with pyrite and a little chalcopyrite. A picked sample of the mineralized material showed no gold content on assay.

On the west side of a lake 5 miles southwest of the head of Poshkokagan Lake, two veins of rusty-weathering carbonate occur (localities 5 and 6, Figure 1) in the form of stockworks up to 5 feet wide enclosing fragments of chlorite schist. The country rock in this vicinity is largely impregnated with similar carbonate. Small crystals of pyrite and chalcopyrite occur in the northern vein. The vein matter is calcite carrying only a small amount of iron carbonate. These veins may be genetically related to the diabase mass lying to the east of the lake or to the porphyritic diabase dyke exposed on the south shore. Veins of this type in the nearby Thunder Bay district contain silver.

[1]Personal communication.

OBONGA-KASHISHIBOG AREA, THUNDER BAY DISTRICT, ONTARIO

By D. F. Kidd

CONTENTS

Illustrations

INTRODUCTION

During the field season of 1933 an area west of Obonga Lake, Thunder Bay district, Ontario, was geologically mapped. It had previously been known that at the west end of Obonga Lake, northwest of Lake Nipigon, a belt of early Precambrian volcanics and sediments appeared from beneath the late Precambrian assemblage that masks the older rocks over large areas around Lake Nipigon. Also, 60 miles to the west at Sturgeon Lake a similar belt had been traced east for 10 miles without its termination being found. It was thought desirable, therefore, to explore as much as possible of the intervening country. The Obonga Lake belt was traced to its western end.

Throughout the field season the writer was associated with T. L. Tanton, in collaboration with whom the field work was carried out.

Obonga-Kashishibog map-area lies between latitudes 49° 47′ and 50° 00′ and longitudes 89° 22′ and 89° 54′. The north edge of the area is 20 miles south of the main line of the Canadian National Railway between Armstrong and Sioux Lookout, Ontario, and the east edge of the area is 20 miles west of Lake Nipigon. Sturgeon Lake district is 40 miles west of the west edge.

The area can be reached by several canoe routes. The most direct and most widely used route starts at Collins Station, 21 miles west of Armstrong. It goes south from Collins Lake to Shawanabis Lake, from the southeast bay of which it crosses, by way of three small lakes, the

Hudson Bay-Lake Superior height of land and descends to Kopka River near the head of Kenakskaniss Lake. It leaves this lake at the southwest corner and by seven small lakes and connecting streams crosses a local height of land to Chrome Lake in the map-area. In this distance there are seventeen portages with a total length of 4 miles, four of which are ½ to ¾ mile long. At Chrome Lake the route branches. One branch goes up Wig Creek and across the height of land again to Kashishibog Lake just west of the area. Between Chrome and Kashishibog Lakes are nineteen portages totalling 2¾ miles, of which two are ¼ to ¾ mile long. All the northern part of the area can be reached from points on this route. The second branch of the route goes from Chrome Lake down Wig Creek to the northwest bay of Obonga Lake. There are two portages each nearly one mile long.

A second route between Obonga and Kashishibog Lakes starts at the southwest end of Obonga Lake, passes through the southern part of the area, and gives ready access to the part not adjacent to the northern route. This southern route is by way of Otterskin Creek and Otterskin, Survey, and Tommy How Lakes. There are twenty portages, totalling nearly 5 miles. Five of these are ¼ to ½ mile long and one is 2 miles long.

Obonga Lake can be reached from Collins by a route that leaves the east side of Collins Lake, passes through Rushbay and Bukemiga Lakes, and down Kopka River. There are fourteen portages totalling 2½ miles, of which three are ¼ to ¾ mile long. It can also readily be reached from Lake Nipigon by way of Wabinosh, Pishidgi, and Kopka Lakes. There are three portages totalling about 1½ miles.

It is said that Kashishibog Lake is accessible from Allanwater Station on the Canadian National Railway west of Collins. Only part of this route was seen, however. Between Harmon Lake, on Brightsand River, and Kashishibog Lake are six portages, totalling about ¾ mile.

PREVIOUS WORK

In 1900 A. H. Smith, geologist to party No. 8 of "The Survey and Exploration of Northern Ontario," followed a route from Kaiashk (Gull) River to the southwest bay of Obonga Lake and travelled down the lake to its foot (6, page 200)[1].

In 1902 W. McInnes (4, pages 209-211) ascended Wabinosh and Kopka Rivers from Lake Nipigon to Obonga Lake, which he examined. He travelled up Wig Creek to the edge of the gneiss and returning travelled from Obonga to Kashishibog Lakes by the Otterskin Creek route described. He reported the presence of a belt several miles wide of "Huronian" rocks.

In 1929 A. R. Graham, for the Ontario Bureau of Mines, examined chromite deposits staked the year previously at Chrome Lake in the area. He published a report and map (1, pages 51-60) covering 200 square miles around the west end of Obonga Lake.

In 1930 M. E. Hurst, for the same department, made further surveys of the chromite deposits and published reports (2, pages 111-119; 3).

[1]Numbers such as this will enable the reader to find the complete bibliographic reference in the list of papers at the end of this report.

GENERAL CHARACTER OF THE AREA

The Hudson Bay-Lake Superior height of land crosses the western part of the area from northeast to southwest. Obonga Lake at the east edge of the area is long and narrow and trends northeast for 16 miles. It drains to Lake Nipigon from its east end. In the map-area the east side of the height of land is drained by Wig and Otterskin Creeks, which enter different bays at the west end of Obonga Lake. On the west side of the height of land the drainage is into Kashishibog Lake and eventually Allan Water.

Obonga Lake is the lowest point known in the map-area, though the valley of Kaiashk River which was not examined is probably lower. Obonga Lake is estimated to be 50 feet higher than Kopka Lake to its east, the elevation of which is given as 913 feet.[1] It is, therefore, slightly under 1,000 feet elevation. The maximum relief, 500 to 600 feet, is reached in its vicinity. This steadily decreases westward until at Kashishibog Lake it rarely exceeds 100 feet. The elevation of the lakes rises in proportion as the relief decreases. Falls and rapids are numerous on Wig and Otterskin Creeks. The latter stream for $2\frac{1}{2}$ miles above Otterskin Lake flows in a precipitously walled valley 200 to 300 feet deep which pursues a winding course across the marked foliation of the rocks. As it does not appear to be along any structural feature, it is suggested that the valley first developed in the rocks of the diabase sheets which once overlay the foliated rocks, and that by erosion it let itself down on to the foliated rocks across which it maintained its original course. The two branches of this stream cascade off the plateau to the west into this valley in a series of chutes and falls that in each case descend 200 feet in $\frac{1}{4}$ mile. The prominent valley now occupied by Otterskin Lake and extending for 2 miles west follows the foliation of the rocks. In its upper part it is essentially an abandoned valley. Wig Creek is in a broad valley in places 200 feet deep and probably of pre-Glacial origin. It has been irregularly deepened by ice scour, and the stream now falls over rock rims from lake to lake.

Except in the vicinity of Kashishibog Lake and along the north edge of the map-area, mostly of Wig Creek, the country is well timbered with poplar, spruce, jackpine, birch, and balsam. Several years ago fires burnt much of the country near Kashishibog Lake, and in June, 1932, a large fire swept for many miles along the north edge of the area.

With the exception of a few white trappers and prospectors, and in summer an Ontario Forestry Branch station at the west end of Obonga Lake, there were no inhabitants in 1933.

GENERAL GEOLOGY

Extending from east to west through the area is a belt of volcanics and sediments with, probably, associated intrusives. On its north and south sides and at its west end the belt is bounded by granite-gneisses and granites. On the east it and its bounding granite-gneisses are overlain by little disturbed sediments and diabase sheets of Keweenawan age.

[1]White: Elevations in Canada.

The volcanics are similar to those that in this part of the Canadian Shield are usually described as of Keewatin age. In them, and for the present inseparable for mapping purposes, are massive, crystalline rocks varying from amphibolite through gabbro to diorite. Also mapped with the volcanics are areas of quartz and quartz-feldspar porphyries. A group of rocks in which serpentine is commonly a prominent constituent is mapped separately. The relationships of these various rocks will be indicated under their descriptions.

The sediments occur with the volcanics as bands from a few feet to three-quarters mile wide. They comprise quartzite, grit arkose, slate and phyllite, greywacke, and conglomerate, the last often with abundant granite pebbles. The wider bands have considerable thicknesses of coarse conglomerate. One band in outline appears to be a lens. In some cases sediments pass along their strike into greywacke interbanded with greenstone. In no single band of sediments was there discovered any evidence of duplication of the strata in cross-section, such as would suggest tight infolding of younger rocks in the volcanics. Some of the sedimentary bands towards their sides contain increasing amounts of greywacke and volcanics until the rocks are all volcanics. Very few places were found where reliable attitude determinations could be made of the sediments or volcanics and, therefore, it has been impossible to determine the general structure. It is concluded, however, that in the map-area there are volcanics younger than some of the sedimentary bands holding conglomerates bearing granite pebbles.

VOLCANICS

The volcanics are the most abundant members of the early Precambrian assemblage. Near the borders of the belt, and to a less extent in its core, they have been altered to various schists in which original volcanic structures are only rarely found. Traced to less altered areas their character can, however, be seen. Where least altered they are commonly massive, greyish green rocks of andesitic composition, often with well-developed pillow structures. At a few places they are very pale greyish green, and are probably more acidic than andesite. Rhyolite and dark green basalt occur at a few places, but are not common. Poorly bedded or unbedded greywacke similar in colour to the andesite is widespread, though at most places not abundant. It probably represents tuff interbanded with the volcanics. Agglomerate or coarse tuff is rare.

Massive or only slightly schistose andesites are common in a belt extending west from Obonga Lake up the valley of Otterskin Lake, and they are present in many exposures farther west to within 3 miles of the canoe route northwest from Tommy How Lake. At other places to the north and south of this core of the belt are scattered outcrops of andesite little or not at all sheared. But even in the areas where the andesite is generally little sheared many outcrops have been altered to chlorite schist. All degrees of alteration from massive andesite to fissile chlorite schist are represented.

The greywacke where unbedded is distinguished by a faint granular appearance and a " sandy feel " on the weathered surface. Except where it occurs in bands with other sediments it is usually only in isolated outcrops in areas of volcanics.

Dark green lavas, probably basalts, were seen 1 mile east of the east bay of Lee Lake, 2 miles northwest of Survey Lake, and 1 mile northwest of the head of Otterskin Lake. Rhyolites interbanded with greenstones are still less common. Rhyolite tuff is present at places on the east shore of the first lake north of Tommy How Lake.

AMPHIBOLITE, GABBRO, AND DIORITE

These rocks are closely related to each other and transitions between the different types can be found. Their occurrence is widespread, but they are particularly abundant southwest of the first lake west of Puddy Lake and south of the south branch of Wig Creek where they form a considerable proportion of the rocks exposed. A belt of diorite trending east and west for several miles lies between Otterskin and Lawrence Creeks.

The amphibolites range from fine-grained hornblende schist or massive hornblende rock, through hornblende porphyrite with an indeterminable groundmass, to even-grained amphibolite with a pimply weathering surface and crystals up to ½ inch across. The rocks are fresh looking and little sheared, though in places they are slightly gneissic. Amphibolites with chlorite are present locally and there are types transitional between amphibolite and hornblende and chlorite schists; at one place dark green chlorite schist contains knots of coarse amphibolite up to an inch across and around which the schistosity passes.

The diorite is variable in composition both in single outcrops and over larger areas. It is an amphibole (probably always hornblende) diorite and transition types exist through gabbro to amphibolite. At the other extreme some phases have so little amphibole as to be best described as anorthosite. Quantitatively this extreme type is unimportant. The grain of the diorite is locally uniform and generally medium to rather fine. Coarse-grained members are usually transitional into amphibolite. The rocks are fresh looking and little sheared.

No sharp boundaries could be detected between the amphibolites, gabbros, and diorites on the one hand and the volcanics and hornblende and chlorite schists on the other. The amphibolites have only been seen where the volcanics have been altered to schists, and apparently types transitional between the two are present, for example hornblende porphyrite. The freshness of the rocks and their massive character and coarse grain show they are not original volcanics. No direct evidence was found that they were gabbroic intrusives. They are either recrystallized gabbroic intrusives with contacts gradational through hybrid rocks into volcanics, or else volcanics completely recrystallized. Rocks of each origin may be represented.

Although the diorite is in places a more feldspathic phase of the general amphibolite type, its occurrence north of Otterskin Lake as a band in the heart of the volcanic-sedimentary belt where the least altered volcanics occur, is suggestive of an intrusive origin. However, sharp boundaries between it and the andesites were not seen and there is no other direct evidence that it is intrusive. It is a fresh-looking, tough, massive, green or brownish green, medium-grained rock with abundant hornblende. At places it has a diabasic texture, but it can be distinguished from the rocks of the diabase sheets by the ferromagnesian mineral, by the presence of a faint gneissic structure, and by the absence of typical diabase jointing.

QUARTZ AND QUARTZ-FELDSPAR PORPHYRIES

These rocks are locally associated with the volcanics, as, notably, east and west of the canoe route northwest from Tommy How Lake where they form a large part of the section. They are also quite widely distributed south of Wig Creek, east of Puddy Lake, and occur as small areas at other places. Northwest of Tommy How Lake they are intimately associated with rhyolite, rhyolite tuff, and, in places, amygdaloidal andesite.

The porphyries are massive to very schistose rocks, commonly nearly white, pale pink, or buff. Some have a green tinge, and where schistose are probably chloritic. They generally hold rounded to lenticular, bluish quartz grains up to $\frac{1}{8}$ inch across, and at places feldspar crystals of about the same size and of the same colour as the matrix. Where sheared they are sericite and quartz-sericite schists.

At only one place was a sharp contact seen between porphyry and andesite. This was on an island and point on the east side of the first lake north of Tommy How Lake. The contact is irregular, but not definitely intrusive. The matrices of the porphyry and the andesite become almost the same near the contact, the main difference being the quartz grains in the porphyry. Nearby the porphyry is in contact with porphyritic amphibolite and both these rocks adjacent to their contact are so altered as to be much alike. The contact in detail is interfingering. At a third place there is a sharp contact between quartz porphyry and biotite schist.

The petrographic characters of the porphyries and their habit of occurring abundantly in local areas, suggest that they are intrusives rather than extrusives and that they are not metamorphic rocks. Their rapid alternation with the andesites, the relative abundance of rhyolite tuff and rhyolite where the porphyries are abundant, the common occurrence of porphyry pebbles in sediments associated with the volcanics, and the frequent schistosity of the porphyries, all point to their having been nearly contemporaneous with the associated volcanics.

SERPENTINE ROCK

The term "serpentine rock" is employed as the name of a variety of rocks characterized by extreme softness and, usually, massive character. They are mainly composed of varying proportions of serpentine, carbonates, talc, and chlorite, and these proportions so vary that over areas up to acres in extent the rock is almost solely composed of one or other of these four constituents. At a few places the rocks are talc or chlorite schists.

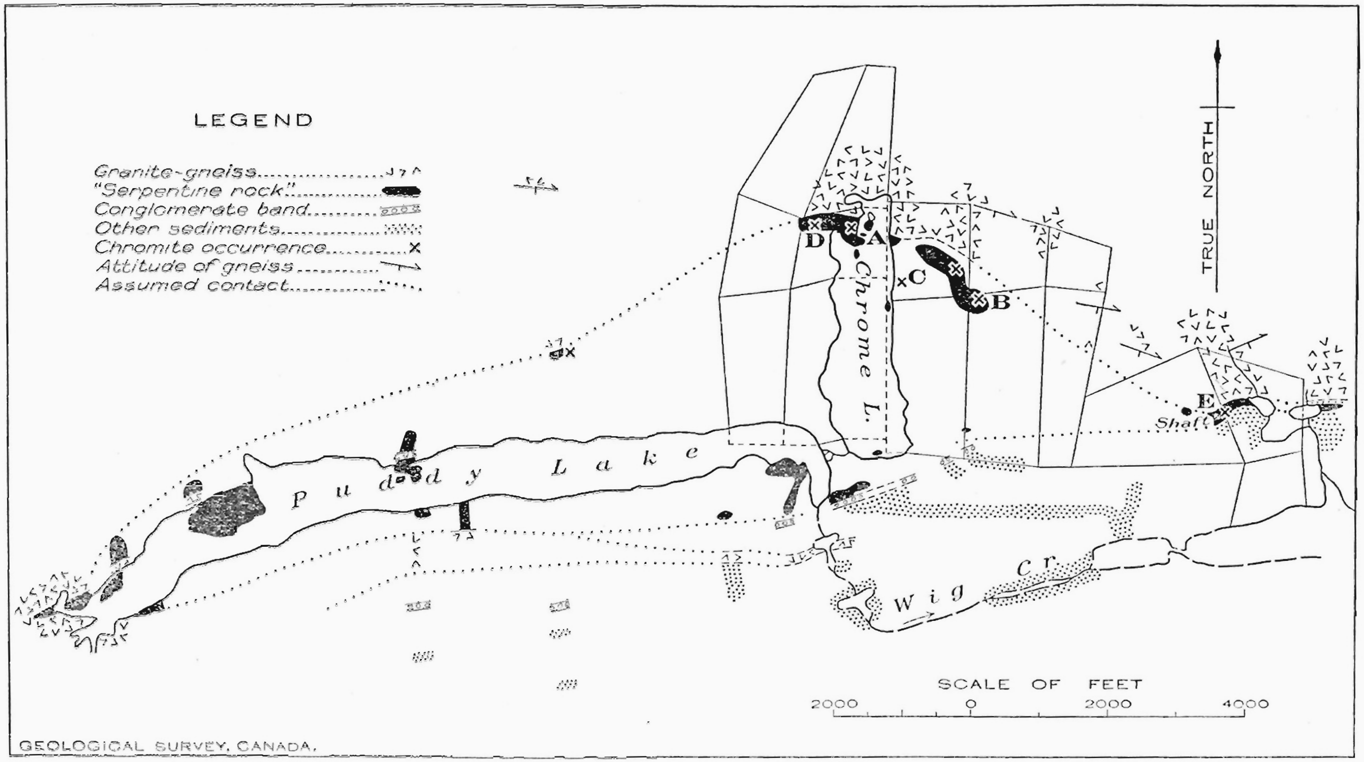


Figure 3. Plan showing areas of outcrop of "serpentine rock" in vicinity of Chrome Lake, and of examined outcrops of "serpentine rock" near west end of Puddy Lake, Thunder Bay district, Ontario.

The "serpentine rock" forms what appears to be a comparatively large lenticular mass and a number of smaller bodies. The large mass outcrops on the north side of Wig Creek east and west of Chrome Lake, and on both sides of Puddy Lake (*See* Figure 3). The other bodies occur within the band of volcanics and although they are represented on the map as having lenticular outlines yet in most cases it was not possible to determine the forms of the bodies. In such cases the boundaries were extended to make lenses paralleling the general foliation of the volcanic belt, this being considered their most likely shape.

The smaller areas of "serpentine rock" are confined to the vicinity of the south side of upper Wig Creek and southeast for several miles. This distribution coincides generally with that of the coarse-grained amphibolites previously described. At several places "serpentine rock" composed mainly of serpentine, and the amphibolite were seen adjacent to each other and in these cases no exact separation could be made; the "serpentine rock" approaching the amphibolite assumed the amphibolite texture and became somewhat harder, whereas the amphibolite near the contact became considerably softer.

The "serpentine rock" of the Chrome Lake lens has received most attention on account of chromite deposits associated with it. Like the other masses it contains serpentine, carbonates, talc, and chlorite in varying proportions, carbonate, carbonate-serpentine, and carbonate-talc rocks being the most abundant. They vary widely in composition in short distances. In all thin sections examined the carbonate is later than the serpentine and veins and replaces it.

The description of these rocks and their origin will be treated more fully in a subsequent section on the chromite deposits.

SEDIMENTARY ROCKS

Three bands of sedimentary rocks $\frac{1}{4}$ to $\frac{3}{4}$ mile wide have been found in the volcanics and separated for mapping purposes. Narrower bands, mostly of greywacke or black slate, occur at other places, but the areas are often too small to map. Two of the wide bands are in the northern part of the area, one along Wig Creek for several miles near Puddy Lake, and the other in and near the valley of Lawrence Creek. The third band is farther west, extending slightly south of east for several miles from near the headwaters of Wig Creek.

The northernmost band is best exposed in the area south and southeast of Chrome Lake where on the north it is bounded by "serpentine rock" of the Chrome Lake lens. Adjacent to the serpentine rock is a few feet of quartzite followed by a prominent coarse conglomerate bed, 100 to 200 feet wide, which has been traced for 2 miles from south of Chrome Lake nearly to the west end of Puddy Lake (*See* Figure 3). The conglomerate is much altered and at most places is a gneiss or schist. It holds many lenses up to 3 feet by 8 inches of granite-gneiss. These represent pebbles and lie in a matrix of sericite or sericite-biotite schist or gneiss. Other pebbles are of pink felsite. Very many of the pebbles have sharp boundaries against the matrix. Some pebble-free bands of sericite schist occur within the conglomerate bed. South of the conglomerate bed is an exposed width of 150 feet of quartzite which grades southwards into finely and regularly banded, green, grey, and black phyllite and slate exposed across a width of 1,800 feet. At some places with the phyllite and slate there are more altered bands of biotite schist or gneiss. Farther south are exposures of sheared quartz and feldspar porphyries and talc and talc-carbonate schists, and some of biotite and biotite-chlorite schist. The southern edge of the sedimentary band has been drawn where the sediments cease to be the most abundant rocks in the section. All the sediments in this band dip steeply to the south, but at no place was it possible to determine the direction towards which the tops of the beds face. Alpite dykes up to 1 foot wide cut the conglomerate at one place.

There are considerable areas of biotite schists on Wig Creek 4 miles west of Puddy Lake. North of the schists are heterogeneous gneisses which at places are recognizable as intensely altered conglomerate. These gneisses and schists are considered to be sedimentary and are presumed to be the western extension of the Puddy Lake band. Their extension to the southwest is inferred.

The easternmost outcrops of the Lawrence Creek band are along the south bank of the creek between points 1½ and 2 miles due west of Obonga Lake. Unbedded or only indistinctly bedded, greenish grey greywacke and dark grey, fine-grained, impure quartzite with a maximum exposed width of 200 feet form the section. To the south are andesitic greenstones, but to the north no outcrops of volcanic or other rocks were seen for ½ mile, so the width of the sedimentary band may be considerable. Between 1 and 2 miles farther west two traverses across the band showed grey and rusty black slates with interbanded greywacke exposed across a width of 1,100 feet with, on the north, across a breadth of 600 feet, scattered outcrops of arkosic grit, quartzite, and, more rarely, conglomerate. At one place a few hundred feet north of the outcrops of sediments is an exposure of fresh-looking rhyolite tuff and near by is some black slate. Quartz and quartz-feldspar porphyries lie farther north. The conglomerate has sliver-like pebbles of grey slate, and rounded pebbles of quartzite and quartz porphyry. All the sediments dip steeply south and at two places their tops, as determined, face to the south.

The third sedimentary band lies to the southwest. It was explored from its west end, at the granite, east for 3¾ miles to a drift area east of which it has not been recognized. In the western part the most prominent member is a massive cobble to boulder conglomerate. This is exposed across a width of 1,300 feet at right angles to the strike. North of it is 75 feet of well-banded argillite, beyond which are no exposures until at some distance greenstones outcrop. On the south the conglomerate passes transitionally into quartzite and greywacke, which outcrop across 300 feet, south of which, across a narrow gap, are dark green pillow lavas. The majority of the pebbles in the conglomerate are of granite, but some are of quartz porphyry, basic hornblende gneiss, hornblendite, or vein quartz. They are usually well rounded and to some degree sorted. Three miles east the width of the band is less, perhaps much less, than 1,300 feet and a width of only 40 feet of conglomerate is exposed. The pebbles in the conglomerate do not exceed 6 inches in size and consist of andesitic greenstone, rhyolite, quartz porphyry, vein quartz, and granite. Interbanded with, and beside the conglomerate, are quartzite and greywacke. To the south are grey slates and then volcanics. To the north is quartzite and then hornblende schist. North of the hornblende schist is a width of 400 feet of pyritic black slate considered to form a lens within the volcanics. The sediments of the main band everywhere dip steeply south. At the west end of the band the pillow lavas at the south edge have their tops to the south (determined from bun structure), and in the eastern part of the band the tops of the beds appear to face south. The decrease eastward of the size of the largest pebbles in the conglomerate, and of the width of the conglomerate, together with the increase in the proportion of finer grained sediments, indicate that the sedimentary band is narrowing rapidly eastward.

Smaller bands of sediments found at several places are up to a few hundred feet wide. One lying ½ mile north of Otterskin Lake contains black slate, greywacke, impure quartzite, and minor amounts of fine conglomerate with feldspar porphyry pebbles up to 1 inch across. A second, just south of the mouth of Lawrence Creek, has conglomerate, quartzite, and greywacke, the pebbles in the conglomerate being of greenstone and quartz porphyry. A somewhat wider band seen along the western part of the 2-mile portage west from Otterskin Lake has an observed width of 400 feet and contains considerable conglomerate with pebbles up to 6 inches across of granite, quartzite, greenstone, chert, and rhyolite. There are also in this band grey and black slates and arkosic quartzite.

These sediments are in some respects lithologically similar to those of the Windigokan series of Tanton and considered by him to be younger than the volcanic complex usually called Keewatin. In this area the field evidence furnishes no basis for the separation of the sediments from the volcanics, but rather indicates that it is more probable the sedimentary bands occur within the volcanic group and that individual bands may be lenses.

GRANITIC GNEISSES AND GRANITES

Granitic gneisses, granites, and related rocks extend for considerable distances north, west, and south from the Obonga Lake belt of early Precambrian volcanics and sediments.

North along the route from Chrome Lake to Collins the rocks for 23 miles are mostly granitic gneisses. West from the area the shorelines of Kashishibog Lake were explored and found to be of granitic gneisses in which the gneissosity displays widely varying attitudes but in many places dips at a low angle. From this lake a survey was carried west along its outlet stream to Clearwater Lake and Brightsand River, a distance of 12 miles, south up this river for 11 miles to Metionga Lake, and round this lake and Mountairy Lake to its north. Brightsand River was also followed downstream for 11 miles to Harmon Lake and the shores of the lake were examined as far as the outlet of Hilltop Lake. Except for a small area at the north end of Mountairy Lake all the rocks on these routes are granitic gneisses of various sorts, with at some places scattered schlieren of hornblende schist or basic gneiss. At the north end of Mountairy Lake both shores for a mile display outcrops of hornblende schist, and in the outlet bay where this lake drains into Hilltop Lake there is marked local magnetic attraction which probably indicates the presence of iron formation. No extension of these rocks along their strike to the east was found on Brightsand River. To the west they may join with a band of early Precambrian rocks shown[1] extending east from Sturgeon Lake to the south end of Seseganaga Lake 10 miles west from here.

South of the western part of the Obonga Lake belt surveys were made in the area of granitic rocks. Along a route south from Tommy How Lake to Blueberry Lake, east from there through Sucker and Pine Lakes to Whitebirch Lake, thence south to Round Lake and from there west through Majata and north through Kitchiwatchi Lakes back to Blueberry Lake, the rocks seen were nearly all granitic gneisses and granites. Hornblende schist and basic hornblendic gneiss occur at a few places on the south shore of Round Lake. There are also at places small outliers of Keweenawan diabase. The survey indicates that for 12 to 15 miles south of the west part of the Obonga Lake belt there are no areas of consequence of volcanics or sediments.

Along the north edge of the Obonga Lake belt there is usually no sharp contact between the volcanics or sediments and the gneisses. All the rocks are well foliated along the same directions, the foliation usually dipping steeply. The volcanics near the contact are generally altered to hornblende schists, and the adjacent gneiss is a hornblende gneiss that at many places because of the amount of hornblende is a diorite-gneiss, though where this is the case the feldspar usually maintains its customary pink to flesh colour. At other places large schlieren of hornblende schist occur in the gneiss.

Where along the north border sediments are in contact with the gneiss, the sediments have commonly been altered to mica schist or micaceous gneiss, and the granite-gneiss itself often contains biotite as well as hornblende. North of the serpentine rock near Chrome Lake the gneiss for a distance of a mile is dominantly a chlorite granite-gneiss.

The border phases of the northern gneiss are cut at many places by younger, massive, coarse-grained, pink granite forming bodies nearly free from dark minerals and transitional to granite-pegmatite. Pink aplite dykes are present at some places. Farther away from the belt of sediments and volcanics, the foliation of the granite and gneiss is at places only gently dipping and there are areas of granite that are only faintly gneissic or are entirely massive. Porphyritic phases with feldspar phenocrysts up to an inch long are present at places both in massive and gneissic granites.

The south edge of the Obonga Lake belt is well exposed only in its western part. From Survey to Tommy How Lakes the contact is rather regular and the amount of transitional phases is smaller than along the north edge of the belt. The foliation in the schists and adjacent gneisses is steeply dipping to vertical. This may indicate the attitude of the con-

[1]Ont. Dept. of Mines, Map 39B, Sturgeon Lake Area, 1930.

tact, and a steep dip may account for the regularity and sharpness of the contact as compared with the somewhat less regular north contact where the dip may be less steep. Adjacent to the contact the intrusive is commonly a biotite-chlorite granite-gneiss, but where the intruded rock is a quartz porphyry the granitic rock is at some places a chlorite-sericite granite-gneiss. At distances of $\frac{1}{2}$ mile or more from the contact the rock is a light grey to pink granite-gneiss that at many places is only faintly gneissic.

A single dyke of feldspar porphyry, 50 to 75 feet wide, was found at intervals for $2\frac{1}{2}$ miles south of Puddy and Chrome Lakes. It is well exposed 150 feet south of the pumphouse on the creek bank southeast of the "E" chromite deposit east of Chrome Lake (*See* Figure 3). The rock is reddish brown, massive, fresh looking, and fine grained except for scattered, well-formed, reddish brown feldspar phenocrysts up to $\frac{1}{8}$ inch long. The phenocrysts are orthoclase in a groundmass of simple twins of this mineral with interstitial quartz and very minor amounts of chlorite and of iron oxides. There has been considerable alteration to brown dust. The rock is a trachyte porphyry. The length of the dyke, and the massive character and fresh appearance of the rock, suggest that the dyke is much younger than any of the granite. It is possibly of late Precambrian age.

LATE PRECAMBRIAN SEDIMENTS AND DIABASE SHEETS

In the eastern part of the area little disturbed sediments overlain by diabase sheets conceal the sedimentary and volcanic rocks and the granitic gneisses. These Keweenawan sediments and diabase sheets occur extensively round the west end of Obonga Lake and as scattered outliers on the higher ground for a few miles west.

The sediments underlie the diabase and are but rarely exposed. Their distribution as shown on Figure 2 is largely inferred from the physiography and other indirect evidence. They comprise buff to reddish weathering, in places nodular, dolomite, coarse, somewhat iron-stained, buff sandstone, in places well bedded, and minor amounts of conglomerate. Because of the limited exposures the thickness of these rocks was not determined; the total anywhere in the area may not much exceed 100 feet and at some places is known to be less. The order of deposition of the members is not known, at one place sandstone overlies dolomite, and at another dolomite is the basal member. The contact with underlying volcanics is exposed in an outcrop just east of the north end of the portage across the base of the peninsula between the bays at the west end of Obonga Lake. Here dolomite rests on andesite, and seams of dolomite occur in cracks in the andesite. Nearby outcrops of andesite at greater elevations indicate that the relief of the floor at the time of deposition of the dolomite was at least 30 feet. One mile northwest of here a scarp exposes 30 feet of coarse, poorly sorted, buff sandstone. Ordinarily the areas considered to be underlain by these sediments lack outcrops, are in many instances flat benches extending from the bases of diabase hills, are traversed by distinctive, youthful, V-shaped valleys, and many of the streams disappear underground (Lawrence Creek in its lower part disappears completely). At a few places on Obonga Lake small shingle beaches of dolomite fragments indicate that the rocks are nearby.

The diabase forms hills around Obonga Lake that vary in height up to 600 feet. Except along the edges of these hills, where steep scarps and talus slopes are common, outcrops are scant. The diabase is massive and very uniform and has the jointing typical of diabase. It is medium and even grained, usually brown in colour but at places brownish grey, and has pyroxene and feldspar as prominent constituents. Magnetite is abundant at a few places. No indication was seen in it of veins or mineralization.

These diabase sheets are the western extension of the large areas of Keweenawan diabase occurring to the east about Lake Nipigon.

PLEISTOCENE AND RECENT ROCKS

Glacial boulder clay is widespread, but bedrock is rarely completely concealed over areas more than a mile across. The drift cover is most extensive in the east part of the area where the bedrock is Keweenawan diabase or sediments. Open muskegs and spruce muskegs of small size are numerous and in the western part of the area where the relief is least they are as much as several square miles in extent.

The general ice movement across the area during glaciation was from slightly east of north. The striæ measured trend from south to south 10 degrees west.

A few feet of unconsolidated, water-sorted gravel, underlying boulder clay but probably of Pleistocene age, is present on the north shore of Obonga Lake just east of the northwest arm. In this vicinity there are also large sand beaches.

ECONOMIC GEOLOGY

The only mineral deposits in the area which have so far received much development are those of chromite in the vicinity of Chrome Lake. Old claim posts and trenches north and west of Tommy How Lake at the nose of the volcanic-sedimentary belt attest to prospecting, probably for gold. In June, 1933, a number of claims were staked along the banks of Lawrence Creek following a reported gold discovery there.

GOLD OCCURRENCES

Lawrence Claims. These claims were staked by J. Lawrence in October, 1932, and the spring of 1933. Surface stripping and the blasting of a single trench have been done at one place. This locality is on the south side of Lawrence Creek 2 miles west of Obonga Lake and 300 feet south of the creek. The rock at the working is chlorite schist, but 100 feet to the north is the south edge of a band of greywacke, arkose, and quartzite extending in this vicinity along the creek valley. The stripping has uncovered in the schist a lenticular mass of white, milky quartz 40 feet long and 9 feet wide at its widest point. At the ends it narrows to a small vein or string of lenses a few inches wide. The foliation of the schist bends round the main quartz lens, but the quartz holds irregular, squeezed fragments of schist. Small amounts of pale pink carbonate are present mainly in and around these schist inclusions. No sulphides or other metallic minerals were positively recognized. Two composite grab samples were taken and have been assayed in the laboratories of the Mines Branch, Department of Mines, Ottawa. The results were:

Sample No.	Gold	Silver
543-4	Trace	Trace
543-5	None	Trace

Sample 543-4 was considered representative of the vein quartz. Sample 543-5 was taken to include as large a proportion of pink carbonate and schist inclusions to vein quartz as possible.

Unless much more favourable assays can be obtained the character of the vein suggests that further development is unwarranted.

CHROMITE OCCURRENCES

The known chromite occurrences are limited to the lenticular body of "serpentine rock" extending east and west of Chrome Lake. According to Hurst (2, page 111) chromite was first found on an island at the north end of Chrome Lake and was staked in 1928 by W. Keefe and R. A. MacDonald. "This group (of claims) was taken over by Golden Centre Mines, Inc., and a subsidiary known as Consolidated Chromium Corporation was organized to develop the property". In October, 1930, due to financial difficulties, the company suspended operations. Following reorganization experimental work has been carried out to find a commercially feasible process for the concentration of disseminated chromite ore and the manufacture of ferrochrome. In February, 1933, to obtain material for large scale tests, a quantity of ore, stated to be 70 tons, was mined from one deposit and hauled by tractor to Collins Station from where part of it was shipped to Niagara Falls, N.Y., for treatment.

Six chromite occurrences are known, five of which, named A, B, C, D, and E, are on claims that were developed by the Consolidated Chromium Corporation. Deposits A and D lie just west of the north end of Chrome Lake, B (two adjacent deposits) and C are a short distance east of the northern part of the lake, and E is 1 mile east of the southern part of the lake. A sixth occurrence known as the MacDonald deposit lies 4,000 feet west of the lake (*See* Figure 3).

Character of the "Serpentine Rock". The "serpentine rock" is inferred to form a lens with a length of $3\frac{3}{4}$ miles and a maximum width of $\frac{3}{4}$ mile. Outcrops are scarce (probably 90 per cent of the area is mantled with a thick drift cover), but are so distributed as to make it reasonable to infer that the whole area is underlain by the " serpentine rock " (*See* Figure 3).

Granite-gneiss borders the north side of the " serpentine rock " except at the east end, east of the E deposit, where a narrow selvage of altered quartzite (quartz-sericite schist and gneiss) lies between the " serpentine rock " and the granite-gneiss. The middle part of the south edge is bordered by a thick bed of coarse conglomerate. Farther east, the bordering rock is altered quartzite. The western part of the south border is formed by a narrow tongue of granite-gneiss lying between the " serpentine rock " and the coarse conglomerate bed.

At places along the north contact there is evidence that the granite-gneiss intrudes the " serpentine rock." On the north side of Puddy Lake near the west end, granite-gneiss and " serpentine rock " across a width of several hundred feet are interfingered in a manner suggestive of intrusion, though no contacts were seen. Just west of Puddy Lake, at the extreme west end of the lens, chlorite and hornblende schists such as are common in the " serpentine rock " near the granite contact, are cut by a 6-foot dyke of gneissic, pink aplite. The hornblende schist has clearly been derived from adjacent, fine-grained chlorite rock. It has at places scattered bunches of feldspar grains and irregular, indefinite streaks of hornblende-gneiss, and it passes into a basic hornblende granite-gneiss with hornblendite streaks. At the MacDonald chromite occurrence the contact is exposed in a trench. The bordering gneiss at the contact becomes fine grained and porphyritic with feldspar crystals. It is separated by a narrow gouge seam from serpentine and serpentine-carbonate rock, with at places lenses of talc-chlorite schist. In an adjacent trench an 18-inch dyke of pink aplite crosses the " serpentine rock." The dyke is composed nearly entirely of fresh oligoclase and scattered, large shreds of biotite. Chlorite schist grading into pale brown serpentine occurs as selvages along its edges. Veins of cross-fibre serpentine with magnetite cut the dyke. Probably the strongest evidence of the intrusive character of the gneiss is the change in it in the vicinity of the " serpentine rock." Along the north contact the gneiss instead of having the usual biotite or hornblende has, for as much as a mile away, chlorite. Also approaching the immediate contact, the gneiss in many cases contains increasing amounts of dark minerals and becomes a basic, hornblende granite-gneiss. From the above evidence it is concluded that the " serpentine rock " lens was intruded along its north edge by granite.

The south contact is poorly exposed. In local areas it parallels the bedding of the bounding sediments, but viewed as a whole it appears that it must cross the bedding (*See* Figure 3), as at different places, as already described, it is in contact with different members of the sedimentary group.

In detail the south contact is not usually sharp. It can be seen at one place south of Chrome Lake. Across a width of several feet quartzite and quartz-sericite schist are intimately interbanded with talc and talc carbonate schists which to the north grade into carbonate-serpentine rock. A similar contact zone but on a somewhat larger scale is exposed in trenches at the " E " deposit. The rocks on the south side of the " serpentine rock" lens are here mainly quartz-sericite schist and impure quartzite. These grade, across the strike, often in a distance of several feet, into such rocks as fine-grained, biotite-sericite schist, carbonate-sericite schist, siliceous or ferruginous carbonate rock, talc-chlorite schist, talc schist with pyrite cubes, and massive, greenish grey, hard rock composed of serpentine. The different types occur as bands paralleling the schistosity, but no regular order is apparent. The only sharp contact seen along the south boundary is at the extreme east end of the lens. "Serpentine rock" composed of serpentine and talc is bounded on the south by fine-grained, pink, sedimentary gneiss. The contact is locally conformable to the jointing and structure of the gneiss. For several feet adjacent to it the "serpentine rock" is massive and composed of lustrous, dark green chlorite. Along the exact contact is a ½-inch, sharp, walled band of black biotite schist.

In the few exposures, in many cases adjacent to mineralization, carbonate, chlorite, and talcose rocks are the most common. The carbonate rocks are massive, but where talc or chlorite are present the rocks are usually schistose. Fine-grained, tough, soft, dark grey or purplish green rock composed mainly of a felt of serpentine fibres is abundant at places, particularly in the vicinity of the "B" deposit and northwest from there. All the evidence in the field and from thin sections indicates that the carbonates have veined and replaced the dark-coloured serpentine. Masses and veins of pale green serpentine, many with associated magnetite veinlets, occur particularly in the western part of the lens on the north side of Puddy Lake. At a few places they have been seen cutting carbonate rocks. A few tiny seams of cross-fibre serpentine (asbestos) have been seen cutting the dark serpentine rock and carbonate rock.

At many places along the north edge of the lens adjacent to the gneiss are outcrops of hornblende schist.

At two places bands up to a few feet wide, of chert with parallel jointing like bedding, have been found. On the west side of the northern part of Chrome Lake, 100 feet southwest of the shallow shaft there, a width of 4 feet of banded chert bounded by gouge seams is exposed in two trenches. Again 400 feet northwest of the "B" deposit there is a 1-foot thickness of chert with some diffused serpentine in it. At several places at the A, D, and E deposits small areas of the "serpentine rock" are distinctly banded, are light greyish green, and are unusually hard. Thin sections of this rock show only a felt of tiny serpentine fibres.

In one specimen from the dump at the shaft on the E deposit, rosettes and bunches of needle-like prisms of tremolite occur in a groundmass of serpentine and talc. In thin sections, the talc was seen to invade and replace both serpentine and tremolite.

Magnetite is widely distributed west of Chrome Lake, particularly round the western part of Puddy Lake. East of the "B" deposit none was positively identified. It occurs as veinlets and as irregular grains disseminated in patches, mostly in pale green serpentine, but also associated with chromite. At several places it was seen disseminated in reddish brown carbonate or with pale green serpentine in veinlets cutting this carbonate. At one place on the north shore of Puddy Lake 1 mile from the outlet, magnetite has the properties of lodestone. Polished sections show in the magnetite a network of tiny seams of hematite forming a regular pattern. The amount seen was small.

Chromite is present at a number of places in the lens, particularly in the eastern part. It occurs as grains, from a fraction of a millimetre to an eighth of an inch in size. The grains may be sparingly disseminated or exhibit any degree of concentration. Where abundant they form streaks or bands up to several feet wide. In places these have sharp edges, but elsewhere the degree of concentration decreases gradually across widths of several inches. The bands pinch and swell and where more than one is present they vary in distance apart. There are indications that single bands may fork. In any single deposit these streaks of chromite have a rude parallelism, and this coincides with any banding in nearby "serpentine rock." The chromite occurs in serpentine or in reddish brown carbonate. Later veinlets up to ½ inch wide, of mauve to white talc, possibly chromiferous, cross it (*See* Plate II).

In transmitted light the chromite is brownish red in colour.

In thin and polished sections many of the grains show the remains of polygonal outlines, now partly obliterated by rounding of the corners and by fracturing of the grains. A part of this fracturing is a splitting of fragments from grain boundaries and suggests auto-shattering. Where the chromite occurs in serpentine this has usually been partly replaced by carbonate. The replacement has generally started at the edges of the chromite grains, so that now in some sections carbonate surrounds the chromite and only the larger intergrain areas have any of the felt of serpentine fibres left. Where carbonate is scarce the serpentine fibres occur interstitially to the chromite and have random orientation. Both this serpentine and the carbonate occur in the cracks in shattered chromite grains.

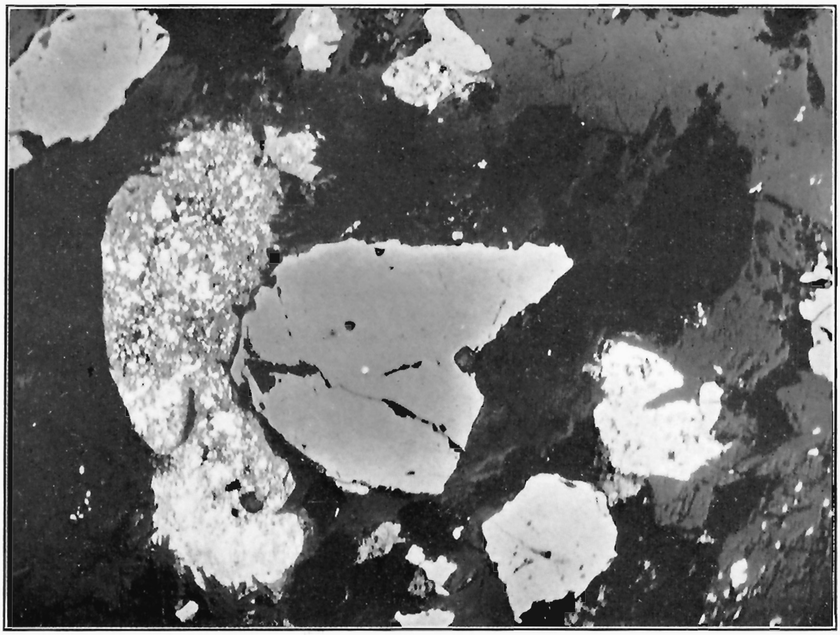
In only one section were the relationships of chromite and magnetite seen. In it (*See* Plate I B) a veinlet of magnetite clearly cuts across a polygonal chromite grain and is, therefore, younger.

Hematite has been seen disseminated in the serpentine rock at a few places (*See* Plate I B). It is uncommon.

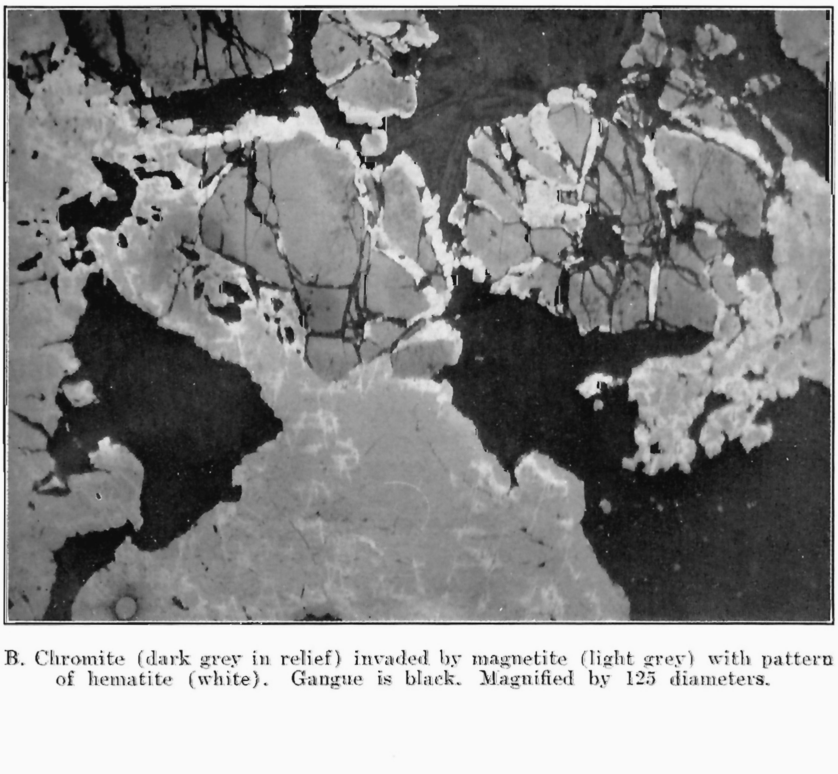
Pyrite has been seen at two localities. In a trench in the southeast part of the "D" deposit specks of pyrite were seen with chromite in hard, greenish grey, banded rock. This rock though appearing to be somewhat siliceous is found in thin section to be a felt of serpentine fibres. A polished section shows pyrite and chromite in similar polygonal grains, and also pyrite invading chromite in worm-like arms from which replacement has extended (*See* Plate I A). Various stages from intact chromite grains to solid pyrite grains pseudomorphous after chromite can be seen.

At the "E" deposit east of the shaft pyrite occurs as cubes in talc schist. Specimens from the dump at the shaft show small, much sheared and slickensided masses of pyrite in a dark green talc schist. A polished section showed the pyrite to enclose irregular blebs, apparently replacement remnants, of magnetite.

The relationships stated indicate, therefore, that the pyrite is later than both chromite and magnetite. The amount seen was very small.



A. Chromite (grey) partly replaced by pyrite (white). Gangue is black. Magnified by 125 diameters.



B. Chromite (dark grey in relief) invaded by magnetite (light grey) with pattern of hematite (white). Gangue is black. Magnified by 125 diameters.

Band of richly disseminated chromite in "serpentine rock". Cut by later (white) serpentine veinlet. One wall of the band is sharp, the other gradational. E deposit.

Origin of the "Serpentine Rock" and the Chromite Deposits. The occurrence of chromite deposits in masses of serpentine is not unusual and it has generally been found that the serpentine was formed by alteration of a body of ultrabasic intrusive rock such as peridotite, pyroxenite, or dunite, and remnants of the original rock have frequently been found. In the Chrome Lake mass little evidence of the original character of the "serpentine rock" was seen in the field. Study of thin sections, however, shows at places structures in the serpentine such as are usually interpreted as indicating its derivation from pyroxene and olivine. In only one section were any remnants of the original pyroxene found. Though in many of the sections most of the serpentine was a felt of blades of antigorite there were many areas in which the serpentine was bastite and had unusually high indices of refraction indicating its formation from pyroxene, or else it had the "mesh" structure characteristic of that formed from olivine. Both types were present in some sections. In the few sections studied the mesh serpentine seemed relatively abundant in those containing considerable chromite and the bastite in those without chromite. The rocks studied in the sections are probably completely serpentinized peridotites to dunites. The two small cherty bands found in the field in the "serpentine rock" may either be remnants of original intruded rocks or possibly may have formed during serpentinization.

The cause of the serpentinization of the original rock is not immediately clear. As the serpentine occurs in cracks in chromite grains the chromite formed before the completion of serpentinization. The carbonate alteration, pale green serpentine and magnetite mineralization, and the pyrite, came later. The source of the solutions that causd the extensive carbonatization and other mineralization seems most likely to have been the granite-gneiss to the north. The concentration of the alteration in the lens may well have been due to the relatively impervious nature of the sediments along its south edge.

The concentration of the magnetite occurrences towards the west end of the lens suggests that the magnetite was derived from the granite, or that due to the influence of the granite the iron oxides of the serpentine rock were concentrated in veinlets. The common occurrence of hornblende schist in the "serpentine rock" along the north contact adjacent to the gneiss suggests that the hornblende schist has formed from the "serpentine rock" and is a contact metamorphic product. If this is the case the serpentinization antedated the changes caused by the granite-gneiss invasion.

As the serpentinization appears to be earlier than the granite the only remaining source for the solutions causing it, of which any evidence has been found, is the ultrabasic intrusive itself which altered to form the "serpentine rock". That is the serpentinization is considered to be a deuteric alteration, that is, one by solutions from the same magma that formed the ultrabasic rock.

As the chromite is veined and fractured by the serpentine it is earlier. As it often shows crystal outlines and is concentrated in streaks of disseminated discrete grains it is probably a segregation of some type in the ultrabasic mass, as previously suggested by Hurst (2, page 115). The writer agrees with Hurst that the field evidence does not support the idea of concentration of the chromite by crystal settling.

The few thin sections studied suggest that the chromite formed in olivine-rich parts of the intrusive. A detailed petrographic study of the serpentine from different parts of the mass would definitely settle this question and if this relationship were substantiated would indicate where prospecting should be done. In the absence of such a study it can only be suggested that since all the deposits so far found are adjacent to the north edge of the lens, mostly in its eastern part though equally extensive exposures of "serpentine rock" occur at other places, the vicinity of the northern edge, therefore, seems the best place to explore for new deposits. The amount of mineralization found in the small percentage of the "serpentine rock" exposed in this section suggests there may be at least equally extensive undiscovered bodies under the drift.

Description of Deposits

"E" Deposit. This is the largest deposit so far found in the "serpentine rock" lens. A considerable amount of surface trenching has been done and also underground work from a shaft on one level. These underground workings were flooded at the time of examination. Chromite is visible on the surface at a number of places, the richer material being in tabular bodies trending east and west and in at least some cases dipping south. The chromite is in closely packed, discrete grains. In places the boundaries of the bodies are sharp, but at others they are gradational across several inches. Some of the bodies can be projected along their strike and identified in several successive cross-trenches. Others, however, do not seem to have this continuity. The amount of chromite mineralization that can be estimated from surface showings depends to a great extent on the way the sections of mineralization in the different cross-trenches are inferred to connect. Accepting the figures of the management for grade of surface assays, it is probable that there is to a depth of 50 to 75 feet in this deposit a tonnage of 20 per cent Cr_2O_3 mineralization of the order of magnitude of thousands of tons, or even of tens of thousands of tons.

"B" Deposit. A number of closely spaced trenches and pits expose the mineralization here. There is a tabular body of chromite dipping southwest at an angle of a few degrees. Its southern part dips underground into a hillock and in this hillock is a second tabular body about 6 feet above the first. The bodies are somewhat irregular; they have rolls with amplitudes up to 10 feet, and several faults displace parts of them a few feet. Except on the southwest and possibly east the boundaries of both bodies are determined by the topography. In a 45-degree drill hole starting below the lower sheet and put down 196 feet, the management reports (7) "no results" and Hurst (2, page 117) states the hole "intersected no chromite-bearing rock".

From what was visible at the time of examination it was considered there might be in these bodies 1,000 tons of chromite mineralization, with 1,500 more tons probable, all in bodies mostly on the surface. According to the management (7) the average grade of this material is 34 per cent Cr_2O_3. A. R. Globe, who is in charge of development, states[1] that in some flooded pits that could not be examined there is further mineralization that would make the total amount greater.

There is a small amount of chromite mineralization 500 feet northwest of the " B " deposit. In an area 75 feet across are four, small, rudely tabular bodies of disseminated chromite and magnetite. These amount in all to only a few tons. They strike northeast and dip southeast from nearly flat-lying to 60 degrees.

" C " Deposit. This occurrence is 200 feet east of the middle of Chrome Lake. There is a single exposure in a swamp at the south edge of a boulder flat. Trenching round it indicates it is probably itself a large boulder. Only a few tons of chromite mineralization are present.

" A " Deposit. The mineralization here is on some islets at the north end of Chrome Lake and on the adjacent west shore. There are several small, apparently tabular streaks with abundantly disseminated chromite. These strike usually north to northwest and dip mostly west, in many cases at low angles. It was impossible to infer connexions between most of the exposures with any assurance. The amount of chromite mineralization determinable, therefore, is small, of the order of tens or hundreds of tons.

There are also here some apparently irregular areas of sparsely disseminated chromite mineralization with only scattered specks of chromite visible. Due to its low grade it was impossible to determine its shape, attitude, or size. The figures of the management for sampling surface exposures and drill holes (7) would indicate apparently a considerable amount of this low-grade mineralization.

" D " Deposit. This lies just west of the "A" deposit. In an area 250 feet by 400 feet are several, small, tabular bodies of abundantly disseminated chromite. They trend east to northeast and dip 45 degrees or less southeast. The amount is of the same order of magnitude as that in the "A" deposit. Assays from drill holes indicate according to the management (7) considerable sparse mineralization.

MacDonald Property. A group of trenches found at the north contact of the "serpentine rock" with granite-gneiss, 4,000 feet west of Chrome Lake and about 1,300 feet north of Puddy Lake, is believed to be at the MacDonald deposit. Hurst states (2, page 119), however, that this deposit " lies near the granite contact and about 1,300 feet west of the ' D ' zone " and on his sketch map shows the only chromite mineralization west of the " D " zone to be at a point 2,600 feet west of it.

Magnetite, disseminated and in veinlets, is present, and in some polished sections chromite also was seen. In the field the chromite is with difficulty distinguished from disseminated magnetite as it too is somewhat magnetic. The amount of mineralization seen was small.

[1]Personal communciation.

MINERAL POSSIBILITIES OF THE AREA

In the course of field work attention was paid to any indications of mineralization. Quartz veins were seen at many places, but all were small or very irregular, and nearly all were entirely barren of sulphides. Rusty pyrite zones and some quartz veins with pyrite were seen at the nose of the volcanic-sedimentary belt north and west of Tommy How Lake. In one small vein here a few specks of chalcopyrite were seen. The lack of persistence in the veins, and of sulphides in them, is not encouraging. Samples were taken from the most promising localities and veins in various parts of the area and assayed in the laboratories of the Mines Branch, Department of Mines, Ottawa. The results were as follows:

Sample No.	Gold (oz. troy per 2,000 lb. ton)	Silver (oz. troy per 2,000 lb. ton)
245	None	Trace
263	None	Trace
299	None	Trace
300	0·03 oz.	Trace
304	Trace	Trace
482	None	Trace
493	None	Trace
560–1	None	Trace

Sample 245 is from the west side of the north arm of the first lake north of Tommy How Lake. It is a rough channel sample across 13 inches of vein quartz, pyrite, and highly sheared rhyolite in a prospect trench in pyrite gossan in a cliff by the lake shore.

Sample 263 is from the west shore of the first lake north of Tommy How Lake ¾ mile north of its outlet. It is a composite grab sample from three adjacent quartz veins, the largest of which is 18 inches wide. Ankerite is present but no sulphides.

Sample 299 is from a prospect pit on the north side of a creek entering the north end of Tommy How Lake from the west, and is 1 mile west of the lake. It is rock mineralized with pyrite in a shear zone adjacent to a quartz vein.

Sample 300 is from the same locality as sample 299. It is a rough channel sample across 30 inches of the vein mentioned.

Sample 304 is from a point ¼ mile west of the locality of samples 299 and 300, on the north bank of the same creek. It is a sample from a vein with quartz, sericite, chlorite, carbonate, and pyrite and was selected to include as much carbonate as possible and no pyrite.

Sample 482 is from the north shore of Otterskin Lake near the west end. It is from a quartz vein 6 to 18 inches wide which contains comb quartz, dark bluish grey quartz, and white to pink calcite.

Sample 493 is from the south shore of Otterskin Lake about at its middle. It is a grab sample from a quartz vein with a maximum width of 36 inches. It is of milky quartz with vugs and fractures filled with hematite.

Sample 560-1 is from a point 4 miles west of the northwest bay of Obonga Lake and ½ mile north of Lawrence Creek. It is a grab sample from a small, irregular quartz vein in massive rhyolite tuff, both mineralized with pyrite.

The Chrome Lake "serpentine rock" lens is already largely staked. The "serpentine rock" areas to the west on the south side of Wig Creek have heretofore been unknown and have not been prospected. Though sought for, no indications of chromite mineralization were seen in them.

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RUSH LAKE AREA, SUDBURY DISTRICT, ONTARIO

By H. M. Bannerman

CONTENTS

INTRODUCTION

The area described in the following pages is situated within the confines of latitudes 47° 45′ and 48° 00′, and longitudes 82° 00′ and 82° 30′, about 125 miles northwest of the city of Sudbury, Ontario. It comprises an area of approximately 450 square miles, and lies between the main lines of the Canadian National and the Canadian Pacific Railways. The field work incident to this discussion was commenced in 1928 and continued in the years 1929 and 1930. Some of the results obtained appear on Map 290A, Rush Lake Sheet, published in 1933.

During the season of 1928 field assistance was rendered by F. C. Foley and Stuart Pady; in 1929 by R. E. Whiting, Wilfred Tansley, and J. D. Turner; and in 1930 by B. C. Freeman, J. D. Turner, and Bruce Russell. To each of these the writer is indebted for faithful and efficient service. Throughout the course of the field work progress was furthered in many ways by the cordial co-operation and hospitality proffered by the various prospectors and inhabitants of the region with which the geological party came in contact. In this respect, especial gratitude is due to J. E. LeFever and Thos. McNaught of Horwood Lake, and to H. D. Lane, of the Acme Timber Company, Tionaga. The Algoma Eastern Railway Company kindly placed at the writer's disposal an unpublished report pertaining to the economic conditions of part of the area, prepared for that company in 1914 by Mr. J. A. Dresser. Survey notes and a plan of the shoreline of Horwood Lake were supplied through the courtesy of the Spruce Falls Power and Paper Company, Limited, and for the geological and geographical representations pertaining to Dore Township the writer is indebted to Mr. G. D. Furse, of the Ontario Department of Mines. To Mr. W. E. Smith, Barrister, Duluth, Minnesota, particular acknowledgment is due for his co-operation and interest in placing at the writer's disposal the results obtained by diamond drilling, sampling, and other explorations carried on from time to time during the years 1909 to 1929 in connexion with mineral discoveries in Genoa and Marion Townships. The work incident to the preparation of this report was carried on in the

geological laboratories of Dartmouth College, and the writer is indebted to Mr. D. M. Larrabee, of the Department of Geology, Dartmouth College, for assistance in certain phases of the work preliminary to the compilation of the report.

MEANS OF ACCESS AND CONDITIONS OF TRAVEL

The area is entirely wilderness, devoid of roads, and with few inhabitants. Its proximity to the main lines of the Canadian National and the Canadian Pacific Railways, coupled with a choice of several intersecting canoe routes, makes it one of comparatively easy access. It is most conveniently approached from the Canadian National Railway by water routes leading southward from either Groundhog River crossing, or from Stackpool. To reach the eastern part of the area the Stackpool route is shorter and is the most frequented by parties journeying to the mining claims about Rush Lake. This route leaves the railway at Stackpool Station, proceeds up Stackpool River to the waters of Kasaswaychin Lake, from which a mile portage westward is necessary to reach Katagi Lake. Thence a 7-chain portage is all that is required to reach the Atekepi Lakes. The entire route from Stackpool to Rush Lake entails about 14 miles of travel, and eight portages with a total carrying distance of a little over 3 miles. The route is well cut out and has been considerably travelled.

To reach Rush Lake from Groundhog River crossing requires a considerably longer journey, and nine portages, but the total carrying distance is only a little over $1\frac{1}{4}$ miles. A small shelter has been provided near the railway bridge on Groundhog River, for the convenience of parties who desire to make connexions with the railway at that point. The route from there to Rush Lake crosses Groundhog Lake, and ascends the river to Horwood Lake. The first portage is encountered on the river connecting these lakes, about 4 miles south of the track, where it is necessary to carry over the dam there maintained by the Spruce Falls Power and Paper Company. Southward from the dam an unbroken waterway, suitable for canoe or power boats, is available to what is now the head of Horwood Lake, a point about $4\frac{1}{2}$ miles south of the boundary of Dale Township, almost the centre of the map-area. Beyond this the route proceeds by Heenan Creek and Woman and Rush Rivers and is broken by many rapids and falls, six portages being necessary within the next 2 miles. The portages are comparatively short, are easy to follow, but are fairly steep. The most difficult is that leading from Horwood Lake to Heenan Creek. This portage, though only 17 chains long, rises to an altitude 140 feet above the level of the lake, and then drops off rapidly to Heenan Creek which at this point is only about 40 feet above Horwood Lake. Heenan Creek is a relatively swift, crooked stream, about 20 feet wide where navigated on this route, muddy bottomed, and inclined to be snarled with leaning and fallen timber. Parties journeying from Horwood Lake to points on Woman River in Marion Township and townships to the south, have here a choice of two routes: follow Woman and Rush Rivers into Marion

Township to a point approximately one-half mile south of the confluence of these streams, thence portage westward, into the waters of Woman River again; or turn westward, upstream, on Heenan Creek from the Horwood Lake portage, and make a one-half mile portage into Kesa Lake, from which a quarter mile carry is all that is required to reach Woman River above the rapids. Of the two routes the latter is shorter, requires less portaging, and is more desirable when water is high. At low water, however, Heenan Creek may present some difficulties for heavily laden canoes. Woman River and Rush River both provide good travel facilities for canoe or outboard motor. The same is true of Opeepeesway River. Swayze (Dore) River, which provides a line of travel from Horwood Lake to the western part of the sheet, is crooked, somewhat treacherous because of sunken logs, and broken by many rapids and falls. Nevertheless its waters are deep, and it provides a good medium of travel for canoe and outboard motor. The waterways through Newton and Heenan Townships are sinuous, shallow, muddy-bottomed streams generally unfit for travel except by canoe; difficult if not impassable during times of low water.

A route from Horwood Lake through Hardiman Township may be had by portaging eastward into a small lake, near the northern end of Northeast Arm, thence following a chain of little lakes southeastward via Freeman Lake to Hardiman Lake. From Hardiman Lake a portage to Elbow Lake is only about 20 chains long. Elbow Lake drains northward into Nat River, which is here connected with Tionaga by a lumber road. South of the railway, however, Nat River is not navigable. The carry from Hardiman Lake southward to McOwen Lake is 170 chains long, but it follows a sand ridge most of the way, and is not difficult. Another route of interest to parties journeying from Stackpool to Rice Lake, Eric Township, is that offered by way of Scraggy Lake and Alike River. The more usual means of making this trip is to follow the main route from Stackpool through Rush Lake, thence ascend Rice River to Rice Lake. The alternative route through Scraggy Lake is shorter and easier when there is a good supply of water. At times of drought, however, the lower reaches of Alike River are likely to prove arduous, as they are sinuous and narrow at best. The small streams in western McOwen and eastern Dale Townships were not navigable when the writer examined the area.

In summer the area in common with the surrounding territory is patrolled by forest rangers, and in this connexion certain trails and lines of communication are worthy of mention. One of these, in excellent condition in 1930, connects Great Pike Lake with Hardiman Lake, and thence proceeds to the Canadian National Railway at Tionaga. This trail is followed by telephone wires. A branch trail and telephone line were being constructed in 1930, from a point about one-half mile east of the west boundary of Hardiman Township, southward across the central part of McOwen and the eastern part of Genoa Township, to connect the forest ranger's station on Rice Lake, Eric Township, with Tionaga.

The only permanent residents within the confines of Rush Lake area, in 1930, were located at the mouth of Swayze (Dore) River, where LeFever Brothers maintain a fur farm. Other than this the only human habitations were those maintained by the forest rangers and prospectors in summer, and by a group of Indians who spend the summers near the railway at Groundhog Lake and Kukatush, but migrate to more remote parts of the country in winter for hunting and trapping purposes.

AGRICULTURE, LUMBER, FISH, AND GAME

The greater part of the unconsolidated material that covers the upland parts of this area is ground moraine, which is thin, extremely rocky, quite unfit for agriculture. Other more or less extended areas, such as central Heenan, southern Whigham, northern Dale, Newton, and the areas immediately north of the latter two townships, are covered by a heavy blanket of fine sand, equally unfit for ordinary agriculture, supporting only a thin covering of rank grasses and a scattered crop of banksian pine. Indeed with the exception of a few restricted areas, notably in the unsurveyed fraction about Horwood Lake, which are covered by lake beds, and where there are local occurrences of heavier morainic deposits, the only parts suitable for farming are confined to the comparatively narrow belts of flood-plain material marginal to the main streams. The season is comparatively short, light frosts are frequent until early July and appear again in early September, but growth is remarkably rapid, so that where soil conditions are favourable, garden vegetables of fine quality and, presumably, the quickly maturing grains, may be grown.

The greater part of the timber is second growth stands of banksian pine, white birch, poplar, and black spruce. A limited amount of cedar occurs on the lowlands and scrubby ash occupies parts of the river margins. A few stands of Norway pine were noted, but clear of the banksian pine there are few important stands of timber within this area that are sufficiently accessible to allow of their present utilization in profitable enterprise. Large tracts of Marion and Genoa were ravaged by forest fires some twenty-two years ago. These are now covered by a thick growth of small jackpine and birch, shrubs and brambles, of no economic significance.

Game of certain kinds is abundant. The woods abound in moose, and are fairly well populated with black bear. Wolves and deer occur but are scarce. Smaller animals such as raccoons, marten, fox, rabbits, and muskrats are present in some abundance, and a few lakes and streams still contain active colonies of beaver. The latter animal is, however, fast being exterminated, judging from the number of comparatively new houses and dams now abandoned, and unless more stringent and effective measures be taken to protect these valuable fur-bearers, it will not be long until they will be eradicated from this region.

Bird life abounds. In addition to the various songsters and other small birds that inhabit these parts in the summer months, a limited number of the larger vultures, such as the duck hawk and fish hawk, occur. One colony of osprey were noted each year which apparently nest in the vicinity of Atekepi Lake. Partridge, grouse, and other small game birds are present as well as an abundance of ducks of various kinds. The streams and lakes in the upper (southern) parts of the area contain considerable quantities of pike, and some pickerel. Pike, pickerel, and bass occur in Horwood Lake, and good trout fishing is reported from the lakes and streams in Hardiman Township, and from Swayze (Dore) River.

RELATED PUBLICATIONS

Geological maps, 155 A (3rd edition, 1933), Geological Survey, Canada, and 1933a, Ontario Department of Mines, embrace the entire area, and parts of it have been examined and described by various investigators. A report by J. A. Allan, published in the 18th Annual Report, Ontario Bureau of Mines, 1909, contains a map and description of that part of the iron range that lies within the confines of Heenan Township. A map and report by T. L. Tanton, published in 1916, embraces the entire northern part of the area and contains a brief description of the eastern section of the iron range and the lead-zinc deposits located in Genoa Township. A more extended discussion, and a map, of the eastern section of the iron range and other economic features of Genoa-Marion Townships, are embodied in a report by E. S. Moore, published in Ontario Department of Mines, 33rd Annual Report, 1926. In 1932, a report by G. D. Furse on the Swayze area, published in the 41st Annual Report, Ontario Department of Mines, includes a map and discussion of the townships of Heenan, Newton, Dore, and Coppell. These, and the various other publications listed below, have contributed from time to time to the information on this area, and its immediate surroundings.

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SURFACE FEATURES

Physiographically Rush Lake area is a part of the Canadian Shield. It lies just north of the great divide which separates the waters of Hudson Bay from those of the Great Lakes. Its drainage is, therefore, northward by devious routes that merge in Mattagami River, eventually to reach Hudson Bay via Moose River. The general elevation of the area is around 1,400 feet above sea-level. The relief is low, usually from 30 to 100 feet. Viewed from the top of one of the higher prominences it presents a monotonously even skyline; it is a gently undulating plain, thickly clothed with forest green, broken at rare intervals by the pale blue sheen of a lake, or the narrow path of a winding stream. Traversed, however, this plain proves to be rough and hummocky, consisting of innumerable low ridges, interspersed by swamplands and lakes connected by a veritable network of streams. Essentially the streams are sluggish and winding, but at relatively frequent intervals they are broken by falls and small rapids which, though an impediment to travel, add much to the unspoiled beauty of this northern wilderness.

Only two ridges rise much over 200 feet above the general level of the country. These are so conspicuously a contrast to the surrounding territory that they stand out as prominent landmarks visible from many parts of the area. One of these is situated just west of Hardiman Township. Its peak is about 275 feet above the level of Horwood Lake, and it is surmounted by the fire lookout tower. The other is located near the southeast corner of Heenan Township. It is composed of siliceous iron formation, and rises some 285 feet above the adjacent section of Woman River, which at this place is in the neighbourhood of 100 feet above Horwood Lake. The Heenan ridge is thus the highest elevation in the area.

A local watershed passes northeast-southwest across Dale Township and swings westerly through southern Newton. It assumes greatest prominence in Dale where it rises 125 to 175 feet above the level of Horwood Lake. A similar range of hills strikes northeasterly across southeastern Heenan, central Marion, and northern Genoa. It is of lesser relief than the range that passes through Dale when compared with the surrounding section of the country, though in fact its summit is of slightly greater altitude. The axial trend of the hills that make up these modest ranges conforms in strike with the rocks that compose them. They are not conspicuous features, for their rise is gradual, by a series of hummocky ridges and interlying depressions. The southern group tends to die out in Genoa as it approaches the great area of granitic rocks that lies to the east. Likewise the northern belt fades out as it passes into the area underlain by granite, about the north end of Hardiman Lake. In truth then, this plain-like landscape, so hummocky in detail, has a gently rolling topography, with the major axes of the rolls in a general northeasterly direction.

The area has all been glaciated, and many of the surface features are directly of glacial origin or have been modified by glacial action. The lakes for the most part are shallow, muddy-bottomed features, of low, irregular shoreline. In many cases they are bounded by glacial debris. This is particularly true of those situated in the areas that are underlain by the batholithic intrusives. Thus Hardiman, McOwen, Lasucor, Arbeesee, and many of the smaller bodies of water located in the eastern part of the area have sand and gravel shorelines for the most part. The same is true of Harry and Marl Lakes in the northwestern corner of the area. These lakes owe their shapes and their existence in large measure to the irregularities in the contour of the glacial deposits in which they lie. Another group of lakes, notably Resound, Alike, Scraggy, and Atekepi Lakes, have rocky shores, and seem to be local disorders in a former well-developed stream valley. Their ragged shores are probably due to glacial plucking, controlled in part by prevailing joint patterns in the bedrock. Others are due to scour, and many are combinations of these extreme types, so it is safe to say that all of the lake basins are in some way related to Pleistocene glaciation.

The drainage system has been deranged by the glacial invasion, but it seems still to reflect its preglacial disposition. The main streams flow northward along markedly direct routes which cut abruptly across the folded structures of the crystalline rocks. The stream valleys are narrow, usually 200 to 500 feet in width, bottomed over a large part of the way by reworked glacial material, but their walls are sharply incised in the bedrock. The valleys of Woman and Rush Rivers trend northward across the sheet and are, over the greater part of the way, abruptly walled by rock ridges which trend transverse to, and which rise 10 to 25 feet above, the streams. In the vicinity of the iron range the hills rise 50 to 75 feet above the streams and in Dale Township the waters of Horwood Lake, which here are normally a part of Woman River, are bounded by sharp walls of rock which strike at right angles to the lake and rise as much as 125 feet above it. Falls and rapids are precipitated here and there by the presence of a band of rock—often a dyke—more resistant to erosion than its associates. In such places the valleys narrow appreciably and the streams are likely to be turned aside sharply and enter a modest gorge as they succeed in cutting through the barrier to resume their northward course. Alike River manifests entirely similar characteristics. Where it cuts northward across the belt of schists its valley is about 250 feet wide and is incised some 25 feet. Heenan Creek wanders in a wide valley as it flows northeastward, diagonal to the rock structures. It is very sluggish from Babiche Lake portage to where it crosses the basic intrusive near the north boundary of the township, whence it is obstructed by ledges of bedrock, and below this it begins to fall more rapidly to the valley of Woman River. The valley of Swayze River is less well defined. The stream follows the rock structures, except where turned aside locally by glacial debris or rock barriers, as it runs its course from the higher ground in Coppell Township to the basin of Horwood Lake.

These valleys are not due to glacial scour. The dominant movement of the ice across this area, so far as can be ascertained from striæ and chattermarkings, was between 12 and 20 degrees west of south. The effect of this movement by the ice has been to enlarge parts of the valleys in a ragged and eccentric manner, by plucking, such that lake basins have been developed locally, or to dam up the valley with debris. Whatever the reason for their original location, the greater part of the modest valleys occupied by these streams must have been carved by the streams. That they are not post-glacial is shown by the presence of till banks within them and by the presence, in the south arm of Horwood Lake, of dissected, Pleistocene lake beds.

Pleistocene and post-Pleistocene deposits of various types occur in abundance. Many of these present interesting geological features, but brevity of time available forbade a detailed study of any of them. Much of the area is covered by bouldery morainic deposits, which are usually thin but occasionally developed into rugged mounds, sometimes enclosing small, peculiarly shaped lakes. In some parts long, narrow ridges of gravel and sand occur which are probably eskers. These bodies are well developed in McOwen, in eastern Genoa, central Heenan, Whigham, and Hardiman Townships. Their trends are somewhat sinuous, but their general course is south and west of south. Some of them rise as much as 70 feet above the surrounding plain and extend as much as 2 miles. They occur in the morainic-covered areas, in sand-covered areas, and in muskegs. Sand deposits cover large areas in central Heenan, northeastern Newton, Whigham, the section from Swayze River east to Horwood Lake, in southern Hardiman, and southern Genoa. They are distinctive features; composed of comparatively well-sorted sand, usually quite fine grained. They are replete with small, undrained ponds and lakes, some of which look like kettleholes, but the surfaces of the sand-plains are often rolling, oblong, more or less jumbled ridges. The latter feature is particularly noticeable in central Heenan where the ridges have a generally developed parallelism running northeast-southwest, often with steep slopes facing northwest. It seems likely that the sand deposits originally were glacial outwash, and (or) local lake beds, but the hummocky ridges convey the impression of wind blown material. The ridges may indeed be fossil sand dunes, built by wind action upon the sandy surface before it was claimed by the thin coating of vegetation that now covers it.

Remnants of fine silt and clay deposits, exposed to an altitude of 20 to 25 feet above the normal water-level of Horwood Lake, occur on the east shore of a lake not far north of the north boundary of Dale Township. Layers of finely crossbedded sand compose the island near the mouth of the bay into which Swayze River empties. Deposits of a nature similar to these extend for some distances inland about the low areas around the lake, but their extensions have not been delimited. These finely bedded materials are lake deposits. They speak of a time, presumably late glacial, when the waters of this lake were much more expansive than at present.

GENERAL GEOLOGY

The bedrocks of the area have been separated into five groups. So far as is known they are all Precambrian in age. Dominant and oldest among them is a vast assemblage of rocks collectively referred to as the Schist Complex. These are mainly schistose volcanics and related types.

They underlie about 50 per cent of the entire area and conjoin with the assemblage similarly classed in the Woman River and Ridout quadrangles[1] to the south and as " Keewatin " in the Swayze area[2] to the west. Second in age relationships and in relative abundance is a series of large massifs of granite, granodiorite, and related gneisses. These generally pink and greyish pink rocks are typically exposed in the eastern and northwestern parts of the area. Wherever they come in contact with the schists they manifest definite intrusive relationships to the same, and the structural trends of the schists conform in a large way with the boundaries of the invading plutonic rock. The third group consists of a profusion of dykes, sills, and irregular-shaped intrusive bodies of igneous rock, intermediate to basic in composition, which intrude the Schist Complex and, in the vicinity of Rush Lake, extend into the gneissic facies of the granite. These bodies maintain a general parallelism, structurally, with the members of the Schist Complex. They have been subjected to a moderate amount of metamorphism such that, where contact relationships are not exposed, difficulty is encountered in distinguishing the members of this group from coarse-grained facies of the older schistose rocks and from granulites developed from the older series in certain places about the batholithic contacts. It is probable that many more occurrences of members of group 3 occur than were shown on the map; for wherever much doubt as to the identification of these types arose, the rocks in question were relegated to the Schist Complex. Moreover, small bodies of these rocks that occur in abundance in southeastern Heenan and in Marion were not separated.

Intrusive into each of the aforementioned groups are a variety of types of quartz and feldspar porphyries (group 4). Two small bodies belonging to this assembly that occur in Marion Township were delineated, but the members of this group are usually present as small dykes or thin sills, and as such they were not differentiated on the map. They are present in greatest profusion in western and central Marion and in the unsurveyed fraction northwest of Swayze River. The fifth group consists of an assemblage of diabase and gabbro dykes, sharply intrusive into each of the other groups. Essentially they are of two types; a medium-grained, porphyritic facies, carrying large phenocrysts of what looks like altered feldspar and a little interstitial quartz, and a brownish, generally coarser grained, olivine-bearing variety. The smaller dykes and the marginal facies of each of these are prone to exhibit well-developed ophitic textures, but the larger masses, such as the occurrence on Northeast Arm of Horwood Lake, are likely to be massive, gabbroid in appearance. The two types have not been observed in contact, hence their relative age is not definitely known. They are fresh, and easily distinguished from the various members of the older groups.

[1]Emmons and Thompson: "Woman River and Ridout Map-areas"; Geol. Surv., Canada, Mem. 157 (1929).
[2]Furse, Geo. D.: Ont. Dept. of Mines, 41st Ann. Rept., pt. 3 (1932).
Rickaby, H. C.: "Some Geological Features of the Swayze Gold Area"; Trans. Can. Inst. Min. and Met., 1933.

A general summary of the stratigraphic sequence of rock types represented in the area is given in the following tabulation:

Recent and Pleistocene	Unconsolidated	Flood-plain, lake beds, forest loam, and muskeg deposits
		Till, esker, and outwash plain deposits
	Great unconformity	
Precambrian	Post-Batholithic	Diabase dykes
		Quartz and feldspar porphyry
		Diabase, diorite, and gabbro
	Batholithic Intrusives	Syenodiorite, hornblende granite, biotite granite, and granodiorite and related gneisses
	Intrusive contact	
	Schist Complex	Rhyolite, pyroclastics, locally grading into clastic sediments; rhyolite and feldspar porphyries, schistose, and in part intrusive
		Iron formations
		Intermediate to basic lavas, chloritic tuffs, impure quartzite, intrusive greenstones

SCHIST COMPLEX

The schists are the oldest rocks in the area. Rocks belonging to this group underlie over 50 per cent of the entire area. In relative abundance they are rivalled only by the granitic and gneissic rocks herein designated batholithic intrusives. The chief development of the schistose group is in the central, western, and north-central portions. Clear of relatively small areas occupied by members of the gabbro-diorite series and the younger porphyries, the townships of Heenan, Newton, Dore, the northwestern half of Marion, and the greater part of the unsurveyed fraction lying within the area north of the townships of Newton and Dale, are underlain by members of this complex. The same is true of Dale Township, barring an area of some 5 or 6 square miles near the centre of the township that is underlain by syenodiorite. From these areas of almost complete dominance, tongues of schistose rocks extend into the areas dominated by the granitic intrusives. Thus, a rather prominent band of schists has been traced eastward from northern Genoa to the eastern boundary of the sheet. This band strikes a little south of east along the northern side of Genoa, and is only a mile wide where crossed by Rush River. East of the Genoa boundary it trends southeastward and widens to approximately 2·5 miles in the vicinity of Northpoint Lake; thence swings to the east and narrows rapidly so that at the eastern margin of the map area it is only about one-half mile wide. Its lateral extension is delimited by intrusive granite and granite-gneiss. Small dykes of the granitic rocks are commonly found to extend into the schist area, but on the whole the boundaries between this band of schist and the prevading massif are sharp and the foliation of the schists parallels the granitic contacts in a marked degree.

Another less persistent band extends into Hardiman Township. This band is poorly exposed, but again the structural trends conform closely with the boundaries and foliation of the surrounding gneiss. Indeed the structural concordance of the schistosity of the older rocks with the boundaries of the batholithic intrusives is a noteworthy feature in most places where these two groups come together. In western McOwen the strike of the schistose rocks is generally north-south. Along the northeast arm of Horwood Lake they trend northeast; along Swayze River they strike northeast, to north, to northwest as they wrap around the granite contact. Only in Marion does this general structural relationship fail. Here the general direction of the schists is northwest to westward, whereas the granite boundary trends approximately southwestward.

Generally speaking the Schist Complex is comprised of three widely different types of rock: (1) green to greenish grey schists, mainly the metamorphic equivalent of intermediate to basic lavas, related intrusives, and associated chloritic tuffs and sediments, with which are also grouped, for convenience sake, certain unschisted andesitic rocks; (2) banded silica iron formations; and (3) pale cream to buff-coloured schists, derived chiefly by alteration of acidic flows, breccias, and related intrusives, pyroclastics, and some associated sediments.

Predominant among the entire assemblage are the green and greyish green schists of type (1). The greater part of the rocks included in this subdivision are comparatively fine-grained aggregates which exhibit a well-developed, schistose structure. Some, however, are more or less coarsely crystalline, somewhat massive in general appearance, but even these when examined closely are found to possess unmistakable flow cleavage. For the greater part they are of volcanic origin; mainly andesitic in composition. Basaltic types occur, but in relatively small quantities. In restricted localities the schistose lavas exhibit pillow structures, vesicles, and other markings common to flows of this type. Occurrences of this sort were noted in the schistose greenstones north of Stake Lake, Marion Township; in the vicinity of Woman River, along Marion Township line; on the shores of Cinqisle Lake, Dale Township; west of Newton Creek, Newton Township; south of Great Pike Lake, in the unsurveyed fraction north of Dale; and, sparingly, in the area between Northpoint Lake and Alike Lake. Distinguishing structures such as these cannot, however, be said to characterize these rocks. More often they reveal no determining structures of a primary nature such that the nature of isolated outcrops must be interpreted on the questionable criteria of texture or remain undetermined.

Mineralogically they differ slightly from place to place in response to differing metamorphic environments, though in bulk composition they are much the same. In many cases they consist of felted aggregates of chlorite, actinolite, epidote, a little secondary feldspar, dusts of magnetite, a little pyrite, and the usual minor minerals. In other instances the main mineral constituent is greenish hornblende, with actinolite and some epidote, carbonate, zoisite, small quantities of plagioclase feldspar, and a little quartz. In some of the coarser grained facies the presence of considerable uralite bespeaks former pyroxene, and in some cases remnants of the latter mineral were observed. In most instances the ferromagnesian minerals make up by far the greater part of the rock. In some cases as much as 70 per cent is hornblende or hornblende and chlorite, the latter commonly occurring as a secondary readjustment of the schist phase, replacing the hornblende.

Marginal to some of the batholithic intrusives, local developments of a granular phase of the schistose volcanics occur, which in hand specimen appear massive to vaguely gneissic, strongly resembling certain phases of later basic intrusives. Examples of these highly metamorphosed varieties of the Schist Complex group may be seen locally, in Genoa, along the granite-schist contact northwest of Rush Lake, and on the northwest shore of Rush Lake, between the trails leading to the iron range—where bodies of undoubtedly recrystallized lava occur, apparently, as roof pendants in the granite. Similar metamorphic types were observed around the eastern end of the syenodiorite stock in Dale Township, and marginal to the granite northwest of Swayze River. In thin section these massive varieties are found to vary somewhat, but are prone to display well-developed porphyoblastic textures, and usually rudely gneissic structures. Hornblende, and sometimes diopside, in well-formed crystals, are the prominent porphyoblasts. Commonly the crystals are somewhat frayed about the edges. They are likely to exhibit zoning, and to carry abundant inclusions of such minerals as biotite, actinolite, epidote, magnetite, and sphene. Clear plagioclase, some as basic as andesine, biotite, and white mica, and quartz occur in the groundmass, along with some epidote and pale chlorite. In some of the slides chlorite occurs in some abundance replacing the amphibole and biotite—the product of retrograde recrystallization from these higher types.

In addition to these schistose and highly metamorphic types, fresh-looking, non-schistose, andesitic flows occur in various parts of the area. Unlike the schistose lavas many of these display well-developed pillow structure, some are highly vesicular. An extensive belt of such rocks bounds the north side of the iron range from Rush River southwestward into Heenan Township. Similar types were noted in Benton Township, adjacent to the iron formations just south of the Heenan Township boundary; in Marion Township, between Puppet Lake and Rush River; about Gowagamak Lake, Heenan Township; immediately west of Great Pike Lake, in the unsurveyed fraction north of Dale Township. Often these flow rocks are associated with dykes and coarser grained masses which resemble the lava in composition and in grade of metamorphism, and which bear a marked semblance to phases of the diorite and diabase grouped as post-batholithic intrusives. East of Puppet Lake dyke rocks and other intrusive masses, which bear striking likeness to the associated fresh lavas, are intrusive into and chilled against members of the acidic schist group. Similar relationships were noted in the case of the Benton occurrence, and those about Gowagamak Lake and along the Newton-

Heenan boundary resemble the associated coarse-grained gabbro-diorite to such a degree that Furse included them with the intrusive complex, in the belief that they were of similar origin.[1]

Thin sections from the pillow lavas that occur adjacent to the iron formation on claim W. S. 8, Heenan Township, and from the occurrence noted in Benton nearby, and from dyke rocks intrusive into the acidic schists, show the rocks in question to be strikingly similar. Compositionally they are essentially a complex of chlorite, uralite, and remnants of augite, in a groundmass of zoisite, chlorite, antigorite, a little quartz, epidote, and saussuritized plagioclase, specks of magnetite, and pyrite. The low degree of metamorphism imposed on these rocks, together with their similarity to, and association with, rocks that bear sharp intrusive relationships to the rhyolites and associated pyroclastics, raises a serious question as to their ultimate correlation. The problem will be referred to again after the diorite and diabasic members of the rock assemblage have been discussed.

Bands of tuff similar in composition to the greenish schists occur at frequent intervals within the volcanic complex. Usually they are of local extent. In some places, however, they attain considerable thicknesses and persist laterally for several miles. In such cases they are likely to be intermixed with, and grade into, rocks predominantly of clastic origin. A mixture of the latter sort comprises the greater part of the tongue of schists that extend into Hardiman Township. Another rather persistent band extends eastward from Upper Rush River, McOwen Township, through Northpoint Lake, and a similar occurrence about the narrows of Alike Lake may be a further extension of the same band. It is manifestly a part of the volcanic complex; composed mainly of tuffaceous beds and greywacke, interlayered with thin lava flows. Still another band of some importance flanks the shores of Northeast Arm, Horwood Lake, and persists across the southern end of Horwood Lake Peninsula. This occurrence, too, is replete with material of volcanic origin. On the east side of the lake it consists of well-bedded quartz-actinolite, and hornblende schists, that trend practically parallel to the granite contact and face toward the lake. With these, particularly near the lake, are some strongly schistose, unstratified rocks that may have been flows. On the west side of the arm micaceous and chloritic quartzites, chloritic and sericitic tuffs, and some fairly coarse agglomerate occur. This assemblage has been severely mashed, crumpled, and has locally suffered considerable carbonatization. It has been intruded by dykes of granite, diorite, and diabase. The presence of an extensive body of lake beds and delta deposits, succeeded to the southwest by a broad sand-plain, obscures the bedrock on the west side of Horwood Lake at this locality, and the continuation of this band has not been located beyond the east shore of the lake. A somewhat similar band of sediments was noted, however, along the course and northwest of Swayze River. The latter occurrence attains an outcrop width of approximately one-half mile. It has been traced brokenly from the 21-chain portage (north of Newton Township), in a general north-north-

[1]Furse, Geo. D.: "Geology of the Swayze Area"; Ont. Dept. of Mines, 44th Ann. Rept., vol. 41, pt. 3, p. 46, and Map No. 41c (1932).

easterly direction for a distance of about 2 miles, whence it swings northwestward around the margin of the granite, or is faulted east, or passes under a series of lava flows. Compositionally it consists of grey quartz schists, chlorite-actinolite schists, and hornblende schists. It exhibits good bedding structures, dips from 45 to 85 degrees westward, and has been cut by numerous dykes and sills of quartz and feldspar porphyry and by gabbro-diorite. It is possible that these bedded deposits are a part of the same band as that occurring about Northeast Arm, Horwood Lake, and it is not impossible that they correspond to the Swayze series, differentiated in 1931, by Furse.[1] The rocks are poorly exposed in this section of the area, and at the time of mapping no particular significance was attached to the discovery of a modest amount of sedimentary material within the volcanic complex. More extended study may reveal an extension of these beds, particularly toward the southwest.

Iron Formation

Iron formations of considerable size and persistence have been traced across the area in a southwesterly direction from the north end of Rush Lake, Genoa Township, to the southeastern corner of Heenan, a distance of just over 12 miles, thence a relatively small band strikes southeasterly across the boundary between Heenan and Benton Townships and has been followed to a point a short distance west of Woman River, south of the boundary of the sheet. Throughout the extent of the range the general geological relationships of the iron formations are similar. They occur in a zone that marks the boundary between volcanic rocks dominantly basic to intermediate, and a complex of dominantly acidic volcanics, pyroclastics, and assorted sediments. The former bound the iron range on the north, northwest, and southwest; the latter, resting on top of the iron formations, bound it on the south, southeast, and northeast; the major structural disposition being that of a crumpled and faulted syncline. The rocks that comprise the iron formations are in the main the ordinary banded silica type so commonly distributed among the older schistose formations of the early Precambrian terrains. They present many metamorphic types, however, and east of Rush River they are associated with rather large, lens-shaped deposits, consisting principally of iron carbonate and pyrite, which contain a higher concentration of iron than do the iron formations proper.

East of Rush River the siliceous member is made up essentially of interbanded silica and iron carbonate and (or) hematite. Locally, pyrite occurs in place of, or along with, the carbonate and other iron-bearing minerals. The bands are lean and in the western part of this section they are not conspicuously magnetic. Toward the eastern end of the range, in Genoa, however, much of the hematite and carbonate give place to magnetite and iron rich amphiboles, and pyrrhotite becomes an important mineral component. Under these conditions they exert strong local attraction, so that the ordinary compass is of little avail. Several small bands of this general nature occur in the section of the range extending from the granite contact, a few chains east of claim W.D. 715, Genoa Town-

[1]Furse, Geo. D.: "Geology of the Swayze Area"; Ont. Dept. of Mines, 41st Ann. Rept., vol. 41 (1932).

ship, to a point about midway between Rush and Woman Rivers, Marion Township. Throughout this distance they are by no means continuous, but tend rather to occur as a series of bands that pinch off and interfinger with their associated tuffs, flows, and other members of the volcanic complex. They lie within a zone upwards of 1,000 feet in width, and occur at various horizons within that zone. The most southerly of the bands in this part of the section is the largest and also the most persistent. Except, however, on claim W.D. 717, Genoa Township, where two narrowly separated bands seem to coalesce to attain a maximum thickness of around 190 feet, or in the vicinity of claim W.D. 1731, where it is repeated by folding, it is seldom more than 40 or 50 feet wide. The others are ordinarily in the neighbourhood of 20 to 30 feet in width; some bands as little as 2 feet in thickness were observed.

In Genoa and eastern Marion the rocks associated with the siliceous iron formations are greenish, schistose, tuffaceous sediments, mainly chloritic to actinolitic in composition, but occasionally they are rich in oxides of iron and carbonates, or fine-grained, siliceous sediments, and sometimes schistose andesite flows occur, also sills of intrusive diorite. In some cases a narrow band of the greenish carbonate-rich sediment occurs in layers up to 10 feet thick within the banded silica. In other cases the siliceous member was observed to grade laterally into cherty tuffaceous sediment. Toward the western end of this section the greenish colour of the tuffs gives place to buff as the chlorite-actinolite rich rocks give place to rocks similar in composition to the acidic complex that overlies the iron range. The lateral transition of these types of interbedded deposits is gradual. Whereas the rocks that interlie the siliceous iron formation bands in the eastern part of the section are dominantly greenish basic tuffs, those that separate the bands in the western part of the section are dominantly buff to creamy, acidic in composition.

On claim W.D. 716, Genoa Township, south of the main range, a block of banded silica trends about 25 degrees east of north, and southwestward from this location small bodies of similar nature occur along the boundary between the Schist Complex and the granite for a distance of about half a mile. These remnants and their associates resemble the southern band of the main range, and it is probable that they are indeed parts of that band, repeated by folding. The granitic intrusive cuts out the iron range for a short distance, north of Rush Lake, but east of the intrusive body a band of iron formation again appears which can be traced, brokenly, as far as the small island near the outlet of Northcott Bay. Beyond that it could not be located. This eastern extension is associated with greenish tuffs, garnetiferous siliceous sediments, and andesitic flows, similar in all respects to the more northerly bands of the range proper. It is narrow, lean, and apparently pinching out eastward.

The sulphide-carbonate deposits associated with the iron formation in the Rush Lake section of the range are irregular, lens-shaped bodies, rich in iron carbonate and pyrite. With few exceptions they lie along the southern margin of the siliceous member. They occur at frequent intervals from claim W.D. 716, Genoa Township, to within half a mile of Rush River, a distance of 4½ miles. West of this point no sizable units of this type were observed. Commonly they abut the southernmost band of the siliceous member and partly replace it. In other instances they lie a few feet south of the siliceous band, entirely in the acidic schists. Only in the vicinity of claims W.D. 1733 and 1734 do deposits of this sort appear in appreciable quantities north of the banded silica. Here small lenses of the greenstone are almost wholly replaced by pyrite and carbonate, and carbonatization of the schists is fairly common. The boundaries of the sulphide-carbonate deposits are not well defined. They tend rather to merge gradually into normal schists such that all grades from the ordinary schists to masses consisting mainly of the carbonate and associated sulphides are found. The outcrop of these deposits is usually a reddish brown, consisting mainly of limonite and partly altered pyrite, derived by surficial alteration of these iron-bearing minerals. In common with the siliceous member of the iron formation, they show a mineralogical change as they are traced eastward toward the granite contact. Near the western end of the section they are composed in the main of carbonate and pyrite, with small amounts of associated magnetite and pyrrhotite. Eastward the magnetite content increases markedly at the expense of the carbonate, and, in Genoa, pyrrhotite becomes an important mineral constituent. A very little chalcopyrite is present.

West of Rush River the nature of the iron formation changes considerably. Sulphides become subordinate, the sulphide-carbonate deposits do not appear, and the range is essentially a cherty banded formation—vastly increased in thickness in comparison with the siliceous member present in the Rush Lake section. The range cannot be traced continuously across Rush River. Indeed it seems to be of minimum importance at this part of the section, and whatever development it has is covered by the flood-plain deposits of the stream. The same is true to a lesser degree in the valley of Woman River, but the similarity of geological associations and structural disposition leaves little doubt but that the whole range is a unit.

Immediately west of Rush River two bands of siliceous iron formation, with interlain siliceous tuffs, may be traced for approximately 1½ miles. Southwestward beyond this the iron formation bands thicken, and concomitantly the fragmental material thins. Thus from a point about midway between Rush and Woman Rivers, throughout the entire remaining section of the iron range only one band can be conveniently differentiated. Tuffaceous material and occasional bands of argillaceous material occur within the banded silica stretching southwestward, but they are present in comparatively small quantities. The iron formations throughout the greater part of western Marion, that which lies across claims W.S. 4 and 6, in Heenan, and the most of the southeasterly trending band that extends from Heenan into Benton Township are dominantly composed of cherty carbonate and beautifully banded jaspilite. Except in local areas of faulting or complex folding they are remarkably fresh and unaltered. In thin section they are found to be composed of extremely fine-grained quartz dusted by, and often surrounded by, specks and plates of hematite. The more iron-rich bands are of finely divided quartz, hematite, fine-grained carbonate, and, occasionally, some pale green chlorite, perhaps greenalite. Most of the slides show a little pyrite, and often a little magnetite. In the locally brecciated bands some of the carbonate has recrystallized into relatively coarse-grained, interlocking crystals, filling fractures in the quartz, and there is a minor development of pale yellowish, radiating amphibole, and of magnetite.

In areas of more intense metamorphism there is a more definite development of these higher grade metamorphic minerals, occasionally to the extent that the formation appears as a quartz-amphibole-magnetite rock quite unlike the fine-grained, brilliantly banded aggregate from which it was developed. The large bodies of iron formation composing the high ridge of claims W.S. 7, 8, and 9, Heenan Township, are in part of the quartz-amphibole-magnetite type. The banded silica in this part of the range reaches a maximum width of about 1,400 feet. It is strongly brecciated in part, however, and intricately folded, and it is likely the outcrop has been widened by these structural disturbances. In the more brecciated parts of these bodies the banding, usually so characteristic of the deposit, has been practically destroyed, so that elongated blocks of quartz occur in undulating attitudes within a schistose matrix of amphibole and magnetite. Even where the banding has been preserved but where folding has been intense, a similar recrystallization into a schistose quartz-amphibole-magnetite aggregate may be observed. Thin sections of these recrystallized bands show that the quartz, though coarsened in grain, still maintains the dust-like inclusions of iron oxide. Much of the carbonate has altered to magnetite, and two kinds of beautifully radiating amphibole are present. One is a pale greenish blue variety, strongly pleochroic; the other is pale yellowish green to colourless. Part of the band that lies across claims W.S. 11 and 12 has suffered somewhat similar alteration, and so has the greater part of the wide bands occurring on claim W.S. 1, Marion Township. In the latter locality complex folding and local igneous intrusions have combined to bring about this alteration.

Here and there throughout the entire length of the iron range the iron formations are cut by dykes, sills, and various types of intrusive bodies, ranging in character from schistose greenstones and rhyolite—apparently belonging to the overlying acidic schist complex—to comparatively unaltered quartz and feldspar porphyry dykes; fine to coarse-grained diorite and diabase, presumably belonging to the later basic intrusives; to fresh unmetamorphosed olivine diabase dykes. Moreover, dykes of the latter three types have been observed to intrude the sulphide-carbonate deposits that occur along the range east of Rush River. The banded silica member belonging to the northern limb of the range, throughout Genoa, Marion, and Heenan, stands at high angles—usually dipping steeply south and southeast but sometimes inclined to the north and northwest. The southeasterly trending band through much of its course dips northeastward at angles of from 60 to 75 degrees.

Relationships between the iron formations and the under greenstones seem to be conformable, as is indicated by the presence of schistose andesite flows and tuffs between the various bands of iron formation that occur toward the eastern part of the range. Likewise no unconformity of any widespread significance seems to separate the members of the iron range from the overlying complex of rhyolites, trachytes, and acidic, fragmental rocks. A short distance east of Woman River small lenses of banded silica were observed to lie within the overlying schists for a distance of 6 to 8 feet south of the contact, and about ¼ mile south of the eastern body of iron formation on W.S. 8, Heenan Township, the matrix of a conglomeratic facies of the acidic volcanic member was found to contain jaspilite and concentrically banded, ferruginous chert blebs, sometimes 15 to 18 inches in length. Apparently then the development of the siliceous iron formations took place during the closing stages of the volcanic activity marked by the vast assemblage of basic to intermediate flows, but continued during the early stages of rhyolitic eruption.

Acid Volcanics and Associated Types

Several bodies of acidic flows, pyroclastics, and related types occur within the area. Small bands of such rocks occur here and there throughout the greenstone areas, such as that underlying the southeastern part of Dale, but only three bodies of these acidic, schistose rock types noted were of sufficient size to warrant separation on the map. The most extensive occurrence of rocks dominantly acidic is located in southeastern Heenan, Marion, and northwestern Genoa, where they underlie the broad V-shaped area east of the iron range extending for the most part as far east as the granite contact. This assemblage is of composite character. In part it is made up of rhyolite and trachyte flows and breccias, in part it is pyroclastic, and in part clastic material. It is dominantly buff to creamy in colour, felsitic in composition, but interbanded with these acidic rocks are moderate amounts of chloritic material and local bodies of schistose intrusive greenstone. This whole assemblage has been folded and intruded by dykes, sills, and other types of intrusive bodies that post-date the folding, and they have suffered considerable carbonatization, particularly in the eastern sections.

Chiefly they seem composed of pyroclastics and of rhyolite and trachyte flows. The fragments that occur in the pyroclastics are mainly felsite porphyry, pink to greyish in colour, varying in size up to 15 inches in diameter. They are angular to oblong to well rounded. The matrix is usually composed of material of similar composition, but locally it contains important quantities of chlorite, and, occasionally, sufficient magnetite to seriously disturb the compass needle. In the western part of the section the buff-coloured matrix is found in thin section to be largely fine-grained quartz, and white mica, a little actinolite, and pale greenish chlorite. The platy minerals are alined to produce a well-directed schistosity. The pyroclasts and pebbles from the same matrix, on the other hand, are quite fresh. They commonly contain well-formed phenocrysts of oligoclase feldspar, and of quartz, embedded in a densely grained groundmass of sericite, quartz, and other minutely crystalline products; and although the phenocrysts are strained, sometimes broken, the mass is not markedly schistose. The trachyte and rhyolite flows and breccias in this (western) part of the area are minutely fractured and sericitized, but are not noticeably schistose. Ordinarily they are porphyritic, with excellently formed oligoclase and quartz phenocrysts, respectively. Sometimes ghosts of former vesicular structure may be observed. Occasionally they display banded flow structure. More commonly, however, they are distinctly brecciated, the fragments being drawn into oblong stretches.

In various places throughout the body patches and bands of waterlain clastics are present. In Genoa, and in central Marion, bands of what seems to have been a silt were noted. The central Marion occurrence is now composed to a very large degree of fine-grained quartz, sericite, chlorite, and a little actinolite. The occurrence in the eastern end of the section is now converted into a quartz-actinolite-garnet schist. Coarser material, some with well-rounded pebbles, occurs, particularly just east of Rush River, in the section between Rush and Woman Rivers, and along the southern edges of claims W.S. 4 and 5, Heenan Township. The pebbles that comprise these conglomerate patches, so far as could be ascertained, are entirely composed of felsite, porphyry, and other types entirely similar in composition and structure to the associated volcanic rocks. No pebbles of iron formation, nor of demonstratively underlying rocks, could be found. Granules of quartz were observed occasionally, however, and in places small lenses of chert and, as previously noted, jaspilite occur among the pebbles. The quartz may have been derived from the volcanics, and the cherts—apparently indigenous to the matrix—have not been transported as fragments. In some localities, notably on claim W.S. 5, Heenan Township, blocks of the conglomerate facies were observed to be smeared in what appeared to be a rhyolite flow, as though they had been picked up and rolled about in liquid lava. Seemingly these water-worn materials comprise only local deposits within a complex dominantly volcanic. They were apparently built up during the time the associated volcanic material was being exuded, and they are for the most part composed of reworked fragments of that material.

In Genoa Township, and along the granite contact in Marion Township, the members of this acidic complex have suffered fairly high-grade metamorphism, and are converted into aggregates such as quartz-actinolite-garnet, quartz-sillimanite-mica, and quartz-hornblende schists. More locally, particularly around the margins of the intrusive greenstones and diorite contacts, they have undergone abundant chloritization, sometimes with the addition of pyrite, and in zones of local shearing, such as characterize the area near the iron formation adjacent to Rush River on both the east and west sides, they have been converted into fissile, quartz mica carbonate schists. Carbonatization is a common type of alteration among each of the various facies that go to make up this member of the complex, and in places, east of Rush River, in the development of the sulphide-carbonate iron deposits this mode of alteration reaches an extreme degree where carbonatization, along with the addition of important quantities of pyrite, has so completely replaced these rocks that they become unrecognizable.

Near the iron formation contact in eastern Marion, and in Genoa, peculiar oblong structures appear in a tuffaceous, quartzitic facies of this schistose member, which at first sight look like elongated pebbles. They are generally parallel to the strike of the foliation and they are surrounded by a narrow border of brownish to greenish material, which, in contrast with the buff colour of the major part of the fragments, gives the rock a banded appearance that conveys the impression of bedding. In detail, however, these structures are found to be lenticular fragments of the rock itself. In thin section the buff-coloured parts are found to be strongly schistose, composed of fine-grained white mica, quartz, sillimanite, andalusite, and actinolite. The marginal, greenish boundaries grade into the more normal, buff-coloured material and are comprised of an abundance of fibrous green amphibole, carbonate, quartz, a little garnet, and pyrite. The latter material is similar to certain of the mineral assemblages developed by metamorphism of the sulphide-carbonate iron deposits. It has undoubtedly been introduced. The structures seem thus to have been produced by a combined process of dynamic and hydrothermal metamorphism. They precede the schisting and are crosscut by dykes of altered diorite and basalt. Presumably they have been imposed at a relatively early stage in the history of these rocks.

Despite the fragmental character of a great part of this member of the Schist Complex, it seldom displays structures, except in the rudest sense, that can be safely interpreted as bedding. Pebble trends were noted in the conglomerate facies in a few localities in Heenan. Stratification was also noted in the tuffaceous facies that crop out near the south boundary of the map in northwestern Mallard Township, and structures taken for bedding were measured in a quartzite phase in central Marion and in the vicinity of Strata Lake. Except in the case of the central Marion occurrence, the strike of these trends corresponded closely to the banding in the nearby iron formation. The discordance in Marion was sharp, but believed to be due to local folding such as afflicts the banded silica nearby. Moore[1] suggested the possibility of an unconformity between the conglomerate facies and the underlying iron formation on the basis of observations made along the iron range a short distance east of Rush River. The writer could not find convincing data, however, to substantiate an unconformity other than one of local import; whereas the presence of cherty lenses in the tuff, jaspilite bands surrounding pebbles in the conglomerate, and pyroclastic material lying between the bands of siliceous iron formation in Marion Township, of precisely the same composition as that comprising the main bodies of fragmental rocks of this member, all seem in the writer's opinion to point to general conformity.

Another body of fine-grained, acidic rocks underlies a considerable area in central Heenan and extends eastward into Marion Township. This band has not been studied in much detail. It is rather poorly exposed. A broad sand-plain extends across the western part of central Heenan, so that beyond Heenan Creek few outcrops occur and the boundaries of the acidic schists cannot be closely fixed. Two outcrops of crushed rhyolite were observed in the area north of Heenan Lake, and on the north shore of Trailbreaker Lake a small outcrop of similar character was noted. A short distance north, and on the east shore of this lake, however, the only outcrops seen were dacitic to andesitic in composition. Thus from the data at hand it seems probable that the acidic band extends across the township, but in rapidly narrowing dimensions.

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[1]Moore, E. S.:"Sahkatawich (Rush) Lake Section, Woman River Iron Range, District udbury"; Ont. Dept. of Mines, 35th Ann. Report, pt. 2, p. 88 (1926).

East of Heenan Creek exposures are more plentiful so that fairly good sections of the rock may be observed. Near the northern border it is a quartz porphyry of medium grain, crushed and sericitized, but not markedly schistose. Southward this type is succeeded by a fragmental facies, seemingly a rhyolite flow breccia, or pyroclastic. This facies is more schistose, and locally exhibits a reddish brown colour on weathered surface, due to the oxidation of an abundance of iron-bearing carbonate which is present in the schist. Outcrops along the trail leading from Woman River to Heenan Creek are composed of strongly schistose quartz porphyry, which contains large phenocrysts of quartz and some oligoclase embedded in a matrix which is now a matte made up mainly of sericite, chlorite, quartz, and carbonate. Northward along Woman River it seems to grade into a finer grained quartz-rhyolite porphyry, which gives place to andesitic green schists a short way north of the portage to Rush River. The part of the body that extends east of Rush River is in part fissile, carbonated schist, in part schistose quartz porphyry, similar in every respect to that noted in Heenan. The quartz porphyry is distinctly younger than the schistose greenstones that occur north of the iron range, and small dykes of petrographically similar porphyry have also been observed to cut the iron formation. Near the iron range east of Rush River porphyry dykes belonging to this facies are, however, cut by dykes of diorite.

Similar types and geological relationships characterize the large body of fine-grained acidic rocks that occur in Newton and Dale Townships. It is typically a crushed, partly altered quartz porphyry; in part, at least, intrusive into the neighbouring greenstones. The long arm that extends eastward into Dale Township is composed of waterlain pyroclastics, with well-rounded pebbles of quartz and rhyolite porphyry similar to the intrusive and flow phases of the main body. Conceivably they are of a common source.

Structural Relations of the Schist Complex

Structurally the Schist Complex is thrown into a series of folds, some tightly compressed and crumpled, others more or less simple. In detail they are imperfectly known over a wide portion of the area, and the repetitions of geological events that have affected the various members of the Schist Complex, coupled with the paucity of persistent sedimentary bands bearing distinctive structures by which the true attitudes of the rocks might be established, render it difficult to determine beyond reasonable doubt the attendant structural relations in various parts of the area. Attempts were made to make structural determinations among the volcanics on the basis of pillow and vesicular structures, but such attempts merely led to indecision owing to the contradictory nature of the evidence adduced.

As has already been indicated, the strike of the foliation in the schists conforms in a large way with the boundaries of invading batholithic intrusives. Thus north of Rush Lake the strike is a little south of east; along the east boundary of Dale Township it is generally north-south, but swings northeast as the schists are traced into Hardiman Township. Along the northeast arm of Horwood Lake the prevailing trends are north-northeast, and similar strikes were measured on the upper portions of Swayze River and in northwestern Newton. Across Marion Township this parallelism between the schistose structure and the intrusive boundaries fails to hold. Here the foliation trends are generally northwest-southeast and east-southeast, in places at right angles to the strike of the bedding of the sediments along the iron range, but they swing westerly to slightly south of west as they are traced across Heenan. Plotted for the whole area the foliation trends reveal a striking tendency to radiate from the east-central part of Newton Township. The strike of the bedding in sediments, and the formational trends in general, are usually northeast in the northern and northwestern part and also in the southeastern part, with the exception of the band that extends across the area east of Genoa, and of the southwestern limb of the iron range. The latter trend generally in a southeasterly direction. Dips of the foliation vary from 50 degrees to vertical, usually they are at high angles. Similarly, the dips of strata vary from 60 degrees up, but usually stand almost on edge. The sediments seldom show discriminating structure that can safely be used to determine the true attitude of the beds. Thus in the vast majority of cases interpretation of tops and bottoms of the strata has had to be made purely on the basis of drag-folding and cleavage.

Age relations between the various igneous rocks belonging to the Schist Complex cannot be convincingly worked out except by resorting to the broad structural relationships, for there has evidently been a repetition of volcanic types. Thus schistose andesites are found to be cut by schistose rhyolites and related types, and, in the great area of dominantly acidic volcanics found in Marion, the acidic lavas and tuffs were observed to be intruded by schistose greenstones. Both of these extreme types disturb the iron formation. They have all been subjected to the same grade of metamorphism. All are schisted and faulted together, hence all are believed to belong to the same general period of volcanism and are, therefore, all considered a part of the same series.

The bulk of the data adduced, however, indicates that the greater part of the acidic complex is relatively younger than the greater part of the basic volcanics. Structural determinations concluded from drag-folds in the steeply dipping tuffaceous sediments along the iron range indicate that except when local cross folds and extreme crumpling affects them, the tops of the beds face southeastward along the range from eastern Heenan across Marion and southward in western Genoa. These determinations are strengthened by one observation, made near the west boundary of claim W.D. 715, Genoa, where a well-bedded, siliceous tuff deposit stands on edge but has crossbedded structures in which the southern edges of the beds are truncated. The small band of iron formation that trends southeasterly across the Heenan-Benton Township line dips generally at angles of 65 to 70 degrees toward the northeast, and though no definite data are at hand to prove that it faces northeastward its associations are so similar to those found for the rest of iron formations that it is believed that the dips recorded represent the true attitude of this band. As indicated above, the strike of the foliation across this part of the area is generally northwest to west-northwest. The major structural relations here are, therefore, synclinal with a plunge toward the east-southeast, and the acidic complex and iron formation rest on the older greenstones. In particular the structure shows great complexity, due to local cross folds and small scale faulting, but these seem in large measure incident to the major structural relations that have been developed at this corner of the complex.

In southwestern Hardiman a narrow band of sediments was found to strike north-northeast to northeast and to face westward. The same relationships were found along the southeast side of Northeast Arm, Horwood Lake. Between those two areas, though there is a broad tongue of granite and south and east of Great Pike Lake a wide area of lavas, this section has not been studied with any particular care, and it is not known whether these two bands that look alike are indeed the same repeated by folding or whether they represent two entirely separate horizons. Between the northern arms of Horwood Lake, on the peninsula, structural determinations are also scanty and based entirely on secondary cleavage. The rocks are highly sheared and appear to be crumpled here. Strikes and dips are erratic. There is a suggestion, however, that the general structure is synclinal with a plunge toward the northeast, and, judging from an apparent offset in the diabase dyke outcropping on the shores of the lake near the north boundary of the sheet, it is possible that it is broken by a strike fault underlying the waters of Northeast Arm. In the valley of Swayze River sediments have been identified that incline generally northwest, but with radically changing dips. It is possible that these are closely related in age to the sediments noted about Horwood Lake. If so, it seems likely that a general synclinal structure extends across the northwestern part of the area underlain by the Schist Complex.

The area between this east-southeasterly plunging syncline that occurs along the southeastern part of the complex and the probable northeasterly trending syncline lying across the northwestern part, seems in part domal, elongated east-northeasterly, culminating about the syenodiorite stock in Dale, and characterized by folds of considerable dimension on its margins. The presence in southern Dale of a band of felsite pyroclastics, trending east-west, is strongly suggestive of a local synclinal axis in this place, but insufficient data of a reliable structural nature are at hand to warrant any conclusions in respect to the structure of this part of the area.

BATHOLITHIC INTRUSIVES

By far the greater part of the townships of Hardiman, McOwen, and Genoa, and of the unsurveyed fractions that lie east of McOwen and Genoa, are underlain by rocks collectively classed as Batholithic Intrusives. These rocks are principally pink to greyish coloured granites, and granodiorites, of medium grain, obscurely porphyritic. Ordinarily they display a poorly defined gneissic structure, but near the boundaries of the schist areas, about inclusions, and in places where they have undergone local shearing, this gneissic structure becomes quite pronounced.

In the northeastern part of this area (Hardiman, McOwen, and the fraction east of McOwen), as in the sections southeast of Rush Lake, the rocks are not well exposed. Barring exposures along the shores of Atekepi, Scraggy, and Resound Lakes, and a few local ridges, outcrops occur mainly as small, elliptical hummocks within the extensive muskegs, and the broad, low-lying areas covered by glacial debris that characterize the eastern part of the area. Normally the batholithic rocks exposed in these sections are of medium grain, but slightly porphyritic. The ferromagnesian mineral most commonly present is greenish biotite, but in the vicinity of schist boundaries a considerable amount of epidote is also likely to occur—a feature common to the contact zones of the granitic rocks in other sections of the area as well. In crushed zones the biotite is usually replaced by chlorite, and in many outcrops, notably near the southern end of Scraggy Lake, numerous greenish veinlets of epidote and cherty looking quartz pervade fractures in the rock.

No extensive petrographic study of the rocks in these eastern sections has been indulged, but from the few slides that have been examined it appears that they vary in composition from a granite to a fairly basic granodiorite. How systematic the variation or how much is granite and how much granodiorite is not known. Except in extreme cases the two types cannot be separated without the aid of the microscope. Sections made from a pink massive granite that occurs near the eastern end of Elbow Lake, Hardiman Township, are found to comprise about 40 per cent soda-orthoclase and microperthite, 35 per cent plagioclase (mainly oligoclase of composition $Ab_{85}An_{15}$), and 5 per cent combined ferromagnesian minerals and minor constituents. The ferromagnesian mineral is largely greenish biotite, but a little hornblende is present, as well as some chlorite and other alteration products. The usual minor constituents, common to rocks of this general nature—zircon, apatite, and magnetite—are present in small amounts. The plagioclase is mainly euhedral, tends to be phenocrystic, surrounded by orthoclase and by intergrowths of the microperthite and quartz. Some sericitization of the feldspars has occurred, but on the whole the rock is fresh. A rock of similar composition, but crushed to such an extent that the quartz is granulated and the feldspars quite badly altered, occurs on an island in Little Rush Lake.

A slide prepared from a specimen collected near the Hardiman Township line northwest of Freeman Lake, on the other hand, contains only 6 per cent combined orthoclase and microperthite to 45 per cent oligoclase (mainly $Ab_{72}An_{28}$ with a little andesine), 38 per cent quartz, and 9 per cent ferromagnesian minerals, together with some magnetite, small amounts of zircon, and apatite. Again the ferromagnesian mineral is largely biotite, but a few crystals of hornblende and of pyroxene are present. The oligoclase crystals are well formed, often zoned; unaltered. The lobe-shaped extension of this large body of granitic rocks from Hardiman Township, into the unsurveyed fraction to the west, is distinctly gneissic in appearance. Thin sections show it to be quite similar in composition to the one just descrbed. The feldspar is preponderately plagioclase. The ferromagnesian mineral is biotite, but epidote and chlorite occur in some quantities. The quartz in part is secondary, myrmekitic intergrowths with what appears to be albite, and a little carbonate are present.

Occurrences east of Rush Lake, along the shores of Northpoint River, and in the area about Resound Lake are similar in general appearance to those of the northeastern sections. They are medium grained, pinkish in colour for the most part, but more or less drab near the schist boundaries. They hold many inclusions of the older rocks, in various states of resorption. Pegmatite dykes occur in them, and extend into the schists in the neighbourhood of Northpoint and Alike Lakes. The pegmatites are prone to carry an abundance of quartz. In one of these, and in a gneissic dyke of granite that penetrates the schists on the west side of the narrows of Alike Lake, disseminations of molybdenite and pyrite were observed.

The body of schists that here separates the granitic rocks of the northwestern section of the area from those in the southeast is quite narrow, but has been traced to the western edge of the swamp lying between mile-posts 4 and 5, Whalen Township. East of this point, according to published maps,[1] the granitic bodies conjoin to entirely cut out the schists.

Another extensive body of granite and related types occurs in the northwest corner of the map-area. This body underlies the greater part of Whigham, and extends into the unsurveyed fraction east of that township. Its southern boundary is obscured by an extensive sand-plain in eastern Whigham, and by swamp deposits along, and east of, the township line such that the contact between it and the schists, at this place, is largely a matter of conjecture. The eastern contact is, however, approximately established. The rocks comprising this granitic area are similar in many respects to those described from the eastern sections. Essentially they are biotite granites and granodiorites, with occasional outcrops carrying appreciable amounts of muscovite, and excessive quartz. An occurrence on the west arm of Harry Lake was found to contain about 50 per cent combined potash feldspar and microperthite; 18 per cent oligoclase ($Ab_{75}An_{25}$); 20 per cent quartz; 5 per cent muscovite; 4 per cent greenish biotite, partly replaced by chlorite; and larger quantities than usual of such minerals as zircon, apatite, sphene, iron ores, together with an unidentified, highly refracting, greenish substance. Clear of slight sericitization of the feldspars, and partial chlorization of the biotite, the rock is fresh. The outcrop is small, and the rock is slightly coarser in grain than is usually found in the rocks of this type farther east. It may represent a pegmatitic phase.

Near the eastern boundary of this body the rocks are generally darker from an increase in biotite content, and they contain a higher ratio of plagioclase. Blebs of quartz and epidote are prevalent and a short distance north of the northernmost lake, lying along the schist-granite contact, a stockwork of milky quartz 10 feet wide, striking north 70 degrees east, was exposed for a distance of 30 feet in the granite. The quartz seemed barren of sulphides. It carried a little feldspar, and displayed a tendency to vuggy comb structure.

The granitic rocks that occur about the north and northwest side of Rush Lake differ in part from those described above, and indeed differ among themselves more or less haphazardly. Along the north side of the lake outcrops of massive to faintly gneissic, soda-rich syenite occur which carry about 18 per cent ferromagnesian minerals, chiefly frayed greenish blue hornblende, and chlorite. The feldspar is largely soda-orthoclase and microperthite, but a moderate amount of oligoclase ($Ab_{80}An_{20}$) is

[1]*See* Geol. Surv., Canada, Map 155A, 3rd edition; Ont. Dept. of Mines, Map 1933a.

present, and less than 1 per cent of quartz. In close association, but without exposed contact, are outcrops of porphyritic granite, carrying as much as 15 per cent quartz and only 6 to 8 per cent ferromagnesian minerals (hornblende and biotite). Westward toward the contact of these batholithic rocks with the schists are outcrops of granodiorites, comprised dominantly of plagioclase feldspar, with upwards of 20 per cent quartz, and an abundance of hornblende, biotite, and some epidote. Southward along the lake shore the predominating rock is pale pinkish weathering granite to granodiorite, usually somewhat gneissic, carrying varying amounts of hornblende and biotite. Locally, they are crushed and veined by greenish stringers of epidote and fine-grained quartz. Occasionally veinlets of quartz and very pink feldspar penetrate them. These crushed zones are strongly gneissic, and in thin section the quartz in them is found to be granulated and the feldspars strongly seriticized. Normally, however, these minerals are found to be in fairly fresh condition. Toward the south end of the lake a little andesine appears among the feldspars, the amount of hornblende increases markedly with a concomitant decrease in quartz, such that near Mallard Township line the rocks approach the composition of a diorite, similar in many respects to the syenodiorite occurring in Dale Township. Here and there outcrops of a very pink facies of granite occur that seem to be intrusive into the more drab-coloured masses. These are probably late phase products of the same magma, though they may indeed represent a later and entirely separate intrusive.

A small body of granitic rock occurs near the northwest corner of Dale Township. It underlies an area of roughly 2 miles by 2¾ miles extent, and is excellently exposed along the west shore of Horwood Lake. In composition it resembles certain phases of the hornblende granodiorite on Rush Lake. Along its margins it displays a strongly developed gneissic structure, which roughly parallels the boundaries, and is caused by orientation of the abundant crystals of hornblende. The more central parts are not so pronouncedly foliated, but they tend to be trachytic due to a directional orientation of the large phenocrysts of feldspar. The boundary phases are dark coloured, sometimes carrying as much as 40 per cent ferromagnesian minerals. Toward the centre it grades fairly uniformly to a pinkish coloured feldspar porphyry, containing about 10 per cent dark-coloured constituents. The phenocrysts are usually well-formed crystals, some as much as ⅝ inch in length, embedded in a medium-grained groundmass of feldspar, hornblende, and biotite. The feldspars are dominantly pink to flesh coloured. The larger ones are prone to exhibit lavender tints, and are at times poikilitic.

A microscopic study of the various phases of this body shows that the feldspar varies from a preponderance of plagioclase (about $Ab_{75}An_{25}$ with lesser amounts of $Ab_{68}An_{32}$) in the dark border facies to a slight excess of the potash-soda varieties in the more felsic facies. Most of the phenocrysts are oligoclase, usually zoned; a few are orthoclase. Microperthite is interstitial; often intergrown with a little quartz. All of the slides show some quartz; a few of them carry as much as 5 to 8 per cent, and those made from the lighter coloured part of the mass sometimes contain as much as 16 per cent of this mineral. In the latter cases a large part of the quartz is secondary, however, seemingly of deuteric origin. The ferromagnesian mineral most prominently represented is a bluish green hornblende. Augite is commonly present, also biotite, and in the more acidic parts the biotite becomes fairly abundant. Chlorite occurs as an alteration product of biotite and of hornblende, and in some cases epidote is a common member of the dark-coloured constituents. Magnetite is relatively plentiful in some of the slides and the usual minor minerals, such as apatite and zircon, are present. A composite of five Rosiwal analyses of slides made from specimens collected along the outcrop on the west side of Horwood Lake, and representative of the gradation, northward, from the more acidic porphyry phase to the basic boundary phase, gave the following: plagioclase 35·2 per cent; orthoclase 14·5 per cent; microperthite 14·0 per cent; quartz 6·5 per cent; pyroxene 2·9 per cent; hornblende 11·2 per cent; biotite and chlorite 12·0 per cent; accessories, including epidote, 3·4 per cent; total 99·7 per cent.

Small pegmatitic and aplitic dykes were observed within the dark-coloured border zones at various points. The boundaries of some of the dykes tend to be obscure, as though they were injected while the gneissic material was still quite hot. They are in all probability late differentiates of the same magma. The more acidic portion of the body is not centrally located, but lies considerably nearer the southern margin. Insufficient data are at hand to delimit the dominantly light-coloured part from the surrounding dominantly mafic material, but it seems apparent that the mass is marginally differentiated stock, possibly plunging to the north or northeast.

Dykes of granitic material pervade the schistose rocks that underlie the peninsular area between the arms of Horwood Lake, and a small body of biotite granite invades greenstone at the second rapids on Woman River south of the Marion-Dale Township line. Some of the dykes in the vicinity of Horwood Lake are of a grey, gneissic biotite granite, others are a pink hornblende-bearing variety.

ALTERED GABBRO, DIORITE, AND DIABASE

In addition to the batholithic intrusives, the Schist Complex has been invaded by many dykes, sills, and irregular-shaped bodies of igneous rock which vary in composition from basic gabbro to diabase to quartz diorite. Rocks included in this category occur locally in all parts of the schist area. They are difficult to distinguish, however, from the coarser grained facies of the older basic lavas, hence only the larger masses, and those of seemingly definite relationships, have been shown on the map.

Many small injections of these rocks occur west of the granitic area in Marion, and near the outlet of Rush Lake they cut and are chilled against a gneissic phase of the batholithic intrusives. They pervade the tuffs and lava flows north of the iron range in Genoa and eastern Marion. They occur as thin sills and branching dykes between the iron formation bands in the same section of the area, and as dykes, sills, and small bosses in the acidic complex that overlies the iron formation in Genoa, Marion, and Heenan Townships. In the latter localities they are frequently found to intrude the schistose greenstones associated with the more acid rocks.

East of the iron formation, on claims W.S. 4 and 8, Heenan Township, dykes of dioritic rocks may be seen cutting across the schistosity of the rhyolite, pyroclastic assemblage, sometimes almost at right angles to the strike of the adjacent iron formation beds, and immediately south of the Heenan-Benton boundary, between mile-posts 4 and 5, diorite masses which cut the pyroclastics seem to grade into fresh, andesitic lava. Similar conditions were observed east of Puppet Lake, Marion Township, where a profusion of intrusive bodies of this general character intersect the buff-coloured schists, and are almost indistinguishable from fresh flow rocks that occur nearer the outlet of Rush Lake. Another large body of coarse-grained rock of this general nature occurs along the north side of Heenan Township. It is upwards to one-half mile wide in places, extends into Dore, and has been traced, brokenly, as far east as Woman River, in Marion Township. This body also is associated with lavas that strongly resemble it.[1]

Other intrusions, similar petrographically, occur in Newton, and a fairly extensive body was found about the northwest corner of this township. Smaller masses were discerned in Dale Township, particularly east of the syenodiorite stock, and in various parts of the area north of Dale and Newton Townships rocks similar to these were observed.

On the whole, these intrusive bodies are compact, greenish grey aggregates, fresher looking and more granular than the rocks of similar composition belonging to the Schist Complex. In isolated outcrops, however, the smaller bodies of these two types are almost, if not entirely, impossible to tell apart. The larger masses are prone to vary erratically in both texture and composition. Though locally sheared they are non-schistose. They all have undergone varying degrees of metamorphism, but the metamorphic trends that they manifest are of a retrograde nature. Thus the feldspars are in large part broken down to saussurite, the pyroxenes to uralite and chlorite. The hornblende too is often converted into chlorite, and intergrowths of secondary quartz and albitic feldspar occur in some of the slides. Their contacts with the older rocks are sometimes marked by a pronounced zone of chloritization, not infrequently accompanied by some pyrite. This feature is particularly noticeable in the parts of the area in which they intrude the buff-coloured, acid pyroclastics.

The occurrence along the north boundary of Heenan Township varies radically in texture and in composition, as though it were a composite body rather than a single intrusion. A part of it is coarse-grained feldspar porphyry with basic feldspar phenocrysts up to 1 inch in length. Other parts are fine to medium grained, equigranular diorite, and many varieties intermediate to these appear. Sometimes the textural changes are abrupt, but the intermediate types are likely to show imperceptible variations from coarse to fine, both along and across the strike of the outcrop, after a manner suggestive of local segregations. The extreme rock types represented are enstatite gabbro and quartz diorite, but the main rock body is chiefly augite or hornblende gabbro. Outcrops of the enstatite gabbro occur near the south boundary of the body in the vicinity of Gowagamak Lake, and—an

[1]Furse, Geo. D.: Ont. Dept. of Mines, vol. 41, pt. 3 (1932).

interesting fact in this relation—the fine-grained, presumably flow rocks that occur about the shores of Gowagamak Lake are basaltic, and on Heenan Creek, near the south margin of the coarse-grained body, outcrops of olivine basalt occur which though serpentinized are non-schistose. Furse considered it probable that these lavas, and also certain fresh-looking flow rocks that occur north of the Newton boundary, were the equivalent of the gabbro intrusive complex. The writer was impressed with the same idea, and more particularly so in regard to the association of fresh-looking pillow lavas and intrusive bodies of hornblende diorite south of the Benton-Heenan boundary and in Marion east of Puppet Lake. Though it is possible by complicated structural assumptions to explain the distribution of these lavas in a way that would enable their correlation with the volcanics of the Schist Complex, the weight of data on hand are against such a correlation, particularly in respect to those found within the assemblage of acidic schist in Marion and Benton Townships, and in the opinion of the writer the most plausible interpretation of the known facts is that these non-schistose lavas are closely related in age and genesis to the basic intrusives; hence that they are younger than the volcanic assemblage referred to as the Schist Complex. Proof or disproof of this belief, as well as reliable criteria for separating these, probable, later lavas from the older volcanics must, however, await further and more detailed field work.

The vast majority of the slides made from the rocks of this series contain quantities of bluish green hornblende similar in every respect to that characteristically present in the hornblende-rich phases of the granitic rocks about Rush Lake, and in the syenodiorite of Dale Township. In some of the darker varieties this mineral, together with its alteration products—mainly chlorite—makes up as much as 70 per cent of the entire mineral assemblage. The feldspar porphyry that occurs in the Heenan intrusive complex has a subordinate amount of hornblende, its place being taken by a pale orthorhombic pyroxene, now largely converted to bastite. The phenocrysts in this facies are changed beyond recognition, appearing in thin section as a fine-grained, fibrous matte of musty grey colour. A dark, medium-grained variety that commonly carries small but well-formed phenocrysts of pink feldspar usually shows some interstitial micropegmatite when examined microscopically. Occurrences of this type were noted in northern Heenan, in northwestern Newton, and at various other points. Magnetite is abundant in many of the slides examined, both as primary blebs and as dust-like reaction products associated with chlorite and hornblende. Pyrite and pyrrhotite are also common in some varieties, likewise apatite.

The boundaries of the mass that occurs near the northwest corner of Newton are not well established, but they seem to conform in shape roughly to the contorted structure of the schists at this place. In part, it is composed of medium-grained, altered diorite; in part of the dark facies bearing the pink feldspar phenocrysts previously described. It is replete with stringers of epidote, pinkish feldspar, and quartz, and in common with the adjacent schists it is cut by many small dykes of quartz and feldspar porphyry. Part of this body shows a fairly high grade of metamorphism, not unlike the hybrid rocks that occur about the batholithic intrusive boundaries.

A peculiar phenomenon was noted near the Marion-Genoa Township line, on claim W.D. 720, just south of the iron range, where a small dyke of gabbroic composition holds as inclusions two boulder-like fragments of granite porphyry. The dyke trends north-south, averages about 15 inches in width, and intrudes a quartzitic facies of the acidic schist complex. It follows a slightly sinuous course, generally at right angles to the schistosity of the quartzite, and carries fragments of the wall-rock. One of the granite inclusions is 4 inches in diameter and well rounded. The other is about $2\frac{3}{4}$ by 7 inches and has smoothly rounded edges. The two fragments lie parallel to each other. At the surface they are neither in contact with each other or with the wall-rock, but are entirely surrounded by the igneous material. There are no fragments of this sort in the adjacent formations nor have any of this particular texture been observed at any other point within these formations. Manifestly, they must have been carried there by the intruding magma, but whether they represent corroded fragments torn from the granite mass that underlies the area a short way south (or marginal dykes of the same), or whether they are actually water-worn pebbles torn from local conglomerate bands—possibly to the south—is not certain. Another large dyke of these rocks occurring east of the iron range, claim W.S. 8, Heenan Township, contains rounded pebbles of rhyolite porphyry near its margins. These have undoubtedly been ripped off the conglomerate facies of tuff that forms the wall-rock of the dyke at this locality.

The age and ultimate correlation of these various types of basic intrusives are open to some question. They are found to bear intrusive relationships to the members of the Schist Complex wherever the contacts between these series are exposed. Usually these contacts are sharp, clear cut, chilled, but often they are obscured by a moderate development of schistose structure in the fine-grained margin of the intrusive. In many cases their contacts are found to trend eccentrically to the secondary structures in the older rock, but often they tend to parallel these structures. Though they are sometimes sheared, locally, and generally altered by low-grade metamorphism they are not schistose even in areas that show strongly developed schistosity among the other basic rocks. Thus they are clearly younger than the members of the Schist Complex.

On the north side of the outlet of Rush Lake a well-exposed section reveals dykes of rocks, petrographically similar to the diorite-diabase phases of these basic intrusives, which are definitely intrusive into a gneissic phase of the batholithic intrusive. The contacts are sharp. The basic rocks are chilled against the gneiss. Fragments of gneiss are included along the margins of the dykes and many apophyses may be seen to extend out from the basic dykes into fractures in the gneiss. The basic rocks trend locally in various directions, but predominantly they parallel the foliation in the older rocks which, here, is about 12 degrees south of east. The chilling of the diabase contact is not a strikingly noticeable feature, due to the fact that it is a rather broad zone, as though the gneissic rock was quite hot when the diabase was injected, and because the contact zone is slightly schistose. Similar relationships, though less well exposed, may be observed on the south side of the river at this point.

Here, too, dykes of quartz and feldspar porphyry may be observed to bear intrusive relationships to the basic intrusives and also to cut the granitic gneiss. The latter holds many large inclusions of the older schists that are intruded by the dyke rocks, and to complete the assemblage of rock types exposed in this section a small dyke of olivine diabase cuts sharply across the gneiss and the altered diabase, and is sharply chilled against both.

Thus it becomes evident that some of the altered diorites and diabases that occur in the area are younger than the gneissic rocks that represent the batholithic intrusives at this place. In other parts of the area, notably about the east end of the iron range, rocks of similar appearance occur that are intruded by the granite. At first these were believed to be a part of the basic intrusive series, but by more careful field investigation and by a comparative microscopic study they have been found to be recrystallized lavas, presumably a part of the Schist Complex. The section in the vicinity of Rush Lake outlet is the only place where the relationships between the batholithic intrusives and these bodies of more basic material have definitely been determined. The relationships between them and the porphyries have, however, been observed in many places with constant results: the porphyries intrude the basic bodies. Consequently, the various bodies of altered gabbro, diorite, and diabase that have been found to be younger than the Schist Complex have been grouped together and treated as of post-batholithic, but pre-porphyry age. It is not known, however, whether or not they are all post-batholithic. Indeed the testimony of investigators[1] working in nearby areas strongly suggests that they are not all of the same age, at least that they do not bear constant relations to the granites. Indeed it may very well be that they belong to the same general period of igneous activity as that which produced the batholithic rocks, and that the contradictory evidence with respect to their age is due to recurring intrusive events during that period.

QUARTZ AND FELDSPAR PORPHYRIES

In addition to the crushed and carbonated quartz and feldspar porphyries that typify a large part of the fine-grained acidic rocks included in the Schist Complex, there are present a profusion of younger porphyries which intrude each of the previously described formations. In part they resemble the older porphyritic rocks so that they add greatly to the difficulties encountered in mapping. They are fresher in appearance, and microscopically they are found to be less altered than those belonging to the older series. They often manifest sharply angular contact relationships with the folded structures in the schists and iron formations. They have been observed to cut the granite about Rush Lake and to intrude gabbro-diorite dykes belonging to the later basic intrusives. Clearly then they are among the youngest igneous rocks in the area—succeeded only by the diabase dykes of group 5.

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[1]Emmons and Thomson: Geol. Surv., Canada, Mem. 157, p. 18 (1929).
Laird, H. C.: Ont. Dept. of Mines, vol. 41, pt. 3 (1932).
Graham, A. R.: Ont. Dept. of Mines, vol. 40, pt. 3 (1931).

For the most part they occur as small dykes and sills, usually quite narrow, in the neighbourhood of 8 to 20 feet. A swarm of such bodies occurs in the area northwest of Swayze River, and west of the granite area in Genoa and Marion. Several were noted on the peninsula between the northern arms of Horwood, and a few cut the sedimentary schists in western Hardiman. Only two bodies of these rocks were found of sufficient size to show on the map. One intrudes the iron formation and pillow lavas about midway between Rush and Woman Rivers, Marion Township. The other, irregular in shape, disrupts the iron range about 1½ miles east of Rush River. These two bodies are not alike. The occurrence west of Rush River is a reddish coloured mass of medium to fine, almost granitoid texture. It consists essentially of pink feldspar, quartz, and biotite, with an unusual amount of pyrite speckled throughout. The larger and better formed crystals are oligoclase. The eastern body weathers a drab-buff to grey. It has huge phenocrysts of quartz in a groundmass composed mainly of greyish feldspar and some biotite. In part it is manifestly granulated, a feature not common to the younger porphyries. The western part of it, particularly, might be more rightfully considered a part of the older porphyry series; comparable to the large body that occurs in central Heenan.

The dykes and sills belonging to this series of younger porphyries vary considerably in appearance, but seem chiefly to be modifications of two types. One, essentially a feldspar porphyry, contains well-formed phenocrysts of feldspar (varying from 2 mm. to as much as 8 mm. in length), a few tiny eyes of quartz, and books of brilliant black mica, embedded in a dense, drab-grey to salmon-coloured groundmass. In thin section the feldspar phenocrysts are found chiefly to be of rythmically zoned oligoclase, but some are soda-orthoclase, and the groundmass is a fine-grained aggregate, largely feldspar, but containing some quartz, a little chlorite, and epidote, specks of iron oxide and apatite, and sometimes small amounts of carbonate and pyrite. The other type is typically a pale greenish grey colour and exhibits well-developed phenocrysts of both quartz and feldspar, and some of muscovite. The groundmass is aphanitic, composed of plagioclase, orthoclase, quartz, and muscovite, with a little biotite, chlorite, and occasional grains of carbonate. The feldspar phenocrysts are again of oligoclase and soda-orthoclase, with the former predominating.

Ordinarily the two types occur within the same general locality, though in some places one or the other is present in prevailing quantities. Wherever they have been observed in contact with one another the feldspar-biotite type was found to be the younger, but they seem of closely related age. They are extremely fresh. Clear of a limited amount of sericitization of the feldspars, a straining of the quartz, and a little chloritization of the biotite they are unaltered.

Younger than either of them but probably belonging to the same general period of igneous activity are dull reddish lamprophyre dykes. These are mainly aphanitic, but carry small books of greenish biotite. Microscopically the groundmass is found to be intergrowths of plagioclase and orthoclase, a little hornblende and epidote, blotches of carbonate, and limonitized pyrite. The biotite phenocrysts are partly altered to chlorite. A dyke of this sort, some 15 or 20 feet in width, cuts north-south across the iron formation and associated rocks just east of the porphyry stock between Rush and Woman Rivers. And, some $\frac{3}{4}$ mile east of Rush River and $\frac{1}{4}$ mile north of the iron formation, a small dyke of this type was observed to intrude one of the feldspar-biotite porphyries which in the same outcrop was found to cut a dyke of the grey quartz-feldspar porphyries.

DIABASE DYKES

A large number of fresh diabase dykes occur. These are the youngest of the solid rock assemblage represented in the area. The greater number of them range in width from a few inches up to 40 or 50 feet, but a few larger ones occur. The largest noted is on the peninsula between the northern arms of Horwood Lake; it attains a width of upwards of 600 feet.

Two distinct types of these rocks have been discerned. The more prevalent is a dense black and greenish black aggregate which often carries huge, more or less rounded, phenocrysts of greasy looking, greenish material, probably altered basic feldspar.[1] The other has a brownish cast, carries an abundance of brownish black pyroxene, long laths of greyish plagioclase, and a little olivine. The two types have not been observed in contact, but the latter variety is believed to be the younger. They cut sharply across the structures of the older rocks. Their contacts are clearly defined, sharply chilled, and seldom accompanied by any appreciable amount of metamorphism. They are present in all parts of the area, and have been observed to cut each of the previously described rock types. Their courses are remarkably straight over considerable distances, but sometimes they make abrupt turns or branch. The dark, porphyritic dykes have a marked tendency to trend northward or a few degrees west of north. The others are less constant, but are likely to strike east of north or about northwest. They have clearly been erupted in the zone of fracture and their trends are apparently controlled by joint systems in the older rock.

Ordinarily they display a well-developed ophitic texture, but some of the larger bodies are in part granitoid. They are distinctly fresh in contrast with any of the other types of basic rock that occur in this area. Essentially they are composed of pyroxene and laths of labradorite with considerable quantities of titaniferous magnetite. The pyroxene is usually ordinary augite, but the olivine-bearing variety is prone to exhibit a pyroxene which in thin section has a peculiar violet colour. It is probably titaniferous augite. The large dyke occurring north of Horwood Lake contains an abundance of this mineral. It is also rich in ilmenite, and olivine is present in subordinate amounts. This dyke perhaps continues northeastward across the peninsula. Rocks entirely similar to it outcrop on both sides of Northeast Arm near the map boundary, and a dyke was followed in a consistent northeasterly direction on the east side of the lake for a half mile or more. North of the boundary of the sheet, throughout this distance, it maintained a width of about 10 chains.

[1]Todd, E. W.: "Groundhog River Area"; Ont. Dept. of Mines, vol. 33, pt. 4, p. 9 (1924).

On the east shore of the Northeast Arm, just north of the map margin, a dykelet $1\frac{1}{2}$ inches wide was observed to intrude the olivine diabase. The dykelet is a fine-grained, blue-black rock which contains well-formed, lath-shaped crystals of labradorite in a groundmass of devitrified glass. A similar dykelet cuts the granite in the vicinity of an olivine diabase dyke near the outlet of Rush Lake. These tiny dyke rocks are probably related to the olivine gabbro, and so far as was discerned they mark the last phase of igneous intrusion in this area.

ECONOMIC GEOLOGY

Mineralization of several types occurs within the area, but no deposits of commercial grade were uncovered at the time of the author's investigation (1930). The early history of prospecting ventures in this region has to do with a search for ores of iron. Considerable attention was devoted to the iron formations during the years 1908 to 1912 and as a result of trenching and drilling operations large bodies of 40 per cent to 45 per cent iron have been proved, but an unfortunate occurrence of pyrite and, sometimes, pyrrhotite, in intimate association with the iron ore minerals militates against the present utilization of these deposits because of the deleterious sulphur that they contribute.[1] Work on the iron formations led directly to the discovery of certain vein deposits. In the year 1910, while drilling for iron on claim W.D. 717, Genoa Township, stringers of galena and sphalerite were discovered in the drill cores of holes Nos. 2 and 3. Later a 3-foot vein of high-grade lead-zinc and copper ore was uncovered by stripping, some 300 feet farther east on the same claim. In subsequent years attention has from time to time been turned to further search for minerals of this nature. In 1927 and 1928 a considerable amount of staking was done adjacent to the iron range in Genoa, and small occurrences of lead and zinc mineralization were discovered at various points. In 1928 and again in 1929 the occurrences of lead-zinc-copper minerals on claim W.D. 717 were explored by a considerable amount of diamond drilling. During the same years indications of gold and copper mineralization were found on the peninsular area between the northern arms of Horwood Lake. And, in 1933, since the writer left the field, veins carrying gold have been reported[2] from the northwest corner of Mallard Township and from the unsurveyed fraction northwest of Swayze River. Small quantities of silver are reported from the lead-zinc veins in Genoa,[3] and from a pegmatitic, molybdenite-bearing sample[4] collected near the west shore of Alike Lake, in the unsurveyed area east of Genoa.

In addition to these deposits of metallic ore minerals a few small bodies of altered peridotite which carry a very small amount of chromite and tiny veins of short-fibred chrysotile asbestos were noted in the area.

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[1]Moore, E. S.: "Sahkatawich (Rush) Lake Section, Woman River Iron Range"; Ont. Dept. of Mines, pt. 2, p. 94 (1926).
[2]Rickaby, H. C.: Preliminary Report Covering Geological Work Done in Swayze Gold Area During Summer of 1933; Ont. Dept. of Mines.
[3]Tanton, T. L.: Geol. Surv., Canada, Sum. Rept. 1916, p. 181.
Bannerman, H. M.: Geol. Surv., Canada, Sum. Rept. 1928, pt. C, p. 27.
[4]Bannerman, H. M.: Op. cit.

One of these outcrops just north of mile-post 5 on the boundary between Genoa and Marion and has been traced eastward approximately one-half mile. It seems to be a sill, but its contacts are not exposed. Its age relations are not known, but presumably it is intrusive into the schists. Another body of similar character occurs about 5 chains south of the McOwen-Genoa boundary, approximately 10 chains east of mile-post 1. Its outcrop dimensions are about 50 by 80 feet. Like the southern occurrence its weathered surface is creamy white to reddish brown in colour, soft and greasy due to the development of talc, serpentine, and carbonates of iron. The asbestos fibre that traverses the serpentinized parts of these rocks is short, and not present in commercial quantities.

IRON DEPOSITS

The extensive iron formations developed in Genoa, Marion, and Heenan Townships can best be described by dividing them into three sections, each section embracing a number of claims. Section 1 will be taken to comprise all of the iron formations in the area lying west of Woman River; section 2 that part of the range located between Woman and Rush Rivers; section 3 the part extending east of Rush River.

Section 1

The deposits comprising the iron range west of Woman River were described by Allan[1] in 1909 and again by Furse[2] in 1932. Essentially they are lean, finely banded, cherty carbonate and jaspilites, too siliceous and fine grained to be considered of commercial significance. This is particularly true of the section from Woman River westward across claims W.S. 6, 5, and 4, and the southeasterly part of the band that lies across the Heenan-Benton boundary line. Locally on claims W.S. 11 and 12, however, the iron content increases so that thin bands of fair grade occur over widths of 10 to 20 feet. The iron ore minerals are magnetite, hematite, and siderite, with a small amount of pyrite. There is no appreciable amount of secondary enrichment. The ore minerals are intimately mixed with fine-grained quartz.

The siliceous iron formations reach a maximum development on claims W. S. 7 and 8 where they stand up in strong relief above the surrounding country. This part of the section has been profoundly disturbed by folding and faulting. Two large bodies of iron formation occur; one broad band rises sharply from a swamp area about the northwest corner of claim W.S. 9 and extends northeastward to the southwest corner of W. S. 7 where it ends just as abruptly, its place being taken by andesite flows. The other, strikingly similar body, lies to the northeast of this, and occupies the southeast section of W. S. 7 and the eastern part of W. S. 8. Both bodies are tightly folded and locally brecciated. Both show a general development of magnetite and iron-rich amphibole in contrast to the more prevalent hematite and carbonate of the adjacent sections of

[1]Allan, R. C.: Ont. Bureau of Mines, vol. 18, pt. 1 (1909).
[2]Furse, G. D.: Ont. Dept. of Mines, 41st Ann. Rept., vol. 43, pt. 3 (1932).

the range. They are highly siliceous, lean in iron, particularly near the western contacts. On the eastern slopes, however, of each of the bodies, local bands rich in magnetite occur which, though intimately mixed with quartz and amphibole and interlaminated with highly siliceous bands, are sometimes present over narrow widths in quantities sufficient to produce a low-grade ore. There is very little pyrite in this part of the range and Allan[1] reports the phosphorus to be low. A considerable amount of trenching had been done across the strike of the bands on claims W.S. 11, 12, and 8, some twenty-six years ago. The trenches were so littered by earth and organic matter when the author visited the area, however, that they revealed little.

Section 2

The iron-bearing formations that lie between Woman and Rush Rivers are essentially similar to those described from the Heenan section. Except where they are locally sheared, compressed by tight folding, or intruded by younger igneous bodies, they are typically finely banded, cherty carbonates and jaspilites.

The iron formation is not over 70 or 80 feet wide where it outcrops at the edge of the flood-plain deposits on the west side of Woman River, and where first picked up on the east side it is found to be of similar dimensions. Eastward, however, it widens rapidly, and divides into a wing-shaped body, apparently due to diagonal faulting. Across W.S. 3 it is largely fresh-looking, cherty carbonate and finely bedded jaspilite. On W.S. 1 and 2 the bands are darker in colour and more altered. They contain a good deal of magnetite and some amphibole, and seem, on the whole, to possess a higher iron content. No analyses have been made, however, and it may be that the apparent enrichment in iron is illusory, due to the relatively increased amount of oxides of iron that are present. On W.S. 1 the band attains a maximum width of about 600 feet, but this increase is probably due to folding and, perhaps, faulting. East of W.S. 1 the bands are interlayered by appreciably more tuffaceous material than is common in the western sections, and they are broken by small faults. The bands, here, are largely hematitic jasper. Near Rush River the associated tuffs are strongly sheared locally, and have suffered considerable carbonatization. There is very little pyrite present in this part of the range, but the bands are rather lean and very fine grained.

Section 3

East of Rush River the character of the iron range changes appreciably. Whereas in the western sections jaspilites and banded, cherty, carbonate iron formations are present in large bands, here they become subordinate and are interbedded with considerable quantities of tuffaceous and cherty sediment and, occasionally, lava flows. The change is not abrupt, as a marked increase in the amount of fragmental material within the siliceous formations is evident as the range is traced eastward from Woman River, but in the eastern section the bands of siliceous iron formation are,

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[1]Allan, R. C.: Op. cit.

in comparison, quite small and the amount of interlayered material quite important. Another, more outstanding difference, and one that may sometime have economic significance, is the presence at intervals all along the eastern part of the range, from a point about 900 feet east of Rush River to the granite contact in Genoa Township, of lens-like bodies of iron carbonate and iron sulphides. Some of these bodies attain considerable size. They carry a higher concentration of iron than is present in any sizable parts of the section previously described, or than is present in any of the siliceous iron formations that occur within this section. Essentially they are composed of fine-grained carbonate and pyrite, but in polished section they are found to contain varying amounts of magnetite and pyrrhotite. They are easily accessible and were it not for the unfortunately high sulphur content that typifies all of them, this part of the range would yield considerable quantities of minable iron ore.

These sulphide-carbonate deposits are located for the most part within the acidic schists, at or near the contact between this member and the most southerly band of the siliceous iron formation, but some of them, for example on claim W.D. 1731, lie partly within the banded silica, and small bodies of similar character were noted north of the main iron range in the vicinity of claim W.D. 1733. The surface outcrop of these bodies is reddish brown, due to the partial oxidation of the iron carbonate and sulphides to red oxides of iron. They exhibit no banding comparable to that of the adjacent siliceous iron formations. They have indefinite boundaries, tend rather to fade out along and across the strike into more normal facies of the rocks in which they lie, and they sometimes surround irregular, siliceous blocks of these associated rocks. Ostensibly they are replacements; later in time of origin than the rocks that enclose them. But they are inclined to follow the main structures of the adjacent formations, and this, together with the facts that they are older than the diorites and porphyries, and than the folding that has affected the Schist Complex, suggests that they are perhaps not much later than the rocks in which they are enclosed.

A block of twenty-four claims includes the greater part of the iron range east of Rush River. They were staked by Mr. W. E. Smith, now of Duluth, and are the property of the Jefferson Mining Company, of which Mr. Smith is the representative. A trail leading eastward from Rush River follows the iron range northeastward across Marion and Genoa to claim W.D. 717, thence it swings southeast to the shore of Rush Lake. This section of the iron range can thus be easily approached and followed.

The locations were staked about the years 1908-9, and subsequently they have been accorded considerable attention in the way of systematic prospecting. A large amount of stripping and some trenching have been done, and in 1910 some 4,000 feet of diamond drilling was driven in search of ores of iron. In 1928 and 1929 additional drilling on claim W.D. 717, in search of lead-zinc ores, also cut considerable thicknesses of sulphur-rich iron formations. The economic potentialities of this part of the range have been discussed in detail by Moore,[1] in 1926, and, briefly, by the writer[2] in 1928.

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[1]Moore, E. S.: Ont. Dept. of Mines, vol. 35, pt. 2, pp. 89-94 (1926).
[2]Bannerman, H. M.: Geol. Surv., Canada, Sum. Rept. 1928, pt. C, pp. 23-24.

Throughout the first $1\frac{1}{2}$ miles (claims W.D. 1736 to W.D. 1732) east of Rush River the iron range and associated deposits are greatly deformed, so that the siliceous bands are found variously trending toward all the points of the compass. They are folded and brecciated and sometimes bands of finely bedded jaspilite give place abruptly along the strike to fissile chloritic, or felsitic, carbonated schists, that occasionally have been observed to strike almost at right angles to the bedding in the iron formation. The regional schistosity throughout this part of the section trends north 60 degrees west to north 70 degrees west. The erratic distribution of the iron formation bands and the variations in strike are caused in part by folding, but the abruptly terminating bands are best explained on the basis of small-scale faulting. The banded silica member occurs in three bands interbedded with acidic tuffs and porphyries. They are small and of no commercial significance. A number of bodies of the carbonate-pyrite type occur on these claims; most of them are poorly exposed, but some of them seem to be of considerable size. On claims W.D. 1736 and W.D. 1735 bodies varying in width from 10 to 100 feet and in length up to 125 feet are exposed by strippings. They are variously orientated and usually they abut a narrow band of siliceous iron formation. In some outcrops they lie on the right, in others on the left, of the banded silica member and followed along the general trend of the range they are found to be interrupted by intrusive bodies of greenstone and by dykes of porphyry. Presumably they are folded and disconnected blocks of bodies that were once continuous. They bear marked similarity to each other both in structural relations to the associated rocks and in mineral composition. It is probable that approximately one-third of the exposed portions would yield upwards of 40 per cent iron, but all are high in fine-grained pyrite so intimately intermixed with the iron ore minerals as to destroy much of their value.

On claim W.D. 1734 fairly large deposits of entirely similar composition occur. They are located for the most part in the schists on the south side of the banded silica, but in part they are in the silica member. They are separated by intrusive bodies of greenstone and diabase and disturbed by a small fault. They each show a width of from 60 to 90 feet. One is exposed 330 feet and another 100 feet along the strike, and it is roughly estimated that one-half of the exposed sections would yield 40 per cent iron, but here, too, fine-grained pyrite comprises about 20 per cent of the mineral assemblage.

The iron formation can be traced northeasterly across claim W.D. 1733, but no sizable deposits are exposed except near the north-central part where a body of average grade, measuring 50 by 150 feet, occurs. Thence on claim W.D. 1732 the range is almost entirely destroyed by a large intrusion of coarse-grained quartz porphyry. A small shaft is sunk in a block of iron formation, which outcrops over a width of 75 feet and a length of 150 feet near the south boundary of this claim, and a diamond drill hole is located about 80 feet southeast of this. The hole is ledged in the quartz porphyry and inclined at an angle of 65 degrees to the northwest. It failed to cut the iron formation.[1] Apparently the latter has been cut

[1]Moore, E. S.: Ont. Dept. of Mines, vol. 35, pt. 2, p. 91 (1926).

off here by the intrusion of porphyry. Moore[1] reports an analysis made from average material from the dump at the shaft on the claim which gave: iron 40·44 per cent; silica 11·25 per cent; sulphur 31·44 per cent.

On claim W.D. 1731 bodies of average sulphide-carbonate iron formation varying in width from 20 to 60 feet may be traced over a distance of about 600 feet. It lies south of a narrow but badly crumpled band of siliceous iron formation and is cut by dykes of altered diabase and by quartz porphyry. A short distance west of the small creek that crosses the range on claim W.D. 1730 the sulphide-carbonate member seems to die out, but the silica member, locally displaced by porphyry, persists to the east side of the creek.

There are no important iron deposits exposed on claim W.D. 1730, though carbonated schists outcrop about 200 feet south of the trail some 700 feet east of the creek and strong dip needle readings were obtained a short distance east of this point. Nor are there any large bodies exposed on W.D. 1729, though a fairly persistent band of siliceous iron formation was traced across this claim and the northwestern part of claim W.D. 728. Near the northeast corner of the latter claim, however, a stripping 30 by 105 feet exposes 15 to 20 feet of sulphide-carbonate iron formation, and at a distance of about 80 feet southeast of the stripping diamond-drill hole No. 9 is driven in rhyolite schists at an angle of 70 degrees to the northwest. A 5-foot sample of the core taken at a depth of 280 feet yielded[2]: iron 41·28 per cent; silica 4·21 per cent; sulphur 15·16 per cent; phosphorus 0·015 per cent. A specimen sample collected at the surface by Moore[3] gave on analysis: iron 42·10 per cent; sulphur 20·20 per cent; lime 0·46 per cent; and magnesia, trace.

About 900 feet east of here, on claim W.D. 727, a somewhat wider but very similar band of the sulphide-carbonate type of deposit occurs along the south contact of a 30-foot band of siliceous iron formation. The banded silica stands on edge, and strikes north 50 degrees east. Two diamond drill holes (Nos. 7 and 8) have been driven at this location to test the continuity of the body. Both holes are located in the acidic schist south of the trail, inclined 45 degrees and 75 degrees, respectively, to the north. No. 7 hole intersects 101 feet, and No. 8, 126 feet, of sulphide-carbonate iron formation and shows the body to be slowly bending southward. A 5-foot core sample taken from No. 7 at a depth of 145 feet, and a similar sample taken at a depth of 220 feet from No. 8, gave the following figures:[4]

—	No. 7	No. 8
	Per cent	Per cent
Iron	39·98	41·77
Silica	6·32	3·12
Sulphur	16·61	16·69
Phosphorus	0·012	0·013

[1]Moore, E. S.: Op. cit.
[2]Data published by courtesy of W. E. Smith, analyses made by Lerch Bros., Hibbing, Minn.
[3]Moore, E. S.: Op. cit.
[4]Data published by courtesy of W. E. Smith, analyses by Lerch Bros., Hibbing, Minn.

A body 40 feet wide, of which 25 feet is average material of this type, occurs on the southwest corner of W.S. 726. This is probably a continuation of that exposed on W.D. 727. A wide swamp and drift area intervenes to the east of here and the range can only be traced brokenly across claims W.D. 725 and W.D. 724. On W.D. 723 a body of sulphide-carbonate iron formation 20 feet wide outcrops, part of which is about average grade. Diamond drill holes 5 and 6 are located near the south boundary of this claim, some 75 and 150 feet, respectively, south of the iron formation outcrops. Both are inclined 65 degrees toward the north. Average of analyses of a band 14 feet thick cut by hole No. 5 at a depth of 181 feet gives the following[1]: iron 42·69 per cent; silica 8·87 per cent; sulphur 22·93 per cent; phosphorus 0·0165 per cent. The lowest sulphur analysis was 18·36 per cent.

The sulphide-carbonate member persists eastward to the western edge of claim W.D. 723, but beyond that it was not located, although small outcrops of banded silica were observed, which strike east-west and stand on edge or dip steeply toward the south. Another lens of the sulphide-carbonate member appears, however, near the east boundary of this claim, about 120 feet south of the trail. It is 15 feet wide, as exposed, and it can be traced eastward with fair persistency across claims W.D. 720 and the succeeding claims to W.D. 715 where the iron formations are cut off by batholithic intrusives. Throughout this distance it varies considerably in width. Near the west boundary of claim W.D. 720 a stripping reveals it to be about 20 feet wide. Traced east-northeast across the southern edge of claim W.D. 719 trenches show it to vary from 20 feet to 33 feet in width and near the southeastern corner of the latter claim it expands to an outcrop width of 60 feet. Across claim W.D. 719 and on the eastern margin of claim W.D. 717 it varies from 20 to 40 feet in width, averages about 30 feet, and is flanked on the north by a narrow band of lean, siliceous iron formation which dips southward at angles varying from 75 degrees to 85 degrees. On claim W.D. 719 it is cut by a dyke of the younger diabase which has offset the deposit about 35 feet, the west side being thrown northward, and on claim W.D. 718 another entirely similar dyke intersects it, and a small dyke of quartz-feldspar porphyry also intrudes it. Barring slight structural complications, these intrusives do not seem to have modified the iron formations to any appreciable extent.

The sulphide-carbonate member continues along the hanging-wall side of banded silica more than half-way across claim W.D. 717, but beyond that it seems to lie a little south of the contact. It is 40 feet wide at the west boundary of claim W.D. 717 and across this claim to the eastern side of claim W.D. 715 it averages between 30 and 40 feet in width; it strikes about 70 degrees east of north. East of this the banded silica member persists, but the sulphide-carbonate type seems to pinch out or goes under cover to the south of the siliceous bands. Midway across claim W.D. 715 where the banded silica turns southeasterly only about 5 feet of the sulphide-carbonate member was found.

The mineral composition of the sulphide-carbonate iron formation is somewhat different on these eastern claims from that of the bodies occurring

[1]Data courtesy W. E. Smith. Analyses made by Lerch Bros.

in Marion. Whereas the Marion deposits are of iron carbonate, fine-grained pyrite, and a little magnetite, with only local occurrences of pyrrhotite, those occurring in Genoa contain important quantities of magnetite and, particularly toward the eastern end, on claims W.D. 717 and 715, pyrrhotite compares in abundance with the pyrite. Carbonate is still present but in lesser amounts, and the total iron content is a little higher. These differences are believed by the writer to be due mainly to metamorphism induced by the large intrusive of granitic rock that cuts off the iron formation on the eastern side of claim W.D. 715, although some of the iron as pyrrhotite may have been introduced[1] along with the lead-zinc and copper minerals that have been found in the iron formation on claim W.D. 717.

Two diamond drill holes (Nos. 1 and 4) are driven near the eastern end of the boundary between claims W.D. 720 and 719. They are in the acidic schists south of the 60-foot body of sulphide-carbonate referred to above. Hole No. 1 is located 70 feet south of the iron formation, and dips 65 degrees northward. Hole No. 4 is 90 feet farther south and 40 feet east of this. It is inclined at 62 degrees toward the north. They each cut large bodies of sulphide-carbonate iron formation. Hole No. 1 passes through 58 feet of material, the average of twelve analyses of which gave: iron 46·18 per cent; silica 12·90 per cent; sulphur 16·34 per cent; phosphorus 0·018 per cent. Hole No. 4 cut 42 feet of similar material which averages: iron 46·54 per cent; silica 13·19 per cent; sulphur 16·91 per cent; and phosphorus 0·018 per cent. The iron ratio ranges from a maximum of 50·20 per cent to a minimum of 42·56 per cent; the silica from a low of 5·0 per cent to a high of 20·31 per cent and the sulphur from 9·17 per cent to 30·04 per cent. The body was intersected at 203 feet 6 inches by hole No. 1; at 281 feet by hole No. 4. The iron formation seems to be about 40 feet thick where cut by these holes. The body is curving southward and in both holes it is separated into two parts by a thin band of acid rock, possibly the continuation of the small porphyry dyke found intruding the outcrop of this body at various places along these claims.

Near the west boundary of claim W.D. 717 diamond drill holes Nos. 2 and 3 are at angles of 70° and 86° 30′, respectively, at a point 38 feet south of the iron formation. The banded silica north of the sulphide-carbonate body at this place strikes north 70 degrees east and dips about 80 degrees southward. From depths 148 to 263 hole No. 2 passes through material averaging: iron 46·08 per cent; silica 14·44 per cent; sulphur 16·99 per cent; phosphorus 0·021 per cent. The high for iron is 50·22 per cent; low 32·19 per cent. Silica varies from 7·59 per cent to 29·16 per cent; sulphur from 7·63 per cent to 27·08 per cent. Hole No. 3 cut iron formation of a very similar grade from a depth of 235 feet to 385 feet. A surface sample selected at this place by Moore[2] gave on analysis: iron 48·04 per cent; silica 15·60 per cent; sulphur 19·44 per cent.

In addition to these drill holes which were put down in 1910, additional drilling was done at points east of holes 2 and 3, in 1928 and 1929. The primary purpose of the latter drilling was in search of minable bodies of lead and zinc, but incidentally the cores prove the continuance of iron

[1] Moore, E. S.: Op. cit., p. 89.
[2] Moore, E. S.: Op. cit., p. 93.

deposits of this grade. Thus holes Q 3 and C 9, located 50 feet east of Nos. 2 and 3, and holes Q 4 and C 10, located 50 feet still farther east, each cut a body of iron formation which averages around 30 feet in thickness and runs 46 per cent to 47 per cent iron, 9·5 per cent to 9·70 per cent silica, 21·38 per cent to 21·57 per cent sulphur.[1]

Patches of banded silica iron formation occur south of the main range at this place, on claims W.D. 716 and S 3693. On W.D. 716 a band strikes 25 to 30 degrees east of north, and is bounded on the east side by a highly metamorphosed facies of greenish tuff. Near the east boundary of S 3693 another small band has a somewhat similar trend and is in contact on the east with granite, and on S 3693 still another remnant is caught up in an intrusive mass of coarse-grained diorite. The area to the west of these disconnected fragments is underlain by the rhyolite tuff. They seemingly lie along the contact between the tuff and the granitic intrusives that occupy the area to the east. The rhyolite tuff has not been recognized east of claim W.D. 715, but, instead, the granites are intrusive into more basic lavas and tuffs, similar to those that occupy the area north of the main band of siliceous iron formation. It is probable, therefore, that the iron formation on claims W.D. 716 and S 3693 are fragments of the south limb of an asymmetric fold, and that they can be correlated with the southern band on W.D. 717. They have been stripped in fairly comprehensive manner. The occurrence on S 3693 carries considerable pyrrhotite, pyrite, and magnetite, but no body of important size seems to be present. The extension of the range east of W.D. 715 is of lean banded silica, similar in grade and associations to the more northerly bands that occur across the claims to Rush River. It is of no commercial interest as a source of iron.

From the foregoing data it is evident that large deposits of iron are present on these claims. Extensive bodies in Marion Township will run 40 per cent to 43 per cent, and in Genoa the iron content is in the neighbourhood of 45 per cent to 46 per cent. Moore[2] estimated that, within 100 feet of the surface, there are on the Marion claims (W.D. 721 to 728 and W.D. 1729 to 1736) some 2,800,000 tons of material carrying 40 per cent iron available, and there seems good reason to expect the deposits to persist to much greater depths with reasonable constancy in grade. In the Genoa section, claims W.D. 720 to W.D. 715, stripping and drill core data indicate upwards of 5,000,000 tons of iron formation within a depth of 400 feet which will carry around 45 per cent iron. But throughout the entire range the sulphur content of these bodies runs high. In the Marion section it averages around 18 per cent or 19 per cent and in the Genoa section around 16 per cent. The sulphur, largely present in the form of fine-grained pyrite (FeS_2), shows a general though not parallel tendency to be high along with the iron, in a given body, in direct opposition to the silica variance. It is well distributed throughout the various bodies that have been examined, and the drill core records do not hold out much hope that this deleterious substance will decrease appreciably at depth. Each of the deposits sampled will require special treatment to eliminate the sulphur

[1]Analyses published by courtesy W. E. Smith. Drill holes C9 and 10 driven by Rush Lake Mining Company in 1928. Holes Q3 and Q4 by Canam Metals Company, Limited, in 1929.
[2]Moore, E. S.: Op. cit., pp. 91–92.

before the material can be used as an ore of iron. Experiments[1] have been conducted with a view to preparing a merchantable iron ore from these deposits, and the results show that it can be done, but the cost of such preliminary treatment will in all probability forbid their exploitation on a commercial basis for the present.

COPPER DEPOSITS

Small veins bearing copper mineralization were noted on the peninsula between the two northern arms of Horwood Lake. On claim S 11994, located almost due east of the mouth of Swayze River, a crushed and drag-folded zone 16 feet wide, in highly crenulated, chloritic tuffs, contains a vein that averaged 15 inches wide over an exposed length of 10 feet. The vein is predominantly pyrrhotite and pyrite, but in places as much as 10 per cent of the total is chalcopyrite, and a little sphalerite also occurs. The gangue minerals are chlorite, talc, carbonate, and quartz. The greater part of the sulphides fill cavities in the crushed zone, but some have wandered out into the wall-rock. The quartz is spotty, occurs mainly in cavities, and the zinc and copper minerals show a marked tendency to occur with the quartz. A sample selected by the writer from the more heavily mineralized part of the vein yielded: 0·27 troy ounce silver, 1·87 per cent copper, but no gold.

LEAD-ZINC DEPOSITS

While drilling holes Numbers 2 and 3 on claim W.D. 717, Genoa Township, stringers of galena and sphalerite were discovered in the cores. Analysis of the core of hole No. 3 from a depth of 203 to 215 feet yielded an average of 9·95 per cent zinc and 14·95 per cent.[2] Subsequently, a galena-sphalerite vein of some promise was discovered in a trench 360 feet east of these drill holes. In 1912 additional stripping was done and a small shaft sunk on the vein. In 1928 the property, part of the block of claims owned by Jefferson Mining Company, was optioned to the Rush Lake Mining Company, who proceeded to drill the property in search of commercial ore-bodies of lead and zinc. Ten holes were driven, aggregating over 1,500 feet, by this company in the early spring of 1928, and in 1929 Canam Metals, Limited, obtained a sub-lease on the property and drilled four additional holes, aggregating 1,064 feet. The holes have all been driven from the south side of the deposit. They are dipped toward the north at angles of 60 to 65 degrees, and are staggered along the strike of the vein over a distance of 360 feet.

The deposit has been described by Tanton[3] in 1916, by Moore[4] in 1926, and subsequently by the writer.[5]

[1] *See* Moore, E. S.: Op. cit., p. 94, for extract of report by Dwight and Lloyd Sintering Co., N.Y.
[2] Data by courtesy W. E. Smith. Determinations by W. Millhouse, National Zinc Separating Co.
[3] Tanton, T. L.: Geol. Surv., Canada, Sum. Rept. 1916.
[4] Moore, E. S.: Ont. Dept. of Mines, 35th Ann. Rept., pt. 2, pp. 94-96 (1926).
Trans., Can. Inst. Min. and Met., vol. 29 (1926).
[5] Bannerman, H. M.: Geol. Surv., Canada, Sum. Rept. 1928, pt. C, pp. 24-25.
Geol. Surv., Canada, Sum. Rept. 1929, pt. C, pp. 2-6.

The vein is located at the edge of the southern band of iron formation.

"The wall-rock of the vein is a chloritized, garnet-bearing quartz-actinolite schist, located immediately south of the banded silica, and profusely impregnated and replaced by pyrrhotite, pyrite, and some magnetite. The schists strike north 70 degrees east, parallel to the trend of the banded silica, and the strike of the vein is about 65 degrees. The small shaft that has been sunk on the vein was full of water when the property was examined by the writer. Moore,[1] however, reports it to be about 8 feet deep, and to be bottomed on a lens, 34 inches wide, of almost solid galena. The surface outcropping of the vein is 18 inches wide on the east margin of the pit. It pinches to 15 inches at a distance of 10 feet eastward, and beyond that it is not easily defined, but 50 feet east of the shaft there is an irregular zone 36 inches in width, which carries a fairly high concentration of galena, sphalerite, and chalcopyrite. Numerous small veinlets, composed essentially of sphalerite, permeate the wall-rock on either side of the vein. These are often accompanied by a gangue of calcite, dolomite, and epidote, and in some cases quartz and pink feldspar are sparingly present. In a cross trench 112 feet east of the shaft the main vein does not appear, but 25 feet northward across the strike a number of veinlets of sphalerite occur.

"In thin sections the wall-rock which contains the sphalerite veinlets is found to contain an abundance of chlorite, green, fibrous, radiating amphibole, and talc, together with some calcite and siderite, all of which seem to have developed along with the ore minerals. Many of the garnets are found to be completely replaced by chlorite and dust-like magnetite. The sphalerite and galena are often accompanied by a little pyrite, and are sometimes intricately intergrown with radiating aggregates of anthophyllite or as minute veinlets between fan-like structures in the latter. The anthophyllite replaces the chlorite, and seems to be the latest of the gangue minerals to crystallize.

"Two generations of pyrite appear to be present. The older is abundantly present in the iron formation throughout the eastern section of the range, and it is distinctly earlier than the galena-sphalerite veins. It displays broken and corroded outline, under the microscope, and in places is almost completely replaced by pyrrhotite. The younger pyrite on the other hand is associated with the galena sphalerite veins, but in sparing quantities. It is fresh and relatively unbroken and sometimes it is found as well-formed euhedra in the veinlets with anthophyllite and chlorite. The pyrrhotite is veined and replaced by chalcopyrite, and by sphalerite. The relative age of the chalcopyrite and sphalerite is doubtful, but the galena replaces both."[2]

The diamond drill records show the deposit to be in an irregular system of veins which swell, pinch, overlap, and tail out into the schists and iron formation along a general north-northeast strike. The holes pass through a complex of rhyolite tuff, quartzite, chloritic quartzite schist, altered diabasic intrusives, sulphide-carbonate iron formation, and banded silica, and some of them bottom in the green schists that underlie the banded silica at this place. Stringers of the ore minerals occur in each of these rock types, including the intrusive diabasic rocks. In the stronger rocks the veinlets are prone to occur between sharply bounded and slickensided chloritized walls, but in the soft chloritic material a tendency to disseminate into the wall-rock is manifest.

Lead-zinc mineralization of a similar nature but on a smaller scale was observed in a shear zone in green, chloritic tuffs on claim S 5991, located immediately north of W.D. 717; in highly siliceous banded silica on the south shore of Northcott Bay, Rush Lake, and in a crushed zone

[1]Moore, E. S.: Trans., Can. Inst. Min. and Met., vol. 29, p. 4 (1926).
[2]Bannerman, H. M.: Ibid., p. 5.

in the dioritic facies of the large basic intrusive near Gowagamak Lake. Each of these has been described in Geological Survey, Canada, Summary Report 1929, Part C. As exposed in 1929 they did not contain important quantities of valuable minerals, but they are of interest in determining the age relations of the mineral deposits of this nature. In every case noted both in this area and in Cunningham Township,[1] where a very similar type of mineralization occurs, the lead-zinc and associated vein minerals are found to be distinctly later than the schists and iron formations in which they occur, and also to post-date the basic intrusives, close to which they seem prone to occur. Moreover, on S 5991, Genoa Township, in a small trench near the southwest corner of the claim, a dyke of biotite-bearing quartz-feldspar porphyry is exposed, which carries a sprinkling of pyrite and tiny veinlets of galena and sphalerite in a gangue of calcite. Near at hand a dyke of precisely similar nature is intrusive into a sill of altered diabase, which in turn intrudes the members of the Schist Complex here represented. Accordingly, the porphyry dyke is believed to belong to the later series of younger porphyries prevalent in several parts of the area. Another small occurrence of interest in this regard was observed on the west side of Northeast Arm, Horwood Lake, just north of the map boundary, where a rather large mass of a muscovite-bearing facies of porphyry, with a peculiar pale greenish hue and an almost granophyric texture, intrudes schistose tuffs and impure sediments. Quartz veins that lie in the porphyry carry small amounts of pyrite and galena.

It seems reasonably well established then that the mineralization represented by the metalliferous vein deposits not only post-dates the basic intrusives, but also to some extent at least the younger porphyries. The porphyries are the latest phase of acidic magma represented in the area so far as is known, and on theoretical grounds it is reasonable to believe that the ore minerals are genetically related to them. This idea was suggested by Moore[2] in 1926, and in the opinion of the writer it is well founded. The parts of the area that have been invaded by these porphyries are, therefore, particularly worthy of careful scrutiny for possible occurrences of metalliferous deposits, and in this connexion the writer would draw attention to the areas in Newton and in central Heenan, where porphyries of uncertain age occur, as well as to the sections recounted previously where dykes of the younger porphyries have been identified.

[1]Bannerman, H. M.: Geol. Surv., Canada, Sum. Rept. 1929, pt. C.
[2]Moore, E. S.: Trans., Can. Inst. Min. and Met., vol. 29 (1926).

AMULET MINE, NORANDA DISTRICT, QUEBEC

By M. E. Wilson

CONTENTS

Illustrations

INTRODUCTION

The ore deposits of the Amulet mine belong to the groups of sulphide ore masses occurring here and there in the Abitibi (Keewatin) volcanic complex of western Quebec. Of these the Noranda is the best known and most important example. The Amulet deposits lie about 5 miles northwest of Noranda and, except for the presence of considerably less gold and much more sphalerite, are essentially similar in mineralogical composition to the Noranda ore masses. There is, therefore, little doubt that the ores at the Amulet and the Noranda are related in origin, but the difference in the proportion of minerals composing the ore in the two localities and the absence, so far as known, of the peculiar cordierite-bearing alteration rock, dalmatianite, at the Noranda, suggest that the composition of the emanations from which the ore was deposited and the condition of deposition were somewhat different at the two properties.

FIELD WORK AND ACKNOWLEDGMENTS

The description of the Amulet mine that follows is based on an examination of the property undertaken as a part of the investigation of the Noranda map-area. This geological map, now partly completed, includes an area about 10 miles long and 4 to 4½ miles wide adjacent to the Noranda, Amulet, and Waite-Ackerman-Montgomery and nearby mining properties, and is being prepared on the scale of 800 feet equal 1 inch. The study of the Amulet mine included the preparation of a geological map of an area of about 1 square mile adjacent to the ore deposits, and the examination of the accessible workings and diamond drill cores within the area of the special map.[1]

The writer is indebted to the officials of Amulet Mines, Limited, for their co-operation in his work. Thanks are especially due to Mr. F. M. Connell, President of the company; to Mr. W. G. Hubler in charge of the Amulet at the time of the writer's examination; and to Mr. J. G. MacGregor for the large amount of geological data shown in plans prepared by him at the Amulet. Acknowledgments are also due to J. S. Stevenson and J. D. Turner, student assistants, through whose capable and energetic assistance the preparation of the geological map of the Amulet was made possible.

LOCATION, OWNERSHIP, AND HISTORY

The property formerly owned by Amulet Mines, Limited, and recently acquired by a new company known as Waite-Amulet Mines, Limited, includes three groups of claims in Rouyn district. The most important of these is Group A which lies across the boundary line between Dufresnoy and Duprat Townships. The claims included in the group are M. L. 1889-1892, M. L. 1896-1898, and A 1394-1403, all of which were staked by Joseph and Peter McDonough in the winter of 1922-23, and were sold by them in 1923 to the late R. E. Popham and associates who organized a company known as Amulet Gold Mines, Limited (later changed to Amulet Mines, Limited), to take over the ownership of the property. The first discovery of ore (Mineralized Area Number 1) was made in the autumn of 1924 in claim M. L. 1897; in 1925, three additional areas of mineralization—Number 2 in claim M. L. 1891, and Numbers 3 and 4 in claims M. L. 1889—were found; and in 1929 the Number 5 (or F) group in claim M. L. 1891, east of area Number 1, was discovered by diamond drilling. All these occurrences of ore, as they were discovered, were delimited by systematic diamond drilling, and groups of deposits Numbers 4 (C) and 5 (F) were further developed by vertical shafts and lateral workings. During the summer of 1929 and the following winter a concentrating mill with a capacity of 300 tons a day was built on the property. This mill was completed in April 1930, and from that time the mine and mill were operated continuously until the following October when, owing to the unprecedented decline in the price of copper and zinc, work on the property was discontinued and has not since been resumed. In September, 1933, a union with the Waite-Ackerman-Montgomery mine, which adjoins the Group A claims of the Amulet on the north, was effected, ownership of the combined properties to be vested in a new company to be known as Waite-Amulet Mines, Limited.

[1]Hand-coloured copies of the Amulet map (scale 1 inch equals 100 feet) have been supplied to the Bureau of Mines, Quebec, the Mining Recorder at Noranda, the Secretary of the Western Quebec Branch of the Canadian Institute of Mining and Metallurgy, Amulet Mines, Limited, and Noranda Mines, Limited.

PREVIOUS WORK

The most important previous descriptions of the Amulet mine from a geological standpoint are those of J. G. MacGregor and H. C. Cooke. In these the association of most of the ore deposits with the zone of rhyolite flow breccia that crosses the property, and the close relationship of the cordierite-bearing alteration rock, dalmatianite, with the ore, are described. These relationships, first noted by Mr. MacGregor, are plainly evident on the map of the property. The mineralogical descriptions and analyses of the dalmatianite contained in the paper of T. L. Walker are also important contributions to the geology of the Amulet. The history of the development of the property in greater detail than that given in this report may be found in the reports of A. O. Dufresne and R. H. Taschereau of the Quebec Bureau of Mines. The milling process used to concentrate the ore is described in the paper of Mr. W. G. Hubler and the experimental tests on the ore in the laboratories of the Mines Branch, Department of Mines, Ottawa, are described in the reports of C. S. Parsons, A. K. Anderson, and J. S. Godard.

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GENERAL GEOLOGY

The rocks of the region in which the Amulet mine occurs, except for a quartz diabase dyke of late Precambian (possibly Keweenawan) age, belong to an early Precambrian complex consisting chiefly of Abitibi (Keewatin) lavas cut by numerous intrusive rocks of various ages. These intrusive rocks include numerous minor intrusives, that is, dykes or sills only a few feet wide; masses, dykes or sills of diorite or quartz diorite; and dykes, stocks, or batholiths of granodiorite and related acidic rocks.

The rocks occurring near the ore deposits of the Amulet, with the exception of a single outcrop of chert, are all igneous, the approximate succession of which is as follows:

Late Precambrian (?)	(13)	Quartz diabase dyke
Early Precambrian	(12)[1]	Granodiorite in dykes, a stock and a batholith
	(11)[1]	Albite alaskite granite in small masses or dykes
	(10)[1]	Andesite dykes
	(9)[1]	Dacite (feldspar) porphyry dykes
	(8)	Diorite and quartz diorite in masses, dykes, or sills
	(7)	Rusty-weathering, pyritic, epidotized dyke rock
	(6)	Andesite dykes or sills
	(5)	Rhyolite (quartz-albite) porphyry in small masses, dykes, or sills
	(4)	Andesite dykes and sills
	(3)	Hornblende dacite
	(2)	Quartz diabase masses and dykes
	(1)	Abitibi volcanics (Keewatin): chert, andesite, rhyolite, and rhyolite flow breccia

ABITIBI (KEEWATIN) VOLCANICS

The outstanding geological feature of the Amulet property is the contact between two belts of Abitibi volcanics that crosses the property with a sinuous course from north to south (Figure 4). West of this line of contact the rock consists of rhyolite and rhyolite flow breccia. To the east it is andesite. The rhyolite and rhyolite flow breccia, which are the older rocks, and underlie the andesite, consist largely of blocks of white to pale grey or blue-grey weathering rhyolite up to 30 feet in diameter, enclosed in a buff to grey weathering, variegated matrix that was originally, as can be observed from the pattern on the weathered surface, vesicular or coarsely cavernous. Amygdules are abundant in both the included blocks and the matrix, and flow lines in the matrix may be observed in many places in zones encircling the inclusions. In a few places laminæ were also noted in the breccia blocks along their edges, a relationship suggesting that a certain amount of remelting occurred at these points. Most of the included masses have rounded corners, but at one point a small block was observed with edges parallel the margin of a larger mass nearby. All of these features indicate that both the matrix and the inclusions of the rhyolite breccia were originally lava and that the rock is a flow breccia.

In places in the rhyolite breccia matrix there are zones of banding and lamination up to several feet wide, some of which are composed of spherulites. These weather as small, round protuberances from $\frac{1}{20}$ to $\frac{1}{2}$ inch in diameter, but are usually all the same size in a single band. It is probable that these mark the tops of lava flows. The matrix of the rhyolite breccia is a grey, or grey mottled, flinty-looking rock that under the microscope is seen to consist chiefly of fine, granular quartz and feldspar enclosing small, scattered phenocrysts of acid oligoclase. The included blocks are commonly grey or cream white, this difference in colour arising from the presence of an abundance of sericite resulting from the alteration of the feldspar.

[1]The relationships of the rocks designated by Numbers 9 to 12 and 2 to 3, to one another, have not yet been determined; 9 to 11 all intrude the diorite and quartz diorite (8), but they have not been observed in contact with one another.

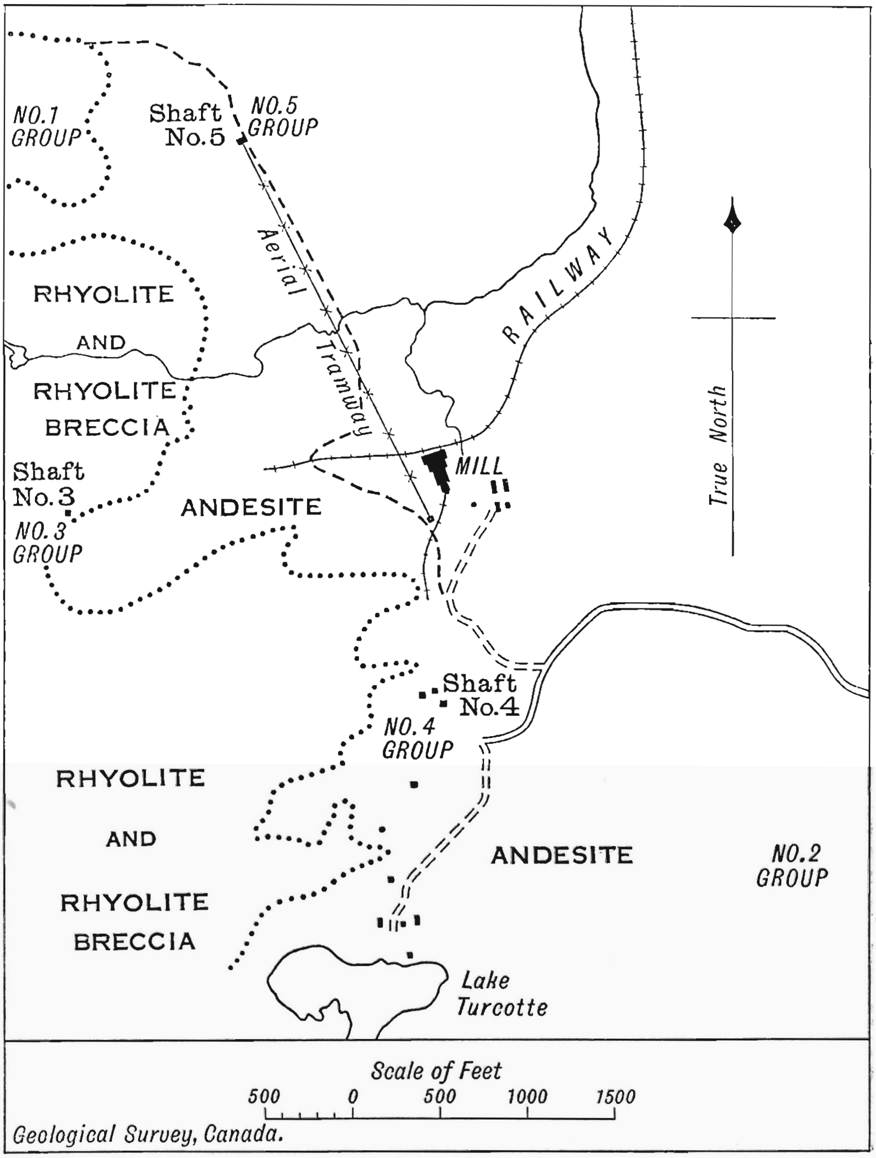


Figure 4. Plan showing positions of ore deposits, Amulet mine.

The andesite in contrast with the rhyolite and rhyolite breccia is largely a fine, massive, fairly uniform, green-weathering rock. It is commonly amygdaloidal, exhibits pillow structure, pahoehoe structure, and concentric lamination and banding in places. These laminæ or bands consist of discontinuous zones of hornblende or granular quartz varying from $\frac{1}{50}$ to $\frac{1}{5}$ inch in width and occur from a fraction of an inch to as much as 3 inches apart, the width of the zones increasing according to their distance from one another. These are common along the margins of pillows, but also occur where pillows are absent. In places masses or areas of breccia mingled with andesite showing ropy structure may be observed, notably in the vicinity of the Number 2 group of ore deposits (Plate III A). Under the microscope the andesite is seen to consist chiefly of elongated crystals of plagioclase ranging in composition from oligoclase to basic andesite, enclosed in a matrix of colourless to pale blue-green hornblende, usually abundant, scattered grains of magnetite, granular feldspar, and in most sections some granular quartz.

On the east slope of a knob of andesite about 50 feet north of the north shore of Turcotte Lake there are rusty-weathering outcrops of banded and laminated chert impregnated, in some bands, with pyrrhotite. The bands range in width up to a maximum of 1 inch. They appear to be gently folded into minor anticlines and synclines so that on the surface they resemble the grain of wood. The dip of the zone in general is about 30 degrees to the southeast. The maxium exposed width of the belt is about 30 feet, but the actual thickness is probably less than half this amount. This presumably marks the contact of two lava flows, it is the only sedimentary rock observed in the whole of the Amulet map-area.

QUARTZ DIORITE AND DIORITE

Next to the Abitibi volcanics, the rock most extensively represented near the Amulet ore deposits is diorite. This, in its main area to the east of the mill and camp buildings, is an exceedingly variegated rock both in texture and in the distribution of its minerals, the white feldspar and the dark green-weathering ferromagnesian minerals occuring in irregular aggregates of varying size and form. Coarse and fine-grained phases also occur heterogeneously mixed, the two phases fading into one another. In places, white-weathering, feldspathic seams and zones are common, whereas at other points the ferromagnesian minerals are so abundant as to form masses of amphibolite several feet in diameter. There are three important dykes of diorite within the area of the map of the Amulet all trending northeasterly, one in the southeast part of the property adjoining mineralized area Number 2 on the northwest; another cutting across the second anticline in the direction of Shaft Number 5; and a third northwest of mineralized area Number 1.

Under the microscope the diorite is seen to consist chiefly of an abundance of pale yellow-green to blue-green hornblende, and plagioclase largely altered to epidote, but where unaltered ranging in composition from acid to basic andesine. In most of the thin sections examined quartz, chiefly in granophyric intergrowth with feldspar, was present, but in two specimens, one from the southern part of the main mass and one from the northwest dyke, it was entirely absent. The rock also contains scattered grains of a black, opaque mineral that is probably, in part at least, ilmenite.

MINOR INTRUSIONS

Nearly everywhere within the Amulet Group A claims, there are numerous small masses, dykes, or sills, of both acid and basic rocks, many of which are of different ages, as shown by their difference in composition, by the manner in which they cut one another, or by their relationship to the diorite and the quartz diorite. There are intrusions of this class of at least nine different ages within the area of the map of the part of the property shown in Figure 4, six of which (Numbers 2 to 7) are older and three (Numbers 9 to 11) are younger than the diorite and quartz diorite. The relative ages of the minor intrusives indicated in the table of succession are not all evident in the Amulet property but have been determined in part from observations in other parts of the region. None of the minor intrusives has been observed to cut either the dalmatianite or the granodiorite.

One of the most common of the minor intrusions is the rhyolite (quartz-feldspar) porphyry which occurs abundantly in small masses and dykes chiefly in the eastern part of the property. It is a fine-grained, siliceous-looking, pale grey-weathering rock in which, as a rule, small phenocrysts of feldspar (albite) or feldspar and quartz are disseminated. A dyke of this porphyry associated with the Number 2 group of deposits is from 12 to 25 feet wide, dips steeply northwest, and can be followed continuously for 550 feet southwesterly from the eastern margin of the map-area, beyond which the same rock occurs in a succession of disconnected masses up to 100 feet long. The mode of occurrence of these masses suggests that they are fragments of a once continuous dyke.

GRANODIORITE AND LATE PRECAMBRIAN QUARTZ DIABASE

There are no outcrops of either the granodiorite or the late Precambrian quartz diabase within the area of the map of the Amulet (Figure 4), but both intrusives occur only a few hundred feet beyond the eastern edge of the map-area. The granodiorite forms a stock-like mass about 4 miles in diameter occupying the islands in the northern part of, and the territory west of, Dufault Lake. The western edge of this mass lies about one-half mile east of the Amulet mill. The late Precambrian quartz diabase occurs in an approximately north-south trending dyke about 50 to 60 feet wide cutting the granodiorite and older rocks close to the eastern edge of the property.

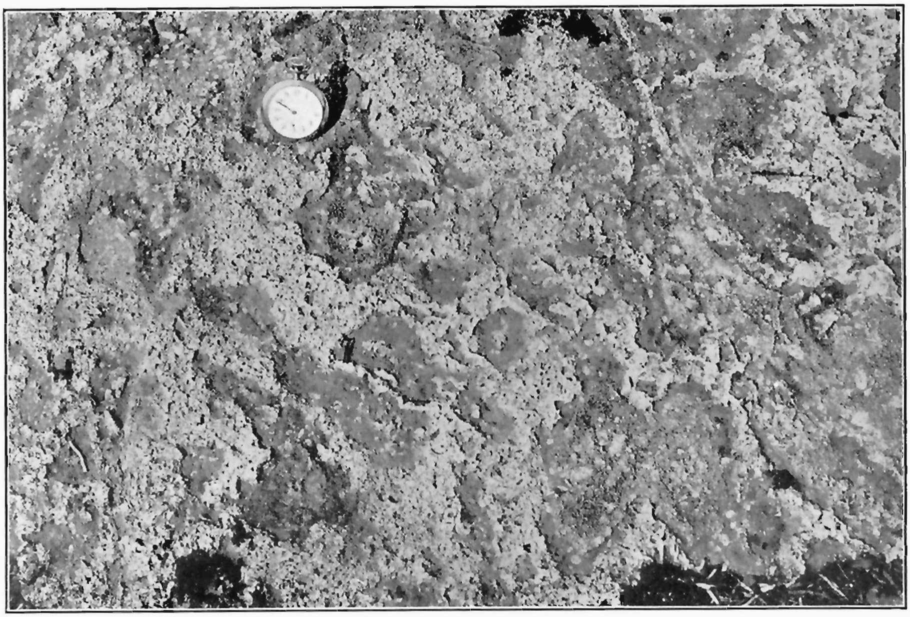
ROCK ALTERATION

The alteration that has occurred in the rocks of the Amulet map-area is of two unrelated kinds; one, their transformation to a rock consisting chiefly of epidote and quartz (epidosite); and the other, the development of the peculiar basic, cordierite-bearing rock known as dalmatianite. The first of these is very common, but only in small, widely scattered masses or narrow zones, whereas the second occurs in extensive areas, associated for the most part with, and chiefly below, the ore deposits.

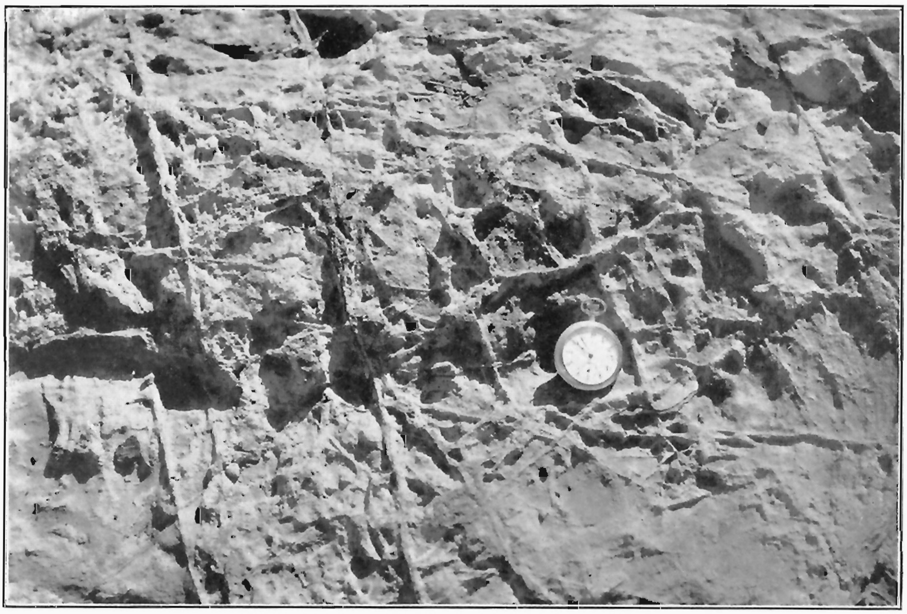
The epidosite occurs chiefly in round to elliptical-shaped, pale, yellowish grey-weathering masses ranging from a few inches in diameter up to 8 feet long by 4 feet wide, but also in seams and as an alteration product of the plagioclase in the andesite lavas and dyke rocks. Small masses of epidosite were observed at a few points in the rhyolite and rhyolite breccia matrix, but they attain their greatest development in the andesite. They occur chiefly within the pillows and other flow forms, as many as three masses occurring in a single pillow. In some places they lie along the contacts of pillows and in a very few places cut across the contacts. There are also numerous fractures in the andesite lavas filled with epidosite similar to that forming the masses. Under the microscope the epidosite is seen to consist of irregular, interlocking grains of epidote and irregular areas of granular quartz, the epidote forming about three-fourths of the rock.

The unique feature of the Amulet mine is the presence of extensive areas of the basic, highly aluminous, alteration rock, dalmatianite. This rock, with the possible exception of the area in the second anticline which adjoins a zone of lamination and banding in the rhyolite, is associated with the ore deposits and lies west of, and hence structurally below, the main ore masses. This relationship is also demonstrated by the diamond drill cores, in nearly all of which the dalmatianite occurs in association with, but largely below, the ore.

On weathered surfaces the dalmatianite presents a peculiar, protuberant appearance due chiefly to the great resistance to weathering of round to bean-shaped, less commonly rectangular-shaped crystals of cordierite. In places the dalmatianite contains small, round protuberances of granular quartz that are almost certainly amygdules. These features are especially well displayed in the western part of mineralized area Number 2. In certain localities the breccia or mesh-like structure (Plate III A) of the lava is preserved on the weathered surface of the dalmantianite, the matrix consisting of grey, granular quartz. On a freshly broken surface the dalmatianite is a fine-grained, grey, dark grey, brownish grey, or greenish grey rock, the variations in colour arising from the predominance of different minerals—the brownish grey variety containing an abundance of mica; the grey, granular quartz and the greenish grey, chlorite. The cordierite in many phases of the freshly broken rock cannot be observed. In some, however, it has a glossy appearance strikingly different from the dull-looking matrix. In some specimens of the rock, beautiful small rosettes of the aluminous variety of anthophyllite, gedrite, and in others small black octahedra, which under the microscope proved to be green spinel, are common. Under the microscope the dalmatianite is seen to consist chiefly of two or more of the following minerals: cordierite, mica, anthophyllite, quartz, spinel, ilmenite, chlorite; and usually one or more of the ore minerals, pyrrhotite, pyrite, chalcopyrite, and sphalerite. The uncommon minerals observed are feldspar and epidote.



A. Breccia in andesite near the Number 2 group of ore deposits; the matrix replaced by quartz and the fragments by dalmatianite. (Negative No. 75224.)



B. "Grid weathering" in andesite near shaft Number 4. (Negative No. 75228.)

STRUCTURAL FEATURES

Folding. The rocks of the Amulet, except for a single occurrence of chert, are entirely igneous and chiefly lava flows in which the structure can be determined from the course of the contact of the rhyolite and rhyolite breccia with the andesite from north to south across the property, from the attitude of this contact at depth as shown by diamond drilling through the andesite to the rhyolite and rhyolite breccias below, and from the attitude of the andesite as shown by the flattened bottoms of pillows (" bun structure"). All these features show that the rocks have been folded into a succession of anticlines and synclines pitching eastward at an angle of about 20 to 25 degrees. Taken as a whole, the structure is an anticlinorium.

Faulting and Fracturing. Fractures and fracture zones are common nearly everywhere. Along some of these evidence of faulting can be observed. Numerous fractures filled with quartz, calcite, or epidote were also observed in many of the diamond drill cores. The many dykes that intersect the andesite, rhyolite, and rhyolite breccia also obviously occupy fractures and the manner in which the dykes of rhyolite porphyry have been broken into fragments is additional evidence of the intense fracturing to which the rocks of the area have been subjected. In some places dykes are cut off abruptly by other dykes, showing that faulting has occurred along the fracture occupied by the later dyke. The predominant strike of the faults, fractures, and dykes is northeasterly. In the workings in the Number 4 group of deposits (Shaft Number 4 or C) a northeasterly trending fault has been followed in drifts for about 1,500 feet. Along this fault the rock has been broken and is cut by so many subsidiary fractures that it is not everywhere possible to determine definitely the position of the main fracture. In places a zone of gouge up to 6 inches wide occurs in what appears to be the main fault plane. The fracture zone has a width in places of 10 feet or more. Slickensiding and grooving were observed on the walls of the workings in both the 150- and 250-foot levels, the striæ in both localities dipping 10 degrees to the east. The fractures along the fault are filled with either calcite or quartz, but ore minerals, so far as observed, are absent, and if present at all occur in very small amounts. On the 150- and 250-foot levels the fault lies 20 and 30 feet respectively to the northwest of its position on the 75-foot level. Its dip is, therefore, about 75 degrees between the 75- and the 150-foot levels and 84 degrees between the 150- and the 250-foot levels.

In places, fine, intersecting seams occur which weather as criss-cross ridges resulting in what has been described as " grid structure " (Plate III B). This structure, although not wholly restricted to mineralized areas, is common within them or in their vicinity. It occurs in many places in mineralized area Number 4, and southward to the water-tank on the top of the hill in the Area property, and is also well developed in a rock face west of the site of the hoist house at Shaft Number 5 (F).

ORE DEPOSITS

GENERAL CHARACTER AND DISTRIBUTION

The ore deposits of the Amulet occur in five groups, three of which are extensive. Four of the groups, Numbers 1, 3, 4, and 5, occur in the rhyolite breccia close to its contact with the overlying andesite, the fifth, Number 2, is in the andesite at a point about 1,000 feet above the rhyolite breccia-andesite contact. All are associated with, and lie chiefly above, masses of the alteration rock, dalmatianite. The ore masses are, for the most part, tabular in form, the highest grade ore in the case of deposits associated with the rhyolite breccia-andesite contact lying directly beneath the andesite cover. The ore consists chiefly of sphalerite and chalcopyrite in the proportions of about two to one.

Group Number 1

The mineralized area with which the deposits of group 1 are associated lies on the crest of Number 1 anticline and for the most part in the rhyolite and rhyolite breccia below its contact with the andesite. In places the alteration to dalmatianite associated with the mineralization extends into the andesite, so that the contact is obliterated. The boundaries of the mass of altered rock are very indefinite, but an area roughly 500 feet square is completely transformed to dalmatianite. Alteration continues beyond this limit, however, for variable distances up to 300 feet. Numerous basic dykes are exposed in the area and others, not exposed, were intersected by the diamond drill. A large dyke of diorite lies along the northwest margin of the area of intense alteration. It is about 25 feet wide, trends northeasterly, and dips, as determined from its intersections by diamond drill cores, about 50 degrees to the southeast. Other dykes trend east-west, north-northeast, or south-southeast. Those to the north and south of pits 7 and 8 are altered to dalmatianite in places.

There are eight pits within the Number 1 area of alteration (Figure 5), in all but one of which some ore is exposed. This consists chiefly of pyrite and chalcopyrite, or of pyrite, pyrrhotite, and chalcopyrite, disseminated in aggregates or in irregular veins. Sphalerite was not observed but may be sparingly present. The proportion of chalcopyrite, on the whole, is not large, so that the ore would be classified, for the most part, as low grade. Since these deposits lie on the crest of the Number 1 anticline about 300 feet west of the outcrop of the contact between the rhyolite and the andesite, and the anticline pitches eastward at an angle of about 25 degrees, the parts of the ore-bodies now exposed must have formed about 120 feet below the contact, and are possibly the lower parts of larger ore masses largely removed by erosion.

Thirteen diamond drill holes have been drilled within or near the Number 1 mineralized area. The rocks encountered, except for basic dykes, consist of rhyolite, a considerable part of which is in various stages of alteration to dalmatianite. In most of the drill cores more or less pyrite, pyrrhotite, chalcopyrite, and in some a little sphalerite, were found, but

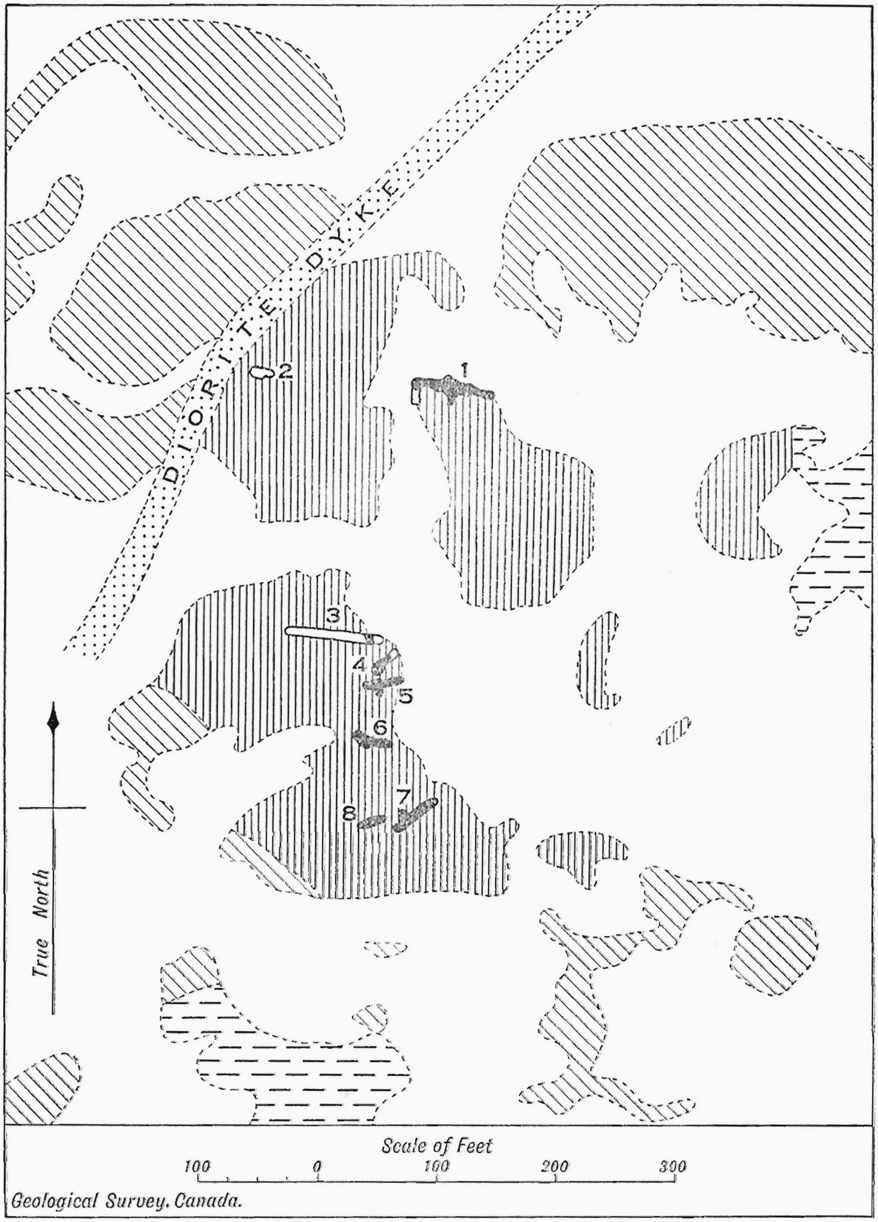


Figure 5. Plan of No. 1 group of ore deposits, Amulet mine, showing pits (Nos. 1 to 8). Ore shown by solid black; outcrops and areas of outcrop of dalmatianite by vertical ruling; rhyolite and rhyolite-breccia (partly altered to dalmatianite) by diagonal ruling; andesite by broken horizontal ruling; and diorite dyke by pattern of stipple.

only in Number 134 at a depth of 86½ to 94 feet was high-grade ore intersected. In Number 131 low-grade ore was cut between 149¾ and 156 feet, and 192 and 201 feet. A more detailed description of the eight pits in the Number 1 area is included in the following table.

Mineralized Area Number 1

Pit number	Dimensions of pit	Character of deposit	Wall-rock	Remarks
1	75 feet long 4–20 feet wide 5–15 feet deep	Area indicated in Figure 5 as mineralized is rusty weathering and traversed by a network of pyrite, chiefly, but with some chalcopyrite. In places there are masses of solid pyrite having a diameter of 1 foot or more. Low-grade ore	Dalmatianite	D.D. holes 39 and 130 nearby. In 39, which passed beneath pit at a depth of 50 feet, the rock is mineralized but too low grade to be ore; 130 is in altered rhyolite and dalmatianite; no ore intersected
2	15–20 feet long 10 feet wide 1–3 feet deep	A mass of pyritic, protuberant-weathering, rusty rock having a maximum exposed width of 4 feet in pit, length 15 feet. Proportion of pyrite not more than 20 per cent. Some chalcopyrite present but not sufficient to be ore	Dalmatianite and rhyolite	D.D. hole 133 to west of pit in altered rhyolite and dalmatianite; no ore
3	85 feet long 3–5 feet wide 5 feet deep	20 feet from east end of pit at cross-trench, a zone of scattered aggregates and masses of pyrite; on the south edge of opening a mass of solid pyrite 1 foot wide occurs dipping northwest 30 degrees. The bottom of pit is not fully exposed, but several masses of pyrite and a lead 4 inches wide of pyrite containing considerable chalcopyrite were observed	Dalmatianite weathering protuberantly and with mesh structure	D.D. hole 143, 25 feet north of pit, intersected fractured rhyolite mineralized with quartz, a little chalcopyrite, and sphalerite; no ore except for about 3 feet at 56½ to 59½ feet
4	25 feet long 4–6 feet wide 3–4 feet deep	Along south wall 10 feet from west end an irregular zone of pyrite and chalcopyrite in leads up to 3 inches wide. In west face, there are two zones of pyrite and pyrrhotite, the upper 5 feet by 18 inches and the lower a mass not fully exposed 4 feet by 8–12 inches. In south extension of pit, zones and masses of pyrite occur here and there with some chalcopyrite in places. The largest of these is about 1 foot in diameter	Dalmatianite	Low-grade ore. D.D. hole 214, 10 feet to east, in dalmatianite, altered rhyolite, and basic dyke or sill
5	25 feet long 2–4 feet wide 1–3 feet deep with an extension to south near west end	Zones, masses, and aggregates of pyrite with some chalcopyrite occur here and there. Maximum width 1 foot	Protuberant-weathering dalmatianite	Low-grade ore

Mineralized Area Number 1—Concluded

Pit number	Dimensions of pit	Character of deposit	Wall-rock	Remarks
6	Northwest end of opening is a pit in hillside 15 feet long, 6-7 feet wide, and 3-10 feet deep; the remainder of pit is 20 feet long, 4-5 feet wide, and up to 4 feet deep	In the southeast face of the deep part of pit there is a zone of mineralization (chiefly pyrite) up to 4 feet wide, of which 1 foot is highly mineralized. In the northeast face there are two zones diverging downward of pyrite with some chalcopyrite. These are up to 18 inches wide. The eastern part of pit is rusty weathering, containing much pyrite with some pyrrhotite and chalcopyrite, disseminated, in aggregates, and in zones up to 1 foot wide. In central part, mineralization is about 25 per cent of rock	Protuberant-weathering dalmatianite	The north wall of east part of pit is slickensided, with the direction of movement to east and 35 degrees from horizontal. D.D. hole 145, 50 feet to southwest, intersected altered rhyolite and silicified rhyolite breccia; seams and veinlets of quartz and pyrite in places; no ore
7	45 feet long 4-7 feet wide and 1-5 feet deep, with an extension to the north 10 feet long	Rock chiefly dalmatianite with in places pyrite, forming the matrix around cordierite crystals. A mass of solid chalcopyrite was observed in dump	Dalmatianite	
8	25 feet long 5-6 feet wide 3-4 feet deep	The rock has been merely broken up by blasting. It consists of dalmatianite containing pyrite disseminated and in aggregates. Part of the bottom of the pit is not exposed. Some chalcopyrite was observed	Dalmatianite	

Group Number 2

The ore masses of this group occur in the andesite of the Number 4 anticline at a point about one-half mile east of, and 1,000 feet above, the rhyolite breccia-andesite contact. They are associated with a mass of dalmatianite and related alteration rock about 600 feet long and 500 feet wide which lies for the most part on the southeast side of a northwest dipping diorite dyke 35 to 40 feet wide. This dyke, where it lies along the margin of the dalmatianite mass, has itself been transformed to dalmatianite for a length of 350 feet. The dalmatianite is more or less mineralized throughout its entire extent, but the ore masses occur chiefly in three localities: (1) in an area extending south from pit 10 (Figure 6); and (2) in a triangular-shaped area extending from pits 23 and 24 to pits 28 and 29; and (3) on either side of the northeasterly trending diorite dyke at the northwest end of the mineralized area.

The chief ore-bodies of the group are two irregular, more or less tabular-shaped masses lying along the easterly dipping upper contact of the dalmatianite. The northern, or Number 1, as determined from its outcrops in pits 10, 13, 14, and 16, and six diamond drill intersections, is about

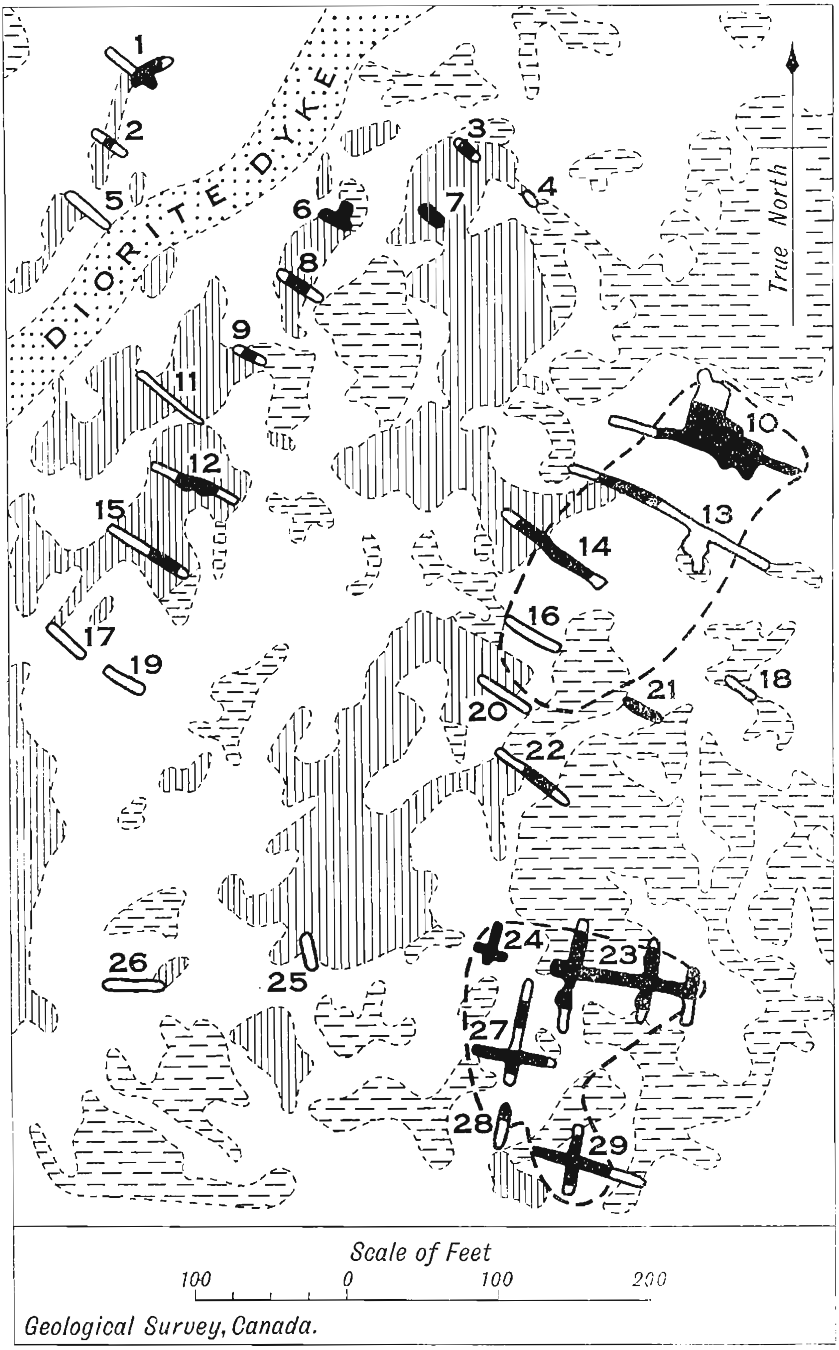


Figure 6. Plan of No. 2 group of ore deposits, Amulet mine, showing pits (Nos. 1 to 29). Ore shown by solid black; outcrops and areas of outcrop of dalmatianite by vertical ruling; andesite by broken horizontal ruling; diorite dyke by pattern of stipple; and horizontal outline of ore-body by heavy pecked line.

250 feet long, 100 feet wide, and 4 to 68 feet deep. The southern or number 2 is a triangular-shaped mass with an extension to the south from its base. It has a maximum length of about 200 feet, a maximum width of about 150 feet, and a thickness from 15 to 32 feet in four diamond drill intersections. The diamond drill holes bored through the Numbers 1 and 2 ore masses, intersected ore almost continuously from the bedrock surface or from points a few feet below bedrock surface down to varying depths up to a maximum of about 68 feet and here and there masses of ore minerals, chiefly chalcopyrite, down to a depth of 275 feet. All the deep, scattered masses, however, are probably too small or too widely separated to be workable.

The northwesterly deposits occur almost entirely in dalmatianite, and consist chiefly of pyrite, pyrrhotite, and chalcopyrite with very little sphalerite. They are, for the most part, of very small extent and of low grade. They lie chiefly in a zone along the west margin of a mass of andesite that occurs within the dalmatianite but has escaped alteration.

The occurrence of well-developed " bun " type of pillows in the andesite to the north of pit 10, the flattened bottoms of which dip northeast, indicates that the Number 4 anticline continues eastward with an easterly pitch to this point and that ore masses Numbers 1 and 2 are structurally above the dalmatianite outcropping to the west. It is noteworthy also that the dalmatianite in this area exhibits in places the mesh-like type of structure (Plate III B) apparently formed by the deposition of granular quartz in the matrix of breccia.

It is probable that the occurrence of ore in andesite at this locality is due partly: (1) to the deformed condition of the rocks as shown both by the presence of fractures and by the manner in which a dyke of rhyolite porphyry has been broken into fragments; and (2) to the presence of open, breccia, and ropy structure in the andesite. There is, however, some uncertainty regarding the barrier that obstructed the ore-bearing emanations. Mr. J. G. MacGregor states that in the McDougall property to the east of the Group 2 deposits, the diamond drill intersected a basic sill which if projected westward would overlie the ore masses. It is possible that such a sill may have been present, but if so, it has been entirely removed by erosion. At the north end of pit 10, pillowed andesite, and at the west end of pit 28, massive andesite, overlie the ore, so that it is probable that a massive, impermeable andesite flow originally lay above the ore deposits. The small ore masses in the northwest part of the mineralized area at the time they were deposited were beneath the diorite dyke and the absence of dalmatianite above the dyke, except at one point, suggests that it was also an obstruction to the upward ascent of the ore-bearing emanations.

Mineralized Area Number 2 (A)

Pit number	Dimensions of pit	Character of deposit	Wall-rock	Remarks
1	Main opening: 35 feet long 3–5 feet wide 2–4 feet deep Northeast extension: 25 feet long 4–5 feet wide 2–4 feet deep	Chalcopyrite, pyrrhotite, and at one point sphalerite occur throughout an area 15 feet long and 4–5 feet wide; a low-grade ore	Dalmatianite	This pit lies northwest of diorite dyke
2	30 feet long 4–8 feet wide 2–5 feet deep	Chalcopyrite with some pyrrhotite in aggregates and zones throughout an area 6 feet long by 2 feet high, in south face	Dalmatianite	Northwest of diorite dyke
3	15 feet long 5–6 feet wide 4 feet deep	Some aggregates and zones of chalcopyrite, pyrite, and pyrrhotite in central part of pit; a low-grade ore	Dalmatianite	
4	10 feet long 4 feet wide 3 feet deep	No mineralization observed	Dalmatianite, andesite to east	
5	40 feet long 4–5 feet wide 3–5 feet deep	No mineralization observed	Dalmatianite, rhyolite porphyry to northwest	
6	5–12 feet long from north to south 6–11 feet wide from east to west, 5 feet deep	Chalcopyrite occurs here and there over practically the entire area of pit bottom	Dalmatianite, andesite to north and east	This pit lies about 30 feet southeast of diorite dyke
7	12 feet long 4–10 feet wide 2–4 feet deep	A little disseminated chalcopyrite occurs here and there in pit, low-grade ore	Dalmatianite	D.D.H. No. 9 (25 feet to south) intersected low-grade copper ore from 14½ to 19¾ feet
8	35 feet long 2–4 feet wide 3–4 feet deep	Chalcopyrite occurs here and there in masses up to 1 foot in diameter, distributed over a length of 15 feet in central part	Dalmatianite, andesite to southeast	
9	25 feet long 3–4 feet wide 2–3 feet deep	Chalcopyrite, disseminated and in zones, occurs over a length of 6 feet in pit	Dalmatianite and altered andesite	
10	A large, irregular opening. The main pit is 75 feet long and 20–50 feet wide. There are extensions to east and west. The former 35 feet long, 3 feet wide; the latter 50 feet long, 2–3 feet wide; depth of both 2–5 feet	East extension: in gossan and rusty sphalerite Main pit: floor at east end chiefly water and rock debris, some pyrite and sphalerite exposed; west half almost continuous pyrite, chalcopyrite, and pyrrhotite; some granular quartz in places; at least half of the ore is high grade. West face, gossan West extension: in gossan for 20 feet; beyond this, rusty weathering and pyritic rock, no ore	Andesite, altered in places	D.D.H. No. 7 (in north end) intersected low-grade ore from 12½ to 22½ feet D.D.H. No. 16 (to west) intersected low-grade ore from 252 to 275 feet. D.D.H. No. 14 (to west) intersected low-grade ore from 165 to 174½ feet

Mineralized Area Number 2 (A)—Continued

Pit number	Dimensions of pit	Character of deposit	Wall-rock	Remarks
11	55 feet long 3–4 feet wide 3–5 feet deep	No mineralization	Dalmatianite	D.D.H. No. 11 (30 feet to south)
12	55 feet long 4–12 feet wide 1–5 feet deep	There is 10 feet of pyritic dalmatianite at each end of the pit in which no ore minerals were observed. The remaining 35 feet of pit contains chalcopyrite filling fractures here and there. This is for the most part low-grade ore. Some blocks containing about 25 per cent chalcopyrite were observed in dump	Dalmatianite, rhyolite porphyry to east	D.D.H. No. 10 (70 feet to northeast) intersected low-grade copper ore from 36 to 44⅓ feet
13	A trench-like opening 150 feet long 3–6 feet wide 4–5 feet deep with an extension to south for 25 feet near middle	East end of pit has been refilled, but dump is andesite. There is no mineralization in south extension. In the west end of pit for 50 feet the walls are gossan. Sphalerite, pyrite, and some chalcopyrite occur in dump, bottom covered by rock debris	Dalmatianite and andesite	D.D.H. No. 6 (in south extension) intersected low-grade ore from 10½ to 16 feet, high-grade ore from 16 to 30 feet, and low-grade ore from 30–55 feet. D.D.H. No. 5 (45 feet to east) cut low-grade ore from 128 to 155 feet and from 168 to 176 feet. D.D. H. No. 27 (65 feet to east) cut low-grade ore from 160 to 164½ feet and from 171½ to 174½ feet
14	A trench-like opening in bedrock 75 feet long 2–7 feet wide 1–3 feet deep	The middle part of pit for 50 feet is either in gossan or chalcopyrite, pyrite, and sphalerite, mineralization sufficiently abundant to form ore	Andesite at east end, dalmatianite at west	D.D.H. Nos. 80 and 64 (30 and 40 feet to north respectively)
15	60 feet long 3–5 feet wide 5 feet deep	25 feet at east end of pit, in pyrite, chalcopyrite, pyrrhotite, or gossan	Dalmatianite	
16	45 feet long 5–7 feet wide 6 feet deep	No mineralization observed	Andesite	
17	30 feet long 3–5 feet wide 3 feet deep	No mineralization observed	Dalmatianite	
18	25 feet long 4–6 feet wide 5–6 feet deep	Filled with rock debris, some pyrite, and pyrrhotite in east and west faces, no ore	Andesite	D.D. H. No. 96 (35 feet to east) no mineralization D.D. H. No. 23 (25 feet to south)

Mineralized Area Number 2 (A)—Continued

Pit number	Dimensions of pit	Character of deposit	Wall-rock	Remarks
19	25 feet long 5 feet wide 3 feet deep	No mineralization observed	Dalmatianite	
20	45 feet long 5–7 feet wide 1–3 feet deep	Rusty, pyritic dalmatianite in western 25 feet, no ore observed		D.D. H. No. 78 (15 feet to northeast) some low-grade ore intersected between 11 and 15 feet
21	30 feet long 2–6 feet wide 3–5 feet deep	Southeast end of pit in barren andesite; northwest end in ore, chiefly pyrite, pyrrhotite, with some chalcopyrite, and a small proportion of sphalerite	Andesite	D.D. H. No. 74 (25 feet to northwest)
22	50 feet long	Mineralized from 10–35 feet from its east end with sphalerite and chalcopyrite, low-grade ore	Andesite at end, dalmatianite at west	
23	Main east-west part: 100 feet long, 6–9 feet wide, 5–12 feet deep	Walls and floor in gossan at east end, floor covered with rock: debris in middle, but ore (chiefly sphalerite and pyrite) in walls and dump. Chalcopyrite and sphalerite exposed in pit floor at west end for 10 feet. Dump consists of pyrite, pyrrhotite, sphalerite, and chalcopyrite in varying proportions	Adjacent rock andesite	D.D. H. No. 1 (in pit near middle). D.D. H. Nos. 2 and 8 (near west end)
	South extension at east end 15 feet long 5 feet wide 2–3 feet deep	No mineralization	Andesite	
	North extension at east end 20 feet long 5 feet wide 2–3 feet deep	Walls either gossan, ore, or pyritic andesite, except at north end where high-grade ore occurs	Andesite	
	Middle south extension 25 feet long 5–7 feet wide 2–5 feet deep	South 10 feet not mineralized, remaining 15 feet in gossan or ore, solid sphalerite in places	Andesite	D.D.H. No. 3 (25 feet to southwest)
	Middle north extension 25 feet long 5–6 feet wide 3–5 feet deep	West face and north end not mineralized or mineralized with pyrite only. East face and floor at south end mineralized with pyrite, pyrrhotite, and sphalerite	Andesite	
	South extension at west end 40 feet long 2–5 feet wide 2–5 feet deep	Northern part mineralized with pyrite and some chalcopyrite. Low-grade ore	Andesite	

Mineralized Area Number 2 (A)—Concluded

Pit number	Dimensions of pit	Character of deposit	Wall-rock	Remarks
	North extension at west end 30 feet long 5 feet wide 2–6 feet deep	Southern part mineralized with pyrrhotite, masses of sphalerite in places,and a little chalcopyrite. Low-grade ore	Andesite	
24	A cross-shaped pit. East-west part 15 feet long 3–4 feet wide 1–3 feet deep North-south part 20 feet long 2½–3 feet wide 1–3 feet deep	Bottom filled with water. Rock, where exposed, is mineralized with pyrrhotite, pyrite, sphalerite, and chalcopyrite, the proportions varying from moderately high-grade to low-grade ore	Andesite	
25	25 feet long 5 feet wide 3–5 feet deep	No mineralization observed	Rusty brown dalmatianite containing circular aggregates of granular quartz	
26	40 feet long 3–4 feet wide 2–4 feet deep	Some pyrite, no ore	Dalmatianite	
27	A cross-shaped pit 75 feet long from north-south 50 feet from east-west 2–5 feet wide 2–6 feet deep	North arm filled with rock debris at north end; south end in andesite; middle part, mineralized with pyrrhotite, masses of sphalerite in place, and a little chalcopyrite—low-grade ore. South arm, mineralized with pyrite and some chalcopyrite for 10 feet; south end, andesite. East arm, mineralized with pyrite, sphalerite, and chalcopyrite for 15 feet, low-grade ore. West arm partly filled in with rock debris; where exposed gossan, quartz, pyrite, and sphalerite	Andesite	
28	30 feet long 3–5 feet wide 1–5 feet deep	A zone up to 1 foot wide of disseminated chalcopyrite in north 10 feet, elsewhere pyrite only	Dalmatianite and andesite	
29	A cross-shaped pit 55 feet long from east to west 50 feet from north to south 2–5 feet wide 1–4 feet deep	East arm, mineralized chiefly with sphalerite, chalcopyrite, some quartz, and pyrite, in places West arm, walls of gossan, floor of sphalerite, pyrite, and chalcopyrite, moderately high-grade ore North arm, mineralized except at north end with sphalerite, pyrite, and chalcopyrite, fairly high-grade ore South arm, sphalerite, and chalcopyrite in masses up to 2 feet by 3 feet, elsewhere pyrite disseminated and in aggregates, on the whole low-grade ore	Andesite altered and intersected by fractures	D.D.H. No. 4, 80 feet to northeast

Group Number 3

Mineralized area Number 3 occurs in the rhyolite breccia near its contact with the andesite on the northwest limb of a subsidiary syncline. Some basic dykes occur nearby. Ore is exposed for a length of 150 feet and for a maximum width of 10 feet in three pits excavated along the contact of the andesite and rhyolite breccia. It consists of pyrite, chalcopyrite, and sphalerite occurring in numerous small fractures, in aggregates, and in zones of veins. Mineralization is sufficiently abundant, on the whole, to constitute a medium grade of ore. Two diamond drill holes, Numbers 140 and 142, were drilled across the ore zone. In Number 140, 6 feet of medium-grade ore was intersected at a vertical depth of about 50 feet. Ore was not intersected in diamond drill hole 142. Northwest of the deposit and hence structurally below the ore mass there are several outcrops of dalmatianite.

Mineralized Area Number 3

Pit number	Dimensions of pit	Character of deposit	Wall-rock	Remarks
1	15 feet long 6–8 feet wide 5–12 feet deep	Water in bottom and walls, difficult of access. The west face for a width of 10 feet is intersected by mineralized fractures, the mineralization decreasing with depth. The east face of pit is similar to the west except that the mineralized zone is only 5 feet wide at the top and increases to 10 feet at bottom. Rock in dump mineralized with pyrite, some sphalerite, and a little chalcopyrite. The fractures are so numerous that the deposit is a breccia is part	Andesite in south wall	Deposit lies along contact of andesite and rhyolite breccia
2	15 feet long 5 feet wide 2–5 feet deep	West face gossan at top, a width of 3 feet of high-grade ore, chiefly sphalerite, at base This mineralized zone breaks up into small veins in pit bottom gradually diminishing in size to a point 5 feet to eastward where it disappears beneath water and rock debris. In the northeast corner of pit and for 5 feet to west in north face, gossan occurs. Elsewhere the rock in pit faces is barren	Andesite in south face Mineralized zone on contact of andesite and rhyolite breccia	A mass of sphalerite, chalcopyrite, and pyrite 1 foot wide exposed at a point 1 foot east of pit 2
3	50 feet long 5–10 feet wide 2–5 feet deep	There is a mineralized zone dipping south at angle of 60 degrees along bottom of base of south face on contact of andesite and rhyolite breccia, not fully exposed. This zone consists of pyrite, sphalerite, and chalcopyrite in varying proportions, chiefly sphalerite or	South wall andesite; bottom of pit not exposed except on west where rhyolite breccia occurs	

Mineralized Area Number 3—Concluded

Pit number	Dimensions of pit	Character of deposit	Wall-rock	Remarks
		pyrite; exposed width 18 inches to 2 feet. At one point laminated pyrite and quartz were noted in mineralized zone, also veinlets of pyrite projecting into hanging-wall. Bottom of pit largely hidden by rock debris		
Shaft number 3	6 feet long 5 feet wide Inclined 60 degrees to south. Filled with water at time of examination, said to be 53 feet deep	In east end of pit Number 3, minerals in dump include: sphalerite, pyrite, and chalcopyrite in masses up to 1 foot in diameter; quartz in masses up to 8 inches long and 2 inches wide; calcite; and epidote	On contact of rhyolite breccia and andesite. Both rocks in dump	

Group Number 4

The ore deposits of group Number 4 are the most extensive so far discovered. They occur on the south limb of the Number 4 anticline adjacent to the Number 4 or C shaft. They belong to an almost continuous zone of mineralization in the rhyolite breccia beneath the andesite contact about 900 feet long, 40 to 240 feet wide, and from a few feet to nearly 200 feet thick.

The superficial area of mineralization of which the Number 4 group of deposits is the continuation at depth lies below the rhyolite breccia-andesite contact northwest of shaft Number 4. West of this contact and along the bottom of the depression northwest of the shaft there is a broad area of rhyolite breccia consisting of numerous blocks of white to grey weathering, sericitized, and silicified rhyolite enclosed in a cavernous or hackly weathering matrix. Here and there throughout this area, the matrix or, in places, the entire rock, has been transformed to dalmatianite. A dyke of dacite (feldspar) porphyry from a few inches to 6 feet wide, continuous for almost a half mile and dipping steeply to the northwest, crosses the anticline in a northeasterly direction on the northwest side of the area.

Southwest along the rhyolite breccia-andesite contact there is an ore zone exposed in pits Numbers 38 to 43 that is nearly 1,000 feet southwest of the other ore masses of the Number 4 group. Possibly this deposit should be classified as a separate mineralized area, but, so far as known, it is not of great extent and lies on the same anticline as the other deposits and has, therefore, been included in the larger group.[1]

There are altogether forty-three pits in the outcrop of the Number 4 zone of mineralization, in nine of which ore masses, all lying in the rhyolite

[1]Pit Number 37 which lies 250 feet northwest of pit Number 39 is also isolated.

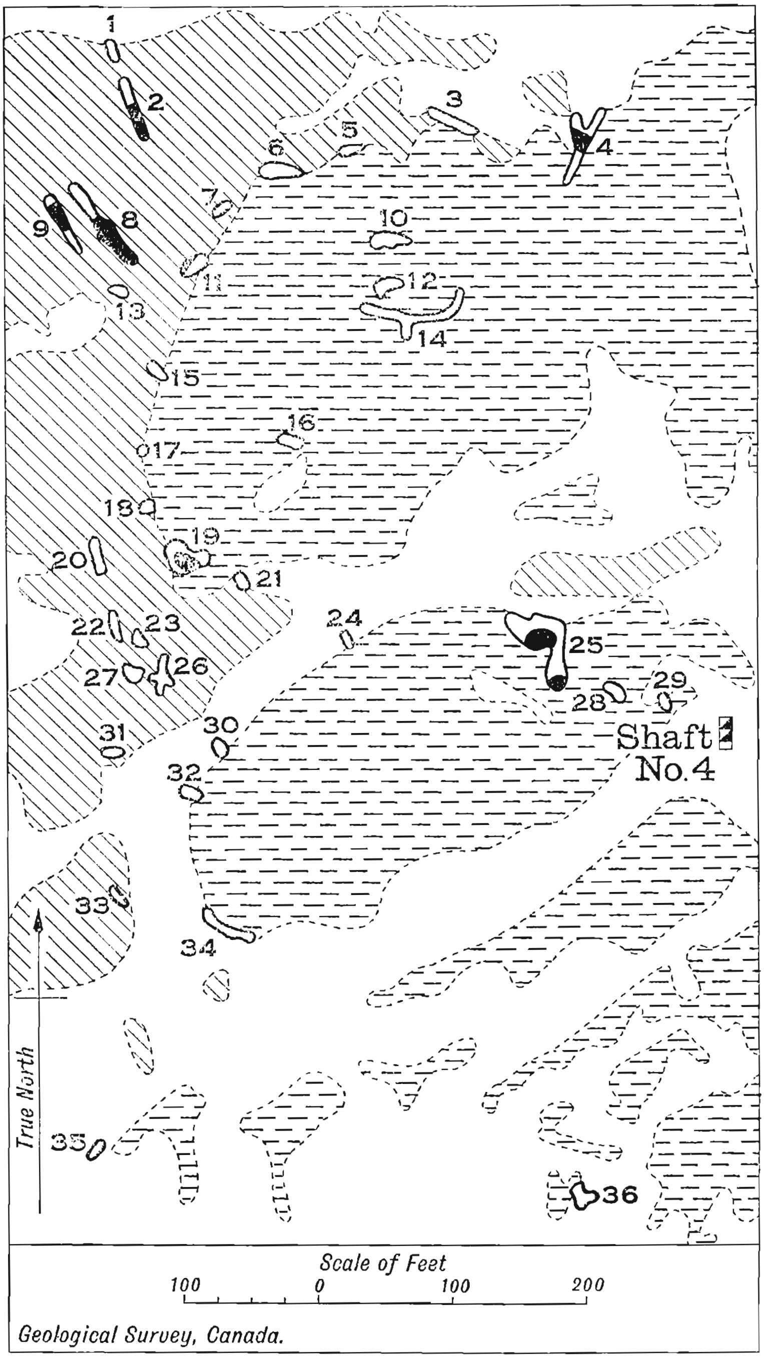


Figure 7. Plan of the outcropping part of No. 4 group of ore deposits, Amulet mine, showing pits (Nos. 1 to 36). Ore shown by solid black; outcrops and areas of outcrop of andesite by broken horizontal ruling; and rhyolite and rhyolite-breccia (partly altered to dalmatianite) by diagonal ruling.

breccia either along its contact with the andesite or less than 200 feet away (considerably less than 200 feet at right angles to the contact) have been discovered. These deposits are for the most part small, although in some the ore is of high grade. The deposits in pits 19 and 25 are, however, the superficial exposures of larger deposits at depth.

Diamond drilling operations and other underground development work near shaft Number 4 have shown that large masses of ore, much of it high grade, lie below the andesite-rhyolite contact in this locality. Scattered, more or less isolated, small masses of ore occur at depth outside the main group of deposits, but disregarding these, four ore-masses are known to be present. These have been designated D, B, C, and E from northwest to southeast respectively.

The B ore mass, which adjoins shaft Number 4 on the northwest, so far as it has been delimited, appears to be in horizontal plan a hook-shaped body about 300 feet long (225 feet in a straight line), having a horizontal width ranging from 40 to 60 feet, and a vertical thickness of 100 to 200 feet Within this mass there are inclusions of dalmatianite and altered rhyolite in which there is little, if any, mineralization. On the other hand, in some diamond drill holes as much as 50 to over 100 feet of continuous high-grade ore was intersected.

The C ore mass, which lies to the southeast of shaft Number 4, so far as its dimensions are known, has horizontally a maximum length of about 440 feet and a maximum width of about 240 feet. The average width is about 140 feet. Vertically the ore occurs at intervals in the rhyolite and rhyolite breccia, from the andesite contact downward to a depth of nearly 100 feet. In parts of this mineralized mass the ore is concentrated in two zones, one 3 to 22 feet thick lying directly beneath the andesite contact and the other 20 to 30 feet thick but 40 to 50 feet lower down. In other parts the upper ore zone joins the lower and at such points (diamond drill holes 115 and 175) there is continuous ore for as much as 68 feet. The ore directly beneath the andesite-rhyolite contact is almost entirely high grade, whereas that in the lower zone is chiefly low grade.

The D ore-body is a smaller mass lying close to the surface about 250 feet northwest of shaft Number 4 and below the open raise in the depression underlain by rhyolite. It has a diameter of about 70 feet horizontally and a vertical thickness of about 40 feet.

The E ore mass lies below the contact to the east and southeast of C and hence at greater depth. Its boundaries have not been delimited and it may be possible that it is practically, in whole or in part, an eastward extension of the C ore deposit. Three diamond drill holes bored diagonally from the east end of the 150-foot level (the east limit, so far as known, of C ore mass) did not intersect ore, but in diamond drill hole 151 from the same level ore was intersected at a point about 50 feet to the south, and only 30 feet to the west, of diamond drill hole 109 in which 20 feet of high-grade ore, possibly belonging to the E ore mass, was intersected. In the region designated as E ore mass, ore ranging in thickness from 8½ to over 68 feet (Number 149), practically all high grade, was intersected in four diamond drill holes, indicating that one or more ore masses of considerable size is present in this locality.

Mineralized Area Number 4 (Northwest of Shaft Number 4 or C)

Pit number	Dimensions of pit	Character of deposit	Wall-rock	Remarks
1	20 feet long 5 feet wide 3–5 feet deep	Some seams and aggregates of pyrite in faces and in blocks in dumps. Not much mineralization	Rhyolite altered to dalmatianite in places	A prospect pit
2	50 feet long 3–7 feet wide 4–7 feet deep	Almost no mineralization in northern part. Seams and aggregates of pyrite here and there (abundant in places) in northern part, also a zone of sphalerite with a little pyrite in east face. This includes an aggregate of sphalerite 18 inches long by 1 foot wide, elsewhere chiefly small seams. Total length of zone 5 feet, width 3 inches to 1 foot	Rhyolite breccia more or less silicified. Some meshed weathering on west side at south end	
3	40 feet long 4–8 feet wide (average 6½ feet) 2–5 feet deep (5 feet in face)	A pyrite zone 2 to 6 inches wide (laminated at its west end) on contact of rhyolite and andesite. Some fracturing along contact No ore	Andesite in south face to contact. Elsewhere rhyolite	A prospect pit
4 Deep central part	30 feet long 6–10 feet wide 4–8 feet deep	West and north faces: veneer of gossan for 5 feet at north end, sphalerite with chalcopyrite and pyrite from 5–10 feet, remainder altered andesite-rhyolite breccia containing pyrite disseminated and in aggregates. North face: gossan. East face: andesite at top, mottled rhyolite breccia at bottom	On contact of andesite and rhyolite	Vertical D.D.H. at south end
North extension	30 feet long 3–4 feet wide 2–4 feet deep	Bottom of pit: partly covered, partly ore, chiefly sphalerite with some chalcopyrite The only mineralization observed is a zone of laminated pyrite 3–5 inches wide and 2 feet long in middle of west face	The rock above the laminated zone has a mottled appearance resembling the rhyolite breccia matrix	Deposit if not on contact is near it
South extension	30 feet long 3–4 feet wide 4–5 feet deep	No mineralization	Andesite	A prospect opening
5	15 feet long 3–5 feet wide 2–4 feet deep	The contact of the andesite and rhyolite passes diagonally from east to west up the south face. It is marked by a rusty, platy zone 1–2 inches wide, and by fracturing for a width of 1 foot. At one point a zone of laminated pyrite projects into the andesite from the contact for 1½ feet. No ore	Andesite in south face to contact, rhyolite elsewhere	A prospect pit

Mineralized Area Number 4 (Northwest of Shaft Number 4 or C)—Continued

Pit number	Dimensions of pit	Character of deposit	Wall-rock	Remarks
6	15 feet long 5–7 feet wide 5–6 feet deep	The contact of the andesite and rhyolite is at the top of the southeast face. There has been some deformation and mineralization along the contact. Dark, laminated pyrite in a zone 3–6 inches wide occurs along the contact for 6 feet. Some disseminated pyrite below contact, also a small proportion of sphalerite present, no ore	Andesite at top of southeast face, rhyolite elsewhere	A prospect pit
7	15 feet long 5–6 feet wide 3 feet deep	Some disseminated pyrite, no ore	Rhyolite breccia	Contact 6 feet up southeast face above pit
8	80 feet long 4–10 feet wide 4–10 feet deep	In the north 30 feet of pit some disseminated pyrite, no ore. In the central part of pit, rock contains pyrite, pyrrhotite, and chalcopyrite disseminated and in aggregates, no large masses—low-grade ore. In southern part of pit, chalcopyrite, pyrite, and sphalerite sparingly disseminated and in seams, some high-grade ore in places near south end	Rhyolite breccia with dalmatianite in places	The numerous fractures filled with pyrite, pyrrhotite, chalcopyrite, and sphalerite in the faces of this pit show the ore deposition was preceded by intense rock deformation
9	50 feet long 3–10 feet wide 3–10 feet deep	Very little if any mineralization in north (10 feet) and south (20 feet) ends. In central part of pit the rock is finely fractured, the fractures containing pyrite, chalcopyrite, sphalerite, and quartz. There are no large masses of ore, but chalcopyrite is very intimately disseminated in places	Rhyolite breccia and dalmatianite	
10	28 feet long 10–15 feet wide 5–8 feet deep	No trace of mineralization observed	Andesite	
11	15 feet long 8 feet wide 5–8 feet deep	There is considerable disseminated pyrite and some sphalerite in a zone 3–4 feet wide along northwest side of pit	Rhyolite breccia	Contact with andesite at top of southeast face
12	18 feet long 5–10 feet wide 10 feet deep	Bottom covered by debris, except for an area of gossan 5 feet long, and 3–4 feet wide. No mineralization in walls	Andesite	Prospect pit
13	10 feet long 8 feet wide 6–9 feet deep	In rusty rock carrying some sphalerite in a matrix of breccia	Rhyolite breccia	
14	90 feet long 3–5 feet wide 4–6 feet deep Extension to south 15 feet long	No mineralization observed	Andesite	A prospect opening

Mineralized Area Number 4 (Northwest of Shaft Number 4 or C)—
Continued

Pit number	Dimensions of pit	Character of deposit	Wall-rock	Remarks
15	16 feet long 4–5 feet wide 3–4 feet deep	Filled with water, no mineralization observed in faces or in material in dump	Rhyolite breccia, except in east face	Prospect pit on andesite-rhyolite contact
16	15 feet long 10 feet wide 5 feet deep	No mineralization	Platy andesite	Prospect pit
17	7 feet long 6 feet wide 5 feet deep	Contact at top of east face indicated by rusty weathering of pyrite aggregates. No other mineralization, some fracturing along contact	Rhyolite breccia	Prospect pit
18	5 feet by 5 feet 12 feet deep	A pyrite zone 4 inches wide near top of east face marks contact. There is no other mineralization	Rhyolite breccia	Prospect pit
19 Upper (northwest) part	20 feet long 15 feet wide 6–10 feet deep	Contact in northeast face. 3–5 feet of andesite above. A pyrite zone 1 inch to 3 feet wide on contact, average width 1 foot	Rhyolite breccia and andesite	D.D. H.'s in pit
Lower (southeast) part	10 feet long 8 feet wide 14 feet deep	A zone of sphalerite and pyrite mingled with rock 3–6 feet wide in northwest face and 2–3 feet wide in southeast face. This presumably follows contact which is obliterated. No chalcopyrite observed		
20	30 feet long 6 feet wide 3 feet deep	Prospect pit in rhyolite. No mineralization observed	Rhyolite breccia	Prospect pit
21	10 feet long 7–8 feet wide 12 feet deep	Bottom covered by debris, no mineralization observed in faces or in material in dump. Contact about half-way down north face	Andesite and rhyolite	Prospect pit on contact
22	20 feet long 6 feet wide 5 feet deep	No mineralization observed	Rhyolite	Prospect pit
23	12 feet long 3–10 feet wide 5 feet deep	No mineralization observed	Rhyolite	Prospect pit
24	12 feet long 5 feet wide 5 feet deep	No mineralization observed	Andesite in south face	Prospect pit at contact
25 northern part	45 feet long 5–15 feet wide 5–15 feet deep	Bottom partly covered by rock debris, a mass of mingled chalcopyrite and sphalerite in central part, high-grade ore	Dark grey, seamed, protuberant-weathering andesite	
Southern part	25 feet long 7–15 feet wide 6–15 feet deep	High-grade ore, chiefly sphalerite, in south face. Bottom of pit covered by rock debris	Andesite	

Mineralized Area Number 4 (Northwest of Shaft Number 4 or C)—Continued

Pit number	Dimensions of pit	Character of deposit	Wall-rock	Remarks
26	Pit in form of cross 25 feet long 4–15 feet wide 3–6 feet deep	Masses of pyrite 3 feet square in south face and 2 feet by 3 feet in north face. These are probably parts of a single zone	Rhyolite breccia	Prospect pit below andesite-rhyolite contact
27	12 feet long 6–10 feet wide 6 feet deep	Bottom covered by rock debris, pyrite disseminated and in aggregates especially abundant in south face	Rhyolite breccia	Prospect pit below andesite-rhyolite contact
28	20 feet long 8–10 feet wide 4–6 feet deep	Bottom covered by debris. No ore observed but some ochre in northeast face	Andesite showing criss-cross ridged weathering	Prospect above contact
29	10 feet long 8 feet wide 8 feet deep	No mineralization	Andesite	
30	8–10 feet long 5–7 feet wide 5–10 feet deep	Filled with water when examined. Rock exposed in south and west faces. A pyritic line runs up the middle of the west face, probably the contact between andesite and rhyolite. South face andesite. No ore observed	Andesite in southeast face	Prospect pit on contact
31	20 feet long 6 feet wide 4 feet deep	No mineralization observed	Rhyolite	Prospect pit below contact
32	15 feet long 6–7 feet wide 8 feet deep	Partly filled with water. Rock in dump chiefly rhyolite. Contact evidently lies along south wall. No mineralization observed	Andesite and rhyolite	Prospect pit on contact
33	20 feet long 3–4 feet wide 3 feet deep	Excavation at end of trench, no mineralization	Amygdaloidal rhyolite altered to dalmatianite in places	
34	50 feet long 3-5 feet wide 4 feet deep	No mineralization observed	Northeast face, except for southeast 10 feet in drift, is in andesite, bottom rhyolite	Prospect pit on contact
35	10 feet long 3-6 feet wide 7 feet deep	No mineralization observed	Contact of andesite and rhyolite, in southeast face halfway down	Prospect pit on contact
36	25 feet long 15 feet wide 1–3 feet deep	Rock mineralized with pyrite and pyrrhotite, no ore	Andesite	

Mineralized Area Number 4 (Northwest of Shaft Number 4 or C)—Concluded

Pit number	Dimensions of pit	Character of deposit	Wall-rock	Remarks
37	8–12 feet long 5–10 feet wide 5–6 feet deep	Pyrite disseminated and in seams in dalmatianite, no chalcopyrite nor sphalerite was seen either in faces of pit or dump	Dalmatianite	
38	10 feet long 5–7 feet wide 6–8 feet deep	Water and debris in bottom. In southwest corner of pit there is a lens of sphalerite with some chalcopyrite 18 inches long and up to 6 inches wide. In the northwest corner there is a zone at least 3 feet long and 1 foot wide of sphalerite and pyrite not well exposed	Andesite	
39	30 feet long 6–8 feet wide 5–10 feet deep	Pyrite in aggregates and seams in rhyolite, lean near north face but abundant near south, neither chalcopyrite nor sphalerite was noted	Rhyolite	
40	15 feet long 12 feet wide 5–10 feet deep	Filled with water, only upper parts of west, north, and east faces exposed. Leads 5–8 inches wide in northwest corner, and 3–4 feet middle of north face. An irregularly mineralized zone 1 foot to 18 inches wide exposed for 6 feet in east face. Leads consist chiefly of pyrite and sphalerite, a little chalcopyrite in north face. High-grade sphalerite ore in dump	Rhyolite and andesite	D.D.H. No. 51 (vertical) and 56 inclined to southwest 35 degrees in pit. High-grade sphalerite ore in first 10 feet of 51
41	10 feet long 5–6 feet wide 3–5 feet deep	No ore, but zone of laminated pyrite 4 inches wide lies on contact of andesite and rhyolite	Rhyolite and andesite	Contact dips 45 degrees to southwest and bends to north west so that east part of south face is andesite
42	25 feet long 5–12 feet wide 2–4 feet deep	Aggregates and veinlets of pyrite up to 3 inches wide in faces of pit, neither chalcopyrite nor sphalerite was seen	Chonchoidally fracturing, splintery rhyolite	
43	9–10 feet long 6–8 feet wide 8 feet deep	A pyritic zone 4 inches wide passes diagonally down the east face, water in pit bottom, no other mineralization observed	South face of andesite, north face of rhyolite breccia; pit on contact	

Group Number 5

This group of mineral deposits discovered by diamond drilling lies on the south limb of the Number 1 anticline close to its crest and, so far as developed, from 135 feet to 690 feet beneath the surface. Owing to the extensive rock alteration, it is difficult to determine the original character of the rock adjacent to the deposits, but it seems certain that in its western part the upper limit of the mineralization is at the andesite contact which, at this point, has a depth of 250 to 275 feet. In diamond drill hole 238, however, high-grade ore was intersected at only 135 feet. At this point, therefore, either there was a prominent elevation on the rhyolite surface, now replaced by ore, or the contact has been dislocated by faulting, or the mineralization has extended beyond the contact into the andesite for about 100 feet. The mineralization of ore grade in this locality has a horizontal extent of about 350 feet from east to west and from 150 to 270 feet from north to south. For varying thicknesses, from 10 to 125 feet, there is practically continuous high-grade ore along the top of the mineralized zone, and below this low-grade ore continues for as much as 75 feet or recurs at intervals down to a depth of 450 feet. At this depth a flat diorite dyke about 50 feet thick was intersected, so that the ore deposits so far developed lie in the main between the andesite and the diorite dyke. To the southeast of the ore deposits the diorite dyke bends upwards to a nearly vertical attitude. Three diamond drill holes were continued through the dyke and in one of these ore was intersected below the dyke at 489 to 500 feet and in another below a second diorite dyke or the same dyke displaced by faulting at 669 to 688 feet.

STRUCTURAL FEATURES

The general structural relationships of the ore deposits have been described in other parts of this report, but their detailed structural relationships have not yet been noted. In the Number 4 and Number 5 groups of deposits, it is noteworthy that the upper surfaces of the deposits do not conform to the regional dip of the andesite-rhyolite contact and that the greatest thickness of ore occurs, in most cases, at points where the upper surface projects upward into the andesite. In the Number 4 mineralized area, the C ore mass in its western part has a roughly horizontal upper surface but lies over 100 feet below the upper surface of the B ore deposit. This abrupt change in elevation is brought about chiefly by the north-easterly-trending fault that dislocated the rhyolite breccia-andesite contact between the two deposits. It is probable that the irregularity of the upper surface of the Number 5 group of ore deposits is also, at least in part, the result of faulting.

The absence of ore minerals, so far as observed, in the fissures associated with the fault between the B and C ore masses of the Number 4 mineralized area, may seem to suggest that this fault occurred after the ore was deposited. It is probable, however, from evidence obtained in the general Noranda map-area that most of the fracturing and faulting in this region occurred before deposition of the ore and it may be that the fault between the B and C ore masses of the Number 4 group was present before ore deposition and that the absence of ore below the andesite contact at this point is due to the fact that the fault permitted the ore-bearing emanations to pass on upwards. The occurrence of ore in the Number 2 mineralized area at a point 1,000 feet above the rhyolite-andesite contact proves that the ore-bearing emanations ascended into the andesite in this manner in some places at least.

ORE MINERALS[1]

The most common minerals composing the ore deposits are pyrite, pyrrhotite, sphalerite, chalcopyrite, quartz, and all the minerals of the dalmatianite—brown mica, cordierite, aluminous anthophyllite (gedrite), chlorite, magnetite, and spinel. The uncommon minerals are calcite, arsenopyrite, galena, and tetrahedrite.

The pyrite when examined under the microscope is seen to occur chiefly in perfect cubes, pyritohedra, or octahedra, enclosed in the other ore minerals and gangue. It also occurs in cross-like areas enclosed in sphalerite and in irregular areas without crystal form.

Arsenopyrite was observed in the ore in irregular areas enclosed in galena.

The pyrrhotite occurs, for the most part, in irregular areas having corroded and embayed margins and lying within grains of chalcopyrite and sphalerite or along their contacts. Where it is associated with pyrite it forms the matrix around the pyrite crystals. In several polished surfaces fine veinlets of pyrrhotite were observed to cut chalcopyrite.

The sphalerite in polished surfaces of the ore occurs abundantly in irregular areas, in some places enclosed in chalcopyrite, in other places enclosing the latter mineral. In thin sections of ore containing sphalerite, chalcopyrite, and granular quartz, the chalcopyrite grains have straight edges with a suggestion of crystal form, whereas the sphalerite grains have concave margins with respect to the quartz grains. This relationship is characteristic of the sphalerite wherever it occurs in association with quartz. In a thin section of a piece of diamond drill core from hole 96, calcite was seen to fill the interspaces between cubes and areas of pyrite and sphalerite.

Chalcopyrite, next to the sphalerite, is the most abundant mineral composing the Amulet ore. It occurs, partly, in parallel rows of rod-like or small, bead-like areas within the sphalerite (the alinement following the octahedral structure of the latter), and, partly, in irregular areas within all the other minerals of the ore, or in the gangue.

Galena is present in polished surfaces of some specimens and occurs chiefly in small areas disseminated in the other minerals. It is present in a few specimens in large areas.

Tetrahedrite was noted in several polished surfaces, largely in small areas within or along the contacts of areas of chalcopyrite and sphalerite. It was also seen to occur in irregular inclusions in galena.

The assays of the Amulet ore show that in addition to zinc and copper it contains silver values up to a maximum of 18 ounces to the ton and gold values up to as much as $6 a ton, the average values a ton for all the ore-bodies, according to the estimate of the manager, being 2·44 ounces of silver and 94 cents in gold (gold valued at $20.67 an ounce). They also show that although the gold and silver values increase in a general way with the degree of mineralization, there is no definite relationship between

[1]This description of the ore minerals is based chiefly on a microscopic study of polished surfaces of specimens of the ore by M. H. Haycock of the Ore Testing Laboratories of the Mines Branch, but partly also on examinations by J. S. Stevenson and the writer. The arsenopyrite and tetrahedrite were identified by Mr. Haycock.

the gold and silver and the copper or zinc contents. This suggests that the gold and silver are not confined to the most abundant ore minerals, chalcopyrite and sphalerite, but are contained in other ore minerals, a conclusion that is confirmed by the following results of a spectrographic analyses made by M. H. Haycock:

Mineral	Gold	Silver	Cadmium	Tin
Pyrite	Present	Absent or negligible	Nil	Nil
Pyrrhotite	Nil	Nil	Nil	Nil
Sphalerite	Nil	Negligible	Present	Nil
Galena	Nil	Present	Nil	Nil
Chalcopyrite	Nil	Present	Nil	Present

It is possible that the silver shown by the spectrograph to be present in the chalcopyrite is contained in inclusions of tetrahedrite, but in that case the chalcopyrite should also contain antimony and arsenic and these are absent. The spectrographic examination of the ore shows that the gold is confined to the pyrite and the silver largely to the galena and chalcopyrite. The tetrahedrite occurs in such small particles that it was not tested spectrographically for silver, but silver is common in tetrahedrite and it is almost certainly present in this case.

The order of formation of the minerals of the Amulet ore as shown by the preceding description of their relationships was in the main about as follows: pyrite, arsenopyrite, pyrrhotite, sphalerite, chalcopyrite, tetrahedrite, and galena, but there are certain exceptions, or possible exceptions, to this succession. The pyrite occurs for the most part in well-formed crystals enclosed in the other minerals and in such cases was undoubtedly formed first, but in some specimens there is an interpenetration of pyrite and sphalerite and inclusions of pyrite in sphalerite. The cross-like inclusions of pyrite in sphalerite also suggest that the pyrite might be later than the sphalerite. It may be possible in the latter case, however, that the crosses are remnants of older pyrite that have survived replacement along crystallographic lines. The presence of the pyrrhotite as inclusions with corroded margins in the sphalerite and chalcopyrite indicates that the pyrrhotite is older than both these minerals, whereas the manner in which it occurs as a matrix around pyrite crystals proves that it is later in age than the pyrite. The occurrence of fine veinlets of pyrrhotite in the chalcopyrite shows, however, that a little pyrrhotite was formed subsequent to or simultaneously with the crystallization of the chalcopyrite. The relationship of the chalcopyrite and sphalerite is not so apparent. In some places in the polished surfaces of the ore the chalcopyrite appears to fill fractures of the sphalerite and its occurrence in zones following the crystal structure of the sphalerite may also indicate a later age. On the other hand, in specimens of the ore definite branching veinlets of sphalerite may be seen to cut the chalcopyrite. It is probable, therefore, that the sphalerite and chalcopyrite were deposited almost simultaneously, but in variable order of precedence at different points in the ore masses. The relationships of the ore minerals indicate, in general, that they were all deposited as part of a single deposition of ore, that the gold-bearing minerals pyrite and arsenopyrite were deposited first, and the silver-bearing mineral, chalcopyrite, tetrahedrite, and galena, with the sphalerite, were deposited last.

ORIGIN OF ORE

There are four controlling factors that require consideration in a discussion of the mode of origin of the Amulet ore deposits. These are: (1) the fractures or other channels along which the ore-bearing emanations may have ascended; (2) the physical character of the rock replaced by the ore; (3) the presence of impermeable barriers which prevented the further ascent of the ore-bearing emanations; and (4) the source from which the ore-bearing solutions came.

That the emanations from which the ore was deposited ascended along fractures is shown by the occurrence of the ore in fractures, by the highly fractured and, in places, faulted condition of the rocks adjacent to the ore deposits, and by the association of many of the deposits with dykes, which, of course, also occupy fractures. In one locality, however, an area of dalmatianite, which elsewhere occurs chiefly below the ore, lies along a zone of lamination and banding in the rhyolite. This zone, which is probably a flow contact, therefore, was also a channel along which emanations could ascend.

Where outcrops of the rhyolite breccia matrix have been weathered, the structure of the rock stands out and it is seen to consist of a network of rhyolite, enclosing areas of dalmatianite, similar in form to the coarsely cellular or scoriaceous structure of lavas. This open character of the breccia was, no doubt, of great importance in the development of the ore deposits of groups 1, 3, 4, and 5, for the openings afforded channels along which the ore-bearing solutions could spread out and become impounded beneath the overlying andesite. In the case of the ore deposits of group 2, the presence of breccia in the andesite (Plate III A) was also almost certainly a factor in the development of the ore deposits for the same reason.

The third important factor in the development of the Amulet ore deposits where the ore deposits occur in the rhyolite breccia is the presence of a dense, impermeable andesite cover, which prevented the further ascent of the ore-bearing emanations. As a result of this impounding of the ore-bearing emanations the ore minerals, especially the sphalerite, chalcopyrite, tetrahedrite, and galena, which were deposited last and hence almost certainly at lowest temperatures, are concentrated close to the andesite, whereas the minerals of the dalmatianite—cordierite, gedrite, biotite, spinel, magnetite, and quartz—which are known to crystallize at higher temperatures, replaced the rhyolite breccia lower down. In like manner, in the case of the Number 2 group of deposits, which occur in the andesite, the ore overlies the dalmatianite. There is some uncertainty regarding what formed the impermeable cover in this locality. In the northwestern part of the mineralized area it was probably, in part at least, a northwestern dipping diorite dyke, but elsewhere, as previously explained, a dense flow of andesite. It is noteworthy that the pyrite and pyrrhotite which were among the first of the ore minerals to deposit are not as highly concentrated in the upper parts of the ore zones as the other minerals. This is indicated for the pyrite by the gold values which are largely confined to it and are fairly uniform throughout the entire ore zone regardless of the amounts of other metals present.

The fourth factor, the source of the ore, cannot be satisfactorily discussed without a knowledge of all the data available from the other ore deposits of the sulphide type in the region. At this stage of the Noranda investigation, therefore, only the relationships of the Amulet ore deposits bearing on the problem will be presented. There are three important intrusives in the region, so far as known, from which the ore deposits could have been derived. These are: (1) the diorite and quartz diorite, (2) the granodiorite or related intrusions, and (3) the late Precambrian diabase. Since the dyke of diorite adjoining the Number 2 mineralized area has been altered to dalmatianite, the ore deposits cannot be older than the diorite, but the alteration of the diorite to dalmatianite does not preclude the possibility that the ore came from the diorite magma, because ore-bearing emanations coming from the magma below may alter the consolidated upper part of the same intrusion. The granodiorite, and the diorite and quartz diorite, are closely related in composition and are probably derived from the same magma by differentiation, so that whether the ore deposits came from the diorite or the granodiorite, the source would be practically the same, except for the stage in differentiation at which they were formed. The ore deposits of the Amulet all lie variable distances, from 600 feet in the case of the Number 2 group, to several thousand feet, west of the dyke of late Precambrian diabase that occurs along the eastern edge of the property. There is much evidence in the case of all the groups that the ore-bearing solutions ascended vertically along fractures and not diagonally from the east as they would almost certainly have done if they were in any way related to the diabase dyke. It is evident, therefore, that if the ore deposits are derived from the late Precambrian diabase they came directly from a larger mass of magma below and not by way of the dyke.

ORE RESERVES, PRODUCTION, AND DEVELOPMENT

The total known ore reserves of the Amulet on June 30, 1930, and their average copper, zinc, gold, and silver content, according to the estimate of the General Manager, were as follows:

Tons	Copper	Zinc	Gold	Silver
	%	%	$	Ozs.
527,153	3·17	11·78	0·94	2·44

To ascertain the present ore reserves the ore mined between July 1 and October 20 must be deducted from the above. The production during the period of operation between April 30 and October 20 was as follows:

Time	Tons	Copper	Zinc	Gold	Silver
		%	%	$	Ozs.
(April 15-June 30)..........................	22,073	3·69	19·41	0·059	19·36
(July 1-Oct. 20)............................	32,218	4·19	16·32	....	....

It may be noted that the ore of the Amulet, taken as a whole, contains about 3½ times as much zinc as copper and that the average of 3·17 per cent copper is equivalent to 9·19 per cent chalcopyrite and the 11·78 per cent zinc to 17·58 per cent sphalerite.

At the time mining operations were discontinued on October 20, 1930, 278 diamond drill holes to varying depths down to 775 feet had been drilled, by means of which the ore deposits of the five mineralized areas, with the exception of the E mass of Number 4 group, and the ore mass or masses of the Number 5 group below the diorite dyke or dykes, had been approximately outlined. In the mineralized areas numerous strippings and pits had been excavated and the ore masses at or near the surface laid bare. In mineralized area Number 3 a prospect shaft inclined 60 degrees to the southeast and 53 feet deep had been sunk. In the mineralized area associated with the Number 4 group, a vertical shaft (Number 4 or C) had been sunk for 255 feet and an adit about 600 feet long opened to connect with the shaft at a depth of 75 feet. For mining the ore-bodies drifts had been driven 260 feet to the west and 250 feet to the east at the 75-foot level; 360 feet to the northeast, 250 feet to the east, and 500 feet to the south at the 150-foot level; and 360 feet to the east, and 280 to the south on the 250-foot level. From these workings the ore was being hoisted to the 75-foot level and conveyed from this point by electric tramway through the adit to the mill. For mining the ore of the Number 5 group a shaft (Number 5 or F) had been sunk to a depth of 355 feet and from it drifts had been driven southeasterly for 280 feet at the 280-foot level, and for 230 feet at 355 feet. Crosscuts from these levels had also been driven across the ore mass. The shaft and drifts from the Number 5 shaft had been allowed to fill with water at the time the writer examined the property, so that the description of this group of deposits in this report is based on an examination of the diamond drill cores and the company's records.

FUTURE DEVELOPMENT

The writer's examination of the Amulet property has been confined, so far, to the part adjoining the known ore deposits shown in Figure 4. The discussion that follows has reference, therefore, to this area only and is incomplete. In the search for other ore deposits the following observations regarding the known ore deposits are important.

(1) The ore deposits are associated with areas of intense deformation and alteration, the presence of which is indicated by veinlets of calcite, epidote, and quartz; by fine, intersecting seams of quartz that weather with a grid-like appearance (Plate III B); by faults; by dykes; and by other related features. The andesite overlying the ore masses of the Number 4 group is well exposed in many places so that, there, it is possible to observe the structural and other features that characterize the rocks above the ore deposits. These are: (*a*) zones of closely spaced, platy fracturing; (*b*) feather fracturing; (*c*) zones of fine, intersecting joints giving the rock a rubbly appearance; (*d*) grid weathering; (*e*) rusty zones resulting from the weathering of pyrite; and (*f*) bleached and silicified zones adjoining fractures. It was these features, especially the grid weathering, in outcrops near the site of shaft Number 5, that directed the attention of J. G. MacGregor to the possible occurrence of ore beneath the andesite at this point. The anticlinal structure of the rocks, the occurrence of dalmatianite beneath the andesite contact to the west, and the pitch of the anticline to the east, however, were also important data suggesting the posssibility of ore at depth in this locality.

(2) The occurrence of four of the five known groups of ore deposits in the rhyolite breccia beneath the andesite contact indicates that this is an especially favourable horizon for the occurrence of ore. But the presence of the ore deposits of the Number 2 group in the andesite, 1,000 feet above the rhyolite breccia-andesite contact, also indicates that ore deposits may be anywhere, either in the rhyolite or the andesite, where the rock has a cavernous structure below an impermeable barrier to the upward ascent of the ore-bearing emanations such as a flat-dipping dyke or a dense lava flow, and where the other conditions here described are present.

(3) The presence of dalmatianite everywhere below the ore deposits shows that ore will be found in association with dalmatianite wherever the rocks structurally above the dalmatianite have not been removed by erosion.

(4) A vesicular or scoriaceous structure or breccia in the rhyolite or andesite is favourable to ore replacement.

(5) Four of the five known groups of ore deposits occur on or near the crests of anticlines.

If the part of the Amulet property included in Figure 4 be examined to ascertain whether anywhere all or some of the above conditions exist, it will be observed that most of the favourable territory in anticlines Numbers 1 and 4 has been developed by diamond drilling down to the rhyolite breccia-andesite contact. In anticline Number 2 there are few outcrops east of the rhyolite breccia-andesite contact and only two diamond drill holes (Numbers 247 and 271), both in the extreme northern part of the north limb. There is no dalmatianite or mineralization in the rhyolite breccia adjacent to the andesite contact, but a considerable mass of dalmatianite occurs adjacent to a zone of lamination and banding in the outcrops farther west. It may also be possible that ore is present in the rhyolite breccia beneath the low, northwest dipping diorite dyke that crosses the Number 2 anticline in the direction of the Number 5 shaft. East of the rhyolite breccia-andesite contact there are two outcrops of dalmatianite in the andesite and an area mineralized with pyrite and pyrrhotite, 100 feet by 10 to 40 feet, in one of the group of outcrops lying west of the aerial tramway. Both of these features show that some ore-bearing emanations have at these points ascended into the andesite. In anticline Number 3 there is no dalmatianite or mineralization in the rhyolite breccia adjacent to the andesite contact, nor was any ore intersected in diamond drill holes put down through the andesite to the north and east of the contact. There is, however, a mass of well-developed dalmatianite in the rhyolite breccia on the north limb of this anticline near the western edge of the area mapped (Figure 4), but whatever ore was associated with this has, of course, been eroded away. On the eastern continuation of the Number 3 anticline, the north limb is largely hidden beneath stratified clay, whereas the south limb is exposed in numerous outcrops. In most of these the features suggesting the presence of ore are not conspicuously developed. Probably the most favourable locality is that adjacent to, and especially north of, the camp buildings where there is a cluster of minor intrusions and some prospect pits in which pyrite is common. At this point the rhyolite breccia-andesite contact occurs at a depth of about 300 feet.

MAGNETITE

Near the margin of the map-area, to the north of mineralized area Number 2, there is a zone or vein of magnetite and quartz about 1 foot wide, exposed for a length of 25 feet. The contacts of the zone with the andesite are definite but irregular. The magnetite is the predominant mineral. Under the microscope the vein material is seen to consist of very irregular, angular grains of magnetite, irregular, interlocking grains of quartz showing undulatory extinction under crossed nicols, and a few grains of an isotropic mineral probably garnet.

SUMMARY

The predominant rocks occurring within the Amulet map-area are lava flows belonging to two groups, the older consisting of rhyolite and rhyolite breccia, and the younger of andesite. The former of these occupies the western part of the map-area and the latter the eastern part. Intruding these lavas are masses of diabase, masses and dykes of diorite, and numerous smaller masses, sills, or dykelets of both acid and basic rocks. The succession in age for most of these minor intrusions is known by the manner in which they cut one another and from their relationship to the diorite and quartz diorite.

In association with the ore deposits and chiefly structurally below them, there are large masses of a peculiar, protuberant-weathering rock, which, because of its spotted appearance on its weathered surface, has been named dalmatianite. Microscopic examination of the rock shows that the peculiar spots from which the rock derives its name consist of cordierite and that the dalmatianite in addition to this mineral consists largely of brown mica, aluminous anthophyllite (gedrite), green spinel, granular quartz, chlorite, magnetite, and the ore minerals pyrite, pyrrhotite, sphalerite, and chalcopyrite. From the association of the dalmatianite with the ore deposits, and the manner in which it has replaced the rhyolite and andesite lavas, andesite dyke rocks, and the diorite, it is concluded that the dalmatianite has been formed by hydrothermal alterations and that this transformation was effected by the emanations from which the ore was deposited.

The rocks of the area have been folded, fractured, and faulted. The volcanics, as shown by the sinuous course of the rhyolite breccia-andesite contact from north to south across the property, have been crumpled into a succession of east-west trending, broad anticlines separated by synclines, pitching eastward at angles of 20 to 25 degrees. That the rocks have been fractured is indicated not only by the presence of numerous fractures, but by the abundance of dykes and the manner in which some of these have been broken into fragments. The predominant strike of the dykes is northeasterly. The presence of faults along some of these fractures is shown by the displacement of dykes and by the grooved and slickensided surfaces of fractures exposed in the mine workings.

The ore deposits lie for the most part in the rhyolite breccia directly beneath the andesite contact, but in places deposition also occurred in the andesite above the rhyolite breccia, as in the Number 2 mineralized area and possibly at one point in the upper part of the Number 5 group of deposits. The Number 2 group of deposits lies in the andesite nearly one-half mile to the east of, and structurally about 1,000 feet above, the rhyolite breccia at a point where the andesite has been much fractured, where there are numerous dykes, and where considerable andesite breccia is present.

The ore consists chiefly of pyrite, pyrrhotite, sphalerite and chalcopyrite, granular quartz, the various minerals of the dalmatianite, and very small proportions of arsenopyrite, tetrahedrite, and calcite. A spectrographic analysis of the ore by M. H. Haycock of the Ore Testing Laboratories of the Mines Branch shows that the pyrite and arsenopyrite carry gold and the chalcopyrite and galena carry silver. The tetrahedrite, because of the small size of its particles, was not tested spectrographically, but it is almost certain that it also is silver bearing. The relationship of the ore minerals as seen in thin sections and in polished surfaces under the microscope shows that they formed for the most part approximately in the following order: pyrite, arsenopyrite, pyrrhotite, sphalerite, chalcopyrite, tetrahedrite, galena, but the presence of veinlets of both pyrrhotite and sphalerite in the chalcopyrite indicates that there was some variation from this succession. The manner in which the ore deposits of the Amulet were formed was about as follows. The ore-bearing emanations ascended to points in the rhyolite breccia matrix possessing a vesicular structure or in the andesite where there was breccia, through which they could easily penetrate. In these open, permeable rocks they first spread out horizontally and then ascended to places where impermeable barriers were met. This barrier in the case of most groups of deposits (Numbers 1, 3, 4, and 5) was a belt of dense andesite lava, but in one case (Number 2) which is in andesite breccia it was probably a very dense flow of andesite, or possibly, in the northwestern part of the area of mineralization, a northwest-dipping dyke of diorite. Deposition of the ore took place, no doubt, wherever cavities existed, but considerable masses of rock also must have been replaced by ore. The ore minerals practically all were deposited in a zone from 100 to 200 feet below the impermeable cover and chiefly in the upper part of this zone, whereas the dalmatianite was formed in its lower part or below the zone. It would seem, therefore, that if all the minerals, metallic and non-metallic, occurring in or associated with the ore deposits of the Amulet, be included, they exemplify a variety of zoning, the upper zone in this case consisting chiefly of metallic minerals and the lower zone chiefly of the non-metallic minerals of the dalmatianite.

THETFORD AND DISRAELI QUADRANGLES, QUEBEC

By H. C. Cooke

CONTENTS

Illustrations

INTRODUCTION

During the field season of 1933 the investigation of the asbestos and chromite deposits of Thetford area, and the study of the general geology of Thetford and Disraeli quadrangles, were continued. The results may be briefly summarized as follows.

The peridotites and pyroxenites in which the asbestos and chromite deposits of the region occur are termed the serpentine series. It is shown that the gabbro masses of Thetford and Disraeli quadrangles are older than the serpentine series, not one of its youngest members as previously considered. Further, the gabbro magma differentiated so as to yield a variety of rock types. Although most of them are of gabbroid composition, a small amount of granite was formed as the most acid end member, and a considerable amount of pyroxenite as the basic end member. Thus, two pyroxenites occur in the district, the older formed by differentiation of the gabbro magma, the younger a member of the serpentine series.

Considerable masses of very pure serpentine accompany the pyroxenites and proxene-rich peridotites of Red Hills, Diamond Hills, Nadeau Hill, and other areas. These serpentines have commonly been considered as the alteration product of dunite. Evidence was obtained, however, that they formed by alteration of the pyroxenite and pyroxene-rich peridotite after a period of faulting.

The chromite deposits have a double origin. Part of the chromite is an original rock constituent, and crystallized during consolidation of the peridotite magma. A large part, and from an economic viewpoint probably the most important part, is of later age, and was introduced into fault and joint fissures in vein-like forms at some period between the consolidation and faulting of the rock and the formation of the asbestos veins. This discovery has an important bearing on prospecting operations.

GENERAL GEOLOGY

The general geology of Thetford quadrangle has been fairly thoroughly described in the Summary Reports of the Geological Survey for 1930-32, and, accordingly, only new facts learned during the past summer will be discussed here. The following is the table of formations for the area.

Table of Formations

Post-Ordovician (?)		Granite, peridotite, pyroxenite, gabbro
Ordovician	Beauceville series	Black slate, quartzite, conglomerate
Cambrian (?)	Caldwell series	Quartzite, basalt, grey, green, and red slate, Bennett schists

CALDWELL SERIES

The mapping of the Caldwell series was carried across the northwest corner of Disraeli quadrangle, which lies south of Thetford quadrangle. The conclusion, reached in 1931, that the Bennett schists are not a separate series, but are merely the lower, more metamorphosed part of the Caldwell series, was confirmed. No definite contact between the Bennett and the less metamorphosed Caldwell rocks can be found either in Thetford or Disraeli quadrangles; on the contrary, the two everywhere are separated by a zone, wide in places, narrower in others, across which schistosity becomes gradually more and more pronounced.[1]

In Disraeli area three petrographic types were observed which were not seen in Thetford area. The first, a garnetiferous quartzite, is best developed 1 mile to $1\frac{1}{2}$ miles northeast of Breeches Lake, though it also occurs elsewhere. Certain beds, interbanded with normal schistose quartzite, carry garnets up to $\frac{1}{4}$ inch in diameter, now partly altered to chlorite; in places the garnets are so numerous as to constitute about one-third of the rock. These beds are within the zone mentioned above, which lies between the highly metamorphosed Bennett schists and the slightly metamorphosed Caldwell rocks. The second petrographic type, a chlorite rock, forms a band traceable about 3 miles, from a point $\frac{1}{8}$ mile west of the middle of Breeches Lake northward to and along the west flank of Belmina Ridge. This rock is metamorphosed to a fairly coarse hornblendite over considerable widths from its contact with the peridotite of Belmina Ridge. The third type, a trachytic lava accompanied by large volumes of red and grey, cherty tuff, lies west and north of East Lake. The detailed descriptions of these types is reserved for the general report on the region.

BEAUCEVILLE SERIES

The mapping of the Beauceville series was continued into the Disraeli quadrangle as far as Garthby. In the Disraeli quadrangle the series consists mainly of black slates, with which are interbedded some rather pure quartzites petrographically resembling the Caldwell quartzites. None of these pure quartzites appears in Thetford quadrangle. As in Thetford area, the series is sharply folded along rather closely spaced, northeast-striking axes.

[1]For a more extended discussion of this problem *See* Sum. Rept. 1931, pt. D, pp. 3-5.

INTRUSIVES

Gabbro

Relations to Pyroxenite and Peridotite. Gabbro occurs in a number of places in the southern part of Thetford quadrangle and the adjacent parts of Disraeli quadrangle. Previous writers have supposed this rock to be closely allied in age and origin with the peridotites and pyroxenites of the region; in fact, to be an acid differentiate of the same magma. Thus, J. A. Dresser states:[1]

> "The various rocks of the serpentine belt have been formed by differentiation from a common magma . . . . The rocks are arranged in order of decreasing basicity, viz., serpentine or peridotite, pyroxenite, gabbro or diabase, porphyrite, and sometimes aplite, in sills from the base upwards; in stocks from the centre outwards."

During 1931-2 various indications, none of which was conclusive, led the writer to doubt the accuracy of the above statement; but contacts between the gabbro and the other igneous rocks are so universally hidden by drift in Thetford area that conclusive evidence proved impossible to obtain. During 1933, however, evidence was found, proving definitely that the gabbro is not an acid differentiate of the magma producing the Serpentine series, but on the contrary is cut by the rocks of that series and, therefore, is older than they. The evidence is as follows.

In Lot 28, Range V, Wolfestown Township, about $\frac{1}{4}$ mile from the Garthby-Wolfestown boundary and 500 feet from the road past the north end of Breeches Lake, there is a contact between gabbro and peridotite on a low cliff forming the southwest face of Chalet Hill. The gabbro, as in many places, exhibits pronounced flowage textures, which at this point strike north 20 degrees west and dip 30 degrees east. The peridotite emerges from underneath the gabbro at the foot of the cliff, with the contact almost paralleling the dip and strike of the flow textures; then turns sharply to a vertical position and cuts across the flow textures at an angle of 60 degrees (Figure 8). The relations are best seen on the side of a little gully that cuts into the cliff and across the contact, so as to yield a vertical cross-section about 8 feet long. They are also well exhibited a little farther along the face of the cliff, where all the peridotite has been eroded, except for a number of flat chips, 8 or 10 inches across, which still adhere to the gabbro face. In both places it is clearly evident that the contact cuts at a large angle across the well-developed flow textures of the gabbro.

The point separating the two "legs" of Breeches Lake is underlain by gabbro. A dyke-like mass of pyroxenite, now pretty well serpentinized, cuts through the gabbro of the south shore of the point, and presumably crosses the eastern "leg," as what appears to be its continuation is found on the eastern shore, cutting the Caldwell quartzites. It strikes east-northeast and dips almost vertically. Where it crosses the gabbros of the south shore it is a vertical, tabular body about 100 feet wide, with gabbro on both sides, so that the relations are those of an intrusive dyke. The contacts are everywhere covered with drift and boulders; but in one place, on the north

[1]Geol. Surv., Canada, Mem. 22, pp. 42, 43 (1913).

side, what appears to be a parallel offshoot about 6 inches wide cuts through the gabbro. In two places this throws off wedge-shaped apophyses into the gabbro, one of which is about 4 inches wide at the base and a foot long, the other about the same width at base and 18 inches long.

About the middle of Lot 8, Range IV, Coleraine Township, on the northwest slope of Nadeau Hill, a small mass of gabbro is in contact with pyroxenite. The summit of the knob where the contact was found is burned clean of vegetation, so that exposures are excellent. The contact is highly irregular and embayed. The pyroxenite is fine-grained near the contact, either through chilling or some other cause, cuts through coarse gabbro which shows no sign of chilling, and crosses joints in the gabbro. In some places crooked, fine-grained fingers of pyroxenite extend from the main mass into the gabbro; in others a little contact breccia, consisting of

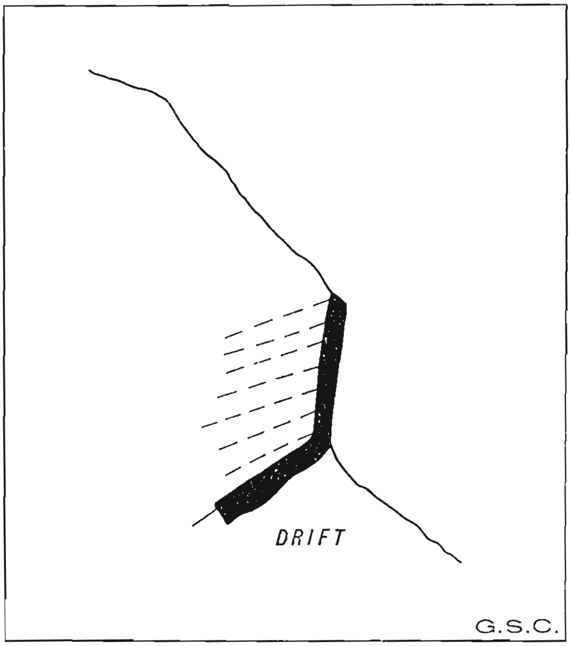


Figure 8. Cross-section showing relations of gabbro and peridotite observed on Chalet Hill. Peridotite indicated by solid black, gabbro by broken lines the direction of which indicate the dip of the flow textures.

half a dozen gabbro fragments in a pyroxenite matrix, has formed. The gabbro, as usual, is cut by many basic dykes; and although a few of these cross the contact and run a short distance into the pyroxenite, others end at the contact and furnish fragments to the contact breccias described. In the particular cases observed, the fragments trail southwards from the dyke whence they came, making it appear as if the pyroxenite magma, at this point, had a movement from north to south.

On the west flank of Mount Adstock, at about the 1,500-foot contour, a strong dyke of coarse pyroxenite cuts the gabbro of the hill. The dyke is about 8 feet wide, strikes slightly north of east, and has an almost vertical dip. The surrounding gabbro is coarse-grained. The contact is sharp, but the pyroxenite for a few inches from the edge has been sheared to a white, featureless material.

On the south side of Nadeau Hill, where pyroxenite is in contact with a large mass of gabbro, the pyroxenite is chilled for some distance from the contact. The exact width of the chilled zone was not measured, but is of the order of 100 to 200 feet. As the contact is approached, the pyroxenite becomes progressively finer in grain, forming a massive, white or very light grey rock of striking appearance. The same change, on approaching contacts with the gabbro, was observed on LeMay Hill, northeast of East Lake, and on the ridge just north of LeMay Hill.

To summarize, the peridotites and pyroxenites[1] have been observed to break through the gabbro, across pre-formed flow textures; to form dyke-shaped masses in it; to exhibit chilled contacts against it; to throw off stringers and apophyses into it; to cut off dykes that intersect it; and, near the contacts, to include fragments both of the gabbro and of intersecting dykes. The conclusion is, therefore, indubitable, that the pyroxenites and peridotites are later than the gabbro, and intrude it.

Petrographic Character of the Gabbro. The term gabbro is here used in a more restricted sense than in the earlier reports by Dresser, Knox, Graham, and other writers. These authors, whose attention was devoted mainly to the asbestos and chromite deposits and their containing rocks, included under the terms gabbro and diabase not only the true gabbros, but also large masses of basaltic lavas afterwards proved to belong to the Caldwell series. The true gabbro is an intrusive, definitely younger than these lavas, though its exact position in the time scale is not yet determined.

The gabbro, thus defined, is a rock of medium to coarse grain, composed normally of about equal parts of feldspar and pyroxene, and weathering accordingly to a greyish green colour. The proportions of the essential minerals vary somewhat from place to place, and the colour alters to lighter or darker accordingly. On the average, the rock is masive and equigranular, with a grain of 1 to 2 mm.; but coarser varieties are not uncommon near the middle of large masses, and toward contacts the rock chills to a fine-grained material petrographically indistinguishable from a basalt. Where the gabbro is in contact with basalt, this makes mapping of the contact very difficult. In a number of places the gabbro exhibits flowage textures, indicating some movement in the later stages of consolidation.

The gabbro is highly altered almost everywhere. Commonly the augite is completely gone over to uralite, actinolite, and chlorite, although identifiable remnants are occasionally found, particularly in the coarser types. Some of the feldspar commonly remains, and proves to be mainly andesine, but most of it has now become sericite, zoisite, and epidote. Ilmenite, now largely altered to leucoxene, is the principal accessory mineral. Some carbonate and sulphides, including pyrite, chalcopyrite, and galena, occur here and there in veinlets and fine disseminations, and are probably not original, but introduced.

[1]The peridotites and pyroxenites are considered as one, because they are closely related in age and origin.

The gabbro has been severely crushed, a fact probably indicating that it was intruded before the main folding of the region. The crushing is well seen on the ridge north of LeMay Hill, where it is pronounced for some hundreds of feet from the contact of the gabbro with the sediments. In places the rock is merely severely fractured, in others it is converted into a breccia of gabbro fragments cemented by a paste of crushed gabbro. The fragments vary in size from 1 or 2 inches to several feet in diameter. F. R. Burton[1] has described a similar condition existing in the gabbro of Mount Louise, the large hill on the south side of the Garthby Road, at the extreme western edge of Disraeli quadrangle.

A peculiarity of the gabbro is the almost universal presence in it of numerous dykes, varying from an inch to several feet in width. They occur so regularly wherever the gabbro is found, and in such numbers, that the observer presently accepts them as a characteristic part of the intrusive. They are limited to the intrusive, and do not pass beyond its borders, so that in this way they behave like true differentiates, such as pegmatites. However, they do not resemble pegmatites or acid differentiates of any kind. F. R. Burton (loc. cit.) has distinguished three types, which he has named gabbro-diorite porphyry, quartz diorite porphyry, and granite porphyry; but the great bulk of the dykes are of the first type, with a limited number of the second, and very few of the third. All these dykes are so highly altered to secondary minerals that conclusions as to their original composition are largely inferential.

Differentiation of the Gabbro. Some of the larger masses of gabbro have been very perfectly differentiated in place, yielding products that vary from pyroxenite at one end of the scale to granite at the other.

The recognition of a pyroxenite as a product of the differentiation of the gabbro magma is a matter of the greatest importance in clearing up the petrology of the intrusives. This pyroxenite, as a part of the gabbro intrusive, is, therefore, older than the normal pyroxenite. In other words, there are in this region two pyroxenites, the older a differentiate of the gabbro magma, the younger a differentiate of the peridotite magma. There can be little doubt that the similarity of the two pyroxenites, and the non-recognition of their differing age and origin, have contributed largely to the older conclusion that the gabbro is intimately related to the pyroxenite-peridotite series.

The largest known mass of pyroxenite derived from the gabbro magma is on Mount Adstock, where it forms the bulk of the hill above the 1,700-foot contour. Smaller masses have been found in the gabbro of LeMay Hill and the ridge north of it, in the small mass of gabbro $\frac{3}{4}$ mile northwest of Brousseau Hill, and on Mount Louise. Wherever found, the masses appear to have been formed by the settling and aggregation of masses of augite crystals. There is never a sharp boundary between the ordinary gabbro and the gabbro-pyroxenite, but one grades into the other by diminution of the amount of feldspar. An infinite variety of specimens could be taken,

[1] "Geology of Lake Aylmer District, P.Q.", 1933. Thesis, McGill University Library.

showing gabbros with less and less feldspar, and finally pyroxenite, which contains practically none. In the LeMay Hill mass, which is a sill dipping northwest, the pyroxenite phases are found near the base of the sill.

The gabbro-pyroxenite is readily distinguishable in the field from the later pyroxenite. All the pyroxene of the gabbro-pyroxenite is dark green, and weathers dark green. Specimens taken by the writer were too much altered for determination, but other writers have identified the pyroxene as diallage.[1] The later pyroxenite, on the other hand, is mainly composed of enstatite, with a relatively minor amount of scattered diallage, and is characterized, both on the fresh and the weathered surfaces, by light greyish to pale green tints. The gabbro-pyroxenite commonly contains a little interstitial feldspar; and even where none can be detected with the eye, it is rarely necessary to go more than a few tens of feet across the outcrop to come upon feldspathic varieties or pegmatitic phases. The later pyroxenite, however, never contains feldspar. The writer has examined some square miles of these rocks in detail, and studied some thousands of fragments with the lens, without detecting any feldspar whatever in them, except in one doubtful instance.

In addition to the above features, which are purely petrographic, there is the fact that the gabbro-pyroxenites are always closely associated with masses of ordinary gabbro, lie wholly within them, and grade into gabbro at the edges; whereas the later pyroxenites, in many instances, have no association whatever with gabbro, and where gabbro does lie close by the relationships are those of an intrusive to an older rock.

The other phases of the gabbro may be more briefly treated, and perhaps may be best described by giving a section across the LeMay sill. A steep-walled valley cuts across the ridge just north of the hill, and the gabbro is excellently exposed on the sides. The north side of the sill is fine-grained gabbro, containing 50 to 60 per cent of pyroxene, and greatly brecciated, as described. This zone is quite thick, between 200 and 300 feet. Southwards the grain gradually coarsens until it attains a size of 3 to 5 mm.; the composition, however, remains about the same. Toward the base of the sill there was a tendency for the pyroxene grains to collect, yielding irregular masses of gabbro-pyroxenite. The base of the sill is composed again of the fine-grained, brecciated material found at the top. Basic dykes of the types described cut all the above phases; and in addition there are occasional splashes, larger irregular masses, and dyke-like bodies of a sort of pegmatite. This material is a very coarse gabbro, with pyroxenes generally about ½ inch in length, though in places much longer, and with a larger proportion of feldspar than in the normal gabbro. The edges of these masses are not sharp, but pass by a rapid gradation into the normal gabbro.

West of LeMay Hill there are some exposures of granite in low ground. The granite appears to be made up of quartz and feldspar in nearly equal proportions, and is deeply weathered. It is cut by numerous dykes of the same type and with the same strike, north 45 degrees east, as those that cut the gabbro nearby. The nearest outcrops of gabbro, about 200 feet to the southeast, contain small dykes and irregular patches of similar granitic

[1]Adams, F. D.: Geol. Surv., Canada, Sum. Rept. 1880-1882, p. 126.

material, and also other patches of material of intermediate composition, i.e., of coarse gabbro containing a good deal of quartz. For these reasons the writer concludes that this granite is probably an acid differentiate of the gabbro magma.

Relations to Other Formations. The relations of the gabbro to the sediments of the region are difficult to determine, partly because contacts are commonly covered, but mainly because the contacts seem to have been places where later intrusion of pyroxenite or peridotite readily took place. The very common association of the three rocks, thus caused, has been a second predisposing cause for considering them to be differentiates of a common magma.

Up to the present time the only relations positively determined are those with the Caldwell series. On the ridge north of LeMay Hill the gabbro is in contact, on the north, with cherty tuffs; and, as already described, its edge is strongly chilled over a wide zone. In Range III, Lot 28, Wolfestown Township, close to the Garthby line, numerous stringers and small dykes of gabbro intrude the Caldwell basalt in a complex manner so as to form a breccia of basalt fragments in a gabbro matrix. The gabbro is, therefore, intrusive into the basalts and other rocks of the Caldwell series.

In the vicinity of Coleraine, in several places, the gabbro forms very extraordinary breccias with the basalts and quartzites of the Caldwell series. Some of the breccias are clearly formed by crushing and movement, others do not seem to be formed in that way. As the significance of these breccias is not yet understood, detailed description of them is deferred; but the presence of undoubted crush breccias including fragments of gabbro, and the crushing of the gabbro masses themselves, already described, strongly suggest the conclusion that the gabbro was intruded and consolidated before the main folding of the region, i.e., either before or during Ordovician time.

Pyroxenites and Peridotites

The pyroxenites and peridotites are a closely related series exhibiting all variations of composition from pure olivine rocks at one end to rocks composed only of pyroxene at the other. They form two main masses, which lie on either side of one of the principal anticlines of the region, that which extends through the middle of Lac a la Truite southwest to pass just south of Coleraine Village. The northwestern mass underlies Granite Hill, Reed Hill, Murphy Hill, Quarry Hill, Provencal Hill, and Caribou Mountain. The smaller, southeastern mass forms Poudrier Hill, Diamond Hills, Cloutier, Nadeau, Bengel, and Brousseau Hills. The two bodies may be connected, on the northeast, through the Red Hills and beneath the wide drift area extending from Red Hills to Poudrier Hill. The possible connexion is along or near the crest of one of the principal anticlinal cross folds of the district. The peridotite body at Thetford Mines appears to be an almost independent mass about 2 miles long and 1½ miles wide, lying northeast of the main northern body. In addition to the principal bodies, there are a number of dykes that need not be described in detail.

The northwestern mass and the subordinate Thetford Mines body consist mainly of olivine-rich peridotite. Nowhere within Thetford quadrangle does this rock contain less than 50 per cent of olivine, and commonly the olivine forms 80 to 90 per cent. Here and there within it are small masses of dunite,[1] which appear to be magmatic segregations. There is no pyroxenite in this body, except small dykes and a little in a few places along the southeastern border. The southeastern mass, on the other hand, contains a large proportion of pyroxenite, perhaps 50 per cent or even more; it has not yet been studied with the detail required for a good estimate; and the remainder is pyroxene-rich peridotite, with 50 to 90 per cent of pyroxene. In this area there is none of the olivine-rich peridotite whatever.

The ultrabasic rocks of the area thus fall naturally into two groups, a "peridotite series," made up of olivine-rich peridotites, and their associated dunites; and a "pyroxenite series," made up of the true pyroxenites and the pyroxene-rich peridotites associated with them. The pyroxenite series, in addition to occupying the southeastern mass as described, also underlies the Red Hills.

The relationship between the peridotite series and the pyroxenite series is shown on Reed Hill. The peridotite of the northwestern mass is composed, in the main, of olivine with 5 to 15 per cent of pyroxene and a few grains of accessory chromite. Towards the southeastern edge, however, the pyroxene content tends to rise, and irregular areas of outcrop are found where it may attain 30 per cent or more. On Reed Hill this tendency is particularly marked. All the peridotite of the hill is rather pyroxenic, averaging from 10 to 20 per cent; but at the south end, close to the margin between the peridotite series and the pyroxenite series, it becomes particularly so. Here the pyroxene content rises rather rapidly, and exhibits great variations within distances of a few inches. Peridotite containing only about 20 per cent pyroxene will contain patches, inches or feet in diameter, carrying 50 per cent pyroxene, and the gradation zone between the two will be only about 3 inches wide. The extreme south end of the outcrop averages between 40 and 50 per cent of pyroxene.

A drift-filled gap about 300 feet wide separates Reed Hill from the next hill to the south, underlain by the pyroxenite series; and the north end of this hill is composed largely of peridotite averaging about 50 per cent pyroxene. Thus relationships are gradational between the olivine-rich peridotite of Reed Hill and the pyroxene-rich peridotites of the hill mentioned and of Red Hills directly to the east.

The mixtures of pyroxenite and pyroxene-rich peridotite are prominently banded, as if flow movements had occurred during consolidation. In a few places the bands are sharply contorted, but commonly they run in long, sweeping, gentle curves. Parallel strings of chromite grains or of pyroxene crystals, which appear likewise to indicate directions of flow, are seen also in many parts of the olivine-rich peridotites. The supposed flow textures strike east to slightly south of east in the northern part of Reed Hill and the adjoining part of Murphy Hill, and swing gradually to south-

[1]Cooke, H. C.: Geol. Surv., Canada, Sum. Rept. 1931, pt. D, p. 6.

southeast at the south end of Reed Hill. They have the same strike throughout the pyroxenites of the hill lying south of Reed Hill, a fact that again suggests the unity of the two rock types.

The mixtures of pyroxenite and pyroxene-rich peridotite are splendidly exposed in the Red Hills, and particularly so on a long, west-facing cliff north of the Hall chrome pit. On the cliff the banding strikes north 80 degrees west and dips steeply north. The bands consist of pyroxenite, in a matrix of pyroxene-rich peridotite; they have widths up to 8 inches, but commonly of 2 to 4 inches. In the cliff mentioned, the pyroxenite was estimated to form 4 to 5 per cent of the total volume of the rock. The grain of the pyroxenite is roughly proportional to the thickness of the band, coarser in the thicker bands, finer in the thinner. Where the width of a band changes, the grain changes correspondingly. The bands are long, narrow lenses, and end as a rule by gradual thinning. A band 2 inches wide will be about 20 feet long. The widths are fairly uniform, though not absolutely so. Thus, a band with an average width of 1 inch may have a maximum width of 2 inches, and in places may thin to ½ inch. The edges are commonly linear and quite sharp, but in places they are irregular, with little bunches of pyroxene crystals off to one side in the pyroxene-rich peridotite. In places a band may be broken, and over a length of a few inches may consist of small bunches of pyroxene crystals embedded in pyroxene-rich peridotite.

Here and there little stringers run off from a band of pyroxenite, or a band at its end may pass into a narrow stringer. Such stringers in general parallel the general banding, but in some instances cut across it at angles of 2 or 3 degrees. One of these, measured as accurately as possible, varied in width from one-twentieth of an inch in places to one-eighth of an inch in others; and was composed of minute pyroxene crystals, the largest of which were about one-fortieth of an inch in diameter.

The banded materials described are cut by numerous dykes of a younger pyroxenite, which break indiscriminately across the older pyroxenites and the pyroxene-rich peridotites. In the particular locality just described these dykes strike north 40 to 50 degrees west, and dip about 60 degrees northeast; the banding, as mentioned, strikes north 80 degrees west, and dips almost vertically. The dykes vary from ½ inch to 2 inches in width, and appear to be composed entirely of pyroxene. In other places the strike is much more variable, and the dykes run in all directions; in places they become so numerous that the rock takes on the appearance of an intrusive breccia, composed as it is of blocks of interbanded pyroxenite and pyroxene-rich peridotite, in a matrix of later pyroxenite.

The later dykes, like the bands, usually end by thinning to a stringer. Their grain is roughly proportional to the width of the band; and as the end is approached, the grain becomes finer and finer as the dyke thins. Their edges are very narrow bands of blackish material, suggesting a chilled edge. The pyroxene of the dykes appears identical with that of the bands.

In addition to the above types of occurrence, large masses of pure pyroxenite, with no admixture of peridotite, occur in several places, as on the eastern flank of the Red Hills and on Nadeau and Bengel Hills. Such masses are usually very coarse-grained. An average crystal diameter of one-quarter to one-half inch is common, and masses of large size have been seen in which the crystals average an inch or more in diameter.

Origin of the Pyroxenite. Many petrographers consider that rocks composed mainly or wholly of one mineral, like the pyroxenites, can never have existed as fluid magmas, but must have crystallized from magmas of more complex composition; when solidification had proceeded far enough to form masses of crystals of the one kind, the residual fluid was drained off or squeezed out to solidify elsewhere. Thus, according to this view, rocks composed of a single mineral are merely crystal residues left behind after the main mass of fluid magma has moved away.

The reasons for this view need not be discussed here. It is sufficient to point out that rocks so formed could not exhibit chilled edges at their contacts with older rocks, because they are crystal masses formed by very slow cooling and settling. They also could not form small dykes, because solid materials, or even crystal aggregates lubricated with a small amount of liquid, could not enter small fissures without jamming. If they were forced a short distance into such fissures, the crystals of the dyke thus formed should either be as large as those of the mass from which they came, or else should consist of the crushed fragments of the larger crystals.

It is obvious that the pyroxenites of Thetford district can not have been formed in any such manner. Their edges are distinctly chilled against the older rocks; they form numerous small dykes, commonly within the main masses of pyroxenite and peridotite, but also extending into the country rocks. The grain of the dykes is not the same as that of the larger masses, neither are they composed of crushed crystals; on the other hand, the grain commonly corresponds to the size of the dyke, being coarse in the larger dykes and fine in the smaller. Pyroxenite dykes cut across pre-existing structures; and breccias, of fragments of older rocks in a pyroxenite matrix, occur in places at contacts. All these facts indicate that the pyroxenites must have been injected as true fluid magmas.

The relations of the pyroxenites to the pyroxene-rich peridotites strongly resemble those of pegmatite to its parent rock. The older pyroxenite bands in pyroxene-rich peridotite appear to have been liquid parts strung out by the movements of a viscous, partly crystallized magma, or, according to another interpretation, may have been cracks in a partly solidified magma, into which the more liquid, pegmatitic parts flowed. When this oldest part solidified, it was further cracked by shrinkage or movement, and the cracks were filled by still liquid, pegmatitic parts of the magma, forming the pyroxenite dykes. Other parts of the still liquid material appear to have been forced completely out of the main body, to solidify around the edges as the large, coarse-grained dykes and irregular masses of pyroxenite that have been described.

Basic Dykes

The igneous activity of the region ended in the intrusion of granitic and basic dykes, together with some small plugs of granite. The acid intrusives have been described in previous reports.

On Nadeau Hill, and likewise on the west end of Mount Adstock, some basic dykes cut the pyroxenites, and are, therefore, among the latest intrusives of the district. The dykes vary in width from a few inches to 3 or 4 feet, and dip almost vertically. Practically all trace of the original composition is now lost. A thin section of one having the freshest appearance showed nothing but a felted mass of actinolite fibres, with a few grains of accessory magnetite.

Serpentinization of the Pyroxenite Series

The pyroxenite series of Red Hills and adjacent areas has a peculiar distribution. The hills are composed of pyroxenite and interbanded, pyroxene-rich peridotite; but the flanks of the hills, and presumably the drift-filled valleys between, are underlain by a pure, grey-weathering serpentine, which has commonly been considered an alteration product of dunite or olivine-rich peridotite. By some these relations have been interpreted to mean that the hills are erosion remnants of a pyroxenite sheet overlying a sheet of peridotite or dunite; the writer also considered it a possibility that the pyroxenite hills, like the granite knobs to the south, were plugs piercing a body of dunite or peridotite. Neither of these hypotheses proved correct, however, but it was clearly established that the serpentine of the hill flanks and intervening valleys is formed by serpentinization of the pyroxenite series itself.

The proofs of this conclusion are irrefragable. In the first place, the serpentine bands, which vary from a few inches in width to hundreds of feet, cut indiscriminately and at all angles across pre-existing structures, namely, across the primary banding already described and across the later pyroxenite dykes. They must, therefore, be either dykes or alteration products. The edges are neither sharp nor linear; for though in many places they have a pronounced linearity, due to their mode of origin, in others the edges are saw-like, with teeth up to 100 feet long. Such places are found where the serpentine bands cross thick bands of pyroxenite and pyroxene-rich peridotite. The light grey serpentine runs far into the pyroxenite series along the peridotite bands, but the pyroxenite bands project into the grey serpentine.

The edges of the serpentine bands, as stated, are not sharp, as in a dyke, but are gradational; and though the transition takes place within an interval of a foot or so, as a rule, nevertheless within that foot all stages of it can be studied. The following observations were made on a particularly narrow band about $\frac{1}{4}$ mile west of the Hall chrome pit, and the transition here described is typical of all bands. The serpentine band in question is about 6 feet wide, and strikes north 70 degrees east, so that it crosses the original banding, which strikes nearly north, at a large angle. The band is exposed for perhaps 30 or 40 feet in length, and on both sides of this exposed length the rock is pyroxene-rich peridotite, estimated to contain about 80 per cent of pyroxene, and weathering to a reddish tint. The extreme edge of the grey band contains as many and as large pyroxenes as the surrounding pyroxene-rich peridotite, but the matrix weathers grey instead of reddish. This material grades in turn into rock of a still greyer tint, in which the pyroxenes are approximately as numerous as before, but their edges seem to have been attacked, so that they are smaller. At its inner edge this material passes rapidly into featureless grey serpentine, that without any visible remnant of original texture forms the middle part of the band. The centre of the band is a fault, which has sheared the serpentine over widths of 6 inches to 1 foot.

Where a serpentine band cuts across a dyke of pyroxenite, the dyke is likewise converted into grey serpentine, but the original textural differences are sufficiently maintained in spite of alteration so that on weathered surfaces the course of a dyke may be followed for many feet, and often for scores of feet, through the serpentine band.

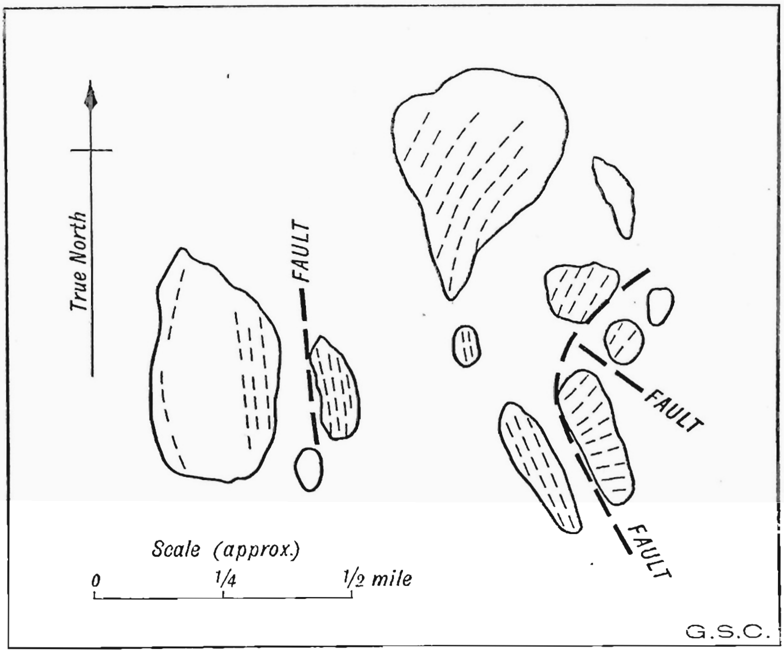


Figure 9. Red Hills area. The enclosed areas are the ridges, on which pyroxenite and pyroxene-rich peridotite are exposed. The intervening areas are supposed to be underlain by serpentine, which is exposed on the sides of the ridges. Dotted lines indicate directions of original banding in the pyroxenite series. Three large observed faults are indicated. The diagram shows the manner in which the serpentine cuts across the original banding.

Figure 9 shows the Red Hills area, taken from the contour map and enlarged to a scale of about $\frac{1}{4}$ mile to 1 inch. The enclosed areas are the ridges, underlain by the pyroxenite series, and the parts between are the valleys, underlain in large part at least by serpentine. The dotted lines in the pyroxenite areas indicate the direction of original banding. The general uniformity of direction maintained by the original banding throughout all these outcrops points to their having been, at one time, parts of a single mass of intrusive; so that the parts now serpentine must have been formed either by alteration of this mass of intrusive, or by injection of a rock that later changed to serpentine. As shown, all the evidence points to the conclusion that the serpentine masses resulted from alteration.

To sum up the evidence; nowhere is it found that an olivine-rich rock intrudes a pyroxene-rich rock, but invariably, wherever two types are in contact, it is the more pyroxenic type that intrudes the more olivinic. The serpentine bands cut across the original banding of the pyroxene series, but their edges are never clean-cut and sharp, as if they had been injected. Wherever the bands are small enough for both edges to be seen, both edges exhibit a gradual transition from the country rock to the grey serpentine of the bands. Where the bands are larger and mainly drift-covered, any edge that can be seen exhibits the same transition. Pyroxenite dykes can be followed, though altered, far into the serpentine bands, which would not be the case if the serpentine bands had been intrusive.

As to origin, the serpentine bands have a fault at the centre in so many instances that it is difficult to avoid the conclusion that serpentine-forming solutions must have entered along this fissure. The pronounced linearity of the bands, too, points to fissuring as the original cause. Many bands, however, have no fissure at the centre, yet are identical in other characteristics with those that have. When it is considered, however, that the alteration of these rocks to serpentine involves an expansion of 10 to 15 per cent, it seems natural to conclude that an original central fissure would have become tightly closed in the process; and it would seem more needful to explain why some bands now have central fissures rather than why some have not. Actually, where bands have central fissures, the serpentine along such fissures is strongly sheared and slickensided, indicating that the fissure has been kept open by movements taking place after the serpentine had formed.

ECONOMIC GEOLOGY

CHROMITE

From the brief preliminary study of the chromite deposits made in 1932 it was stated[1] that the chromite deposits all appear to lie in dunite, and that the chromite is an original constituent of the rock and occurs in bands drawn out by the flow movements of a viscous magma. The more detailed work of 1933 has shown both these statements to be only partly true. Although some of the more important chromite deposits do occur in dunite, others are in the ordinary olivine-rich peridotite, and still others, including some of large size, in the serpentinized, pyroxene-rich peridotite. Although much chromite does seem to be an original constituent of the rock and to form flowage bands, most of the best ore is of later date, and has been introduced into fault fissures in the consolidated rock.

The flowage bands of chromite are of varying thickness, commonly $\frac{1}{4}$ inch to 1 inch. Most of them consist of grains of chromite up to one-

[1]Geol. Surv., Canada, Sum. Rept. 1932, pt. D, p. 54.

twentieth inch in diameter, more or less thickly scattered through a serpentine matrix; in a few the concentration of chromite is such that the band is almost pure chromite. The bands of serpentine between the chromite bands are identical in composition with the matrix, but contain no chromite or at most a few scattered grains. There is no break of any kind between the serpentine matrix of the chromite bands and the pure serpentine that flanks them; but the edges of the chromite bands, marked by an imaginary line through the outermost grains, are straight or gently curving. There is no definite relation between the widths of the chromite bands and those of the serpentine bands between them, but the latter may be wider than, equal to, or narrower, than the former. A chromite deposit of this type consists of parallel chromite and serpentine bands alternating over a width of several feet. Such deposits have been mined at times when chromite commands a good price, and in places where chromite forms the major part of the chromite bands. All such ores, of course, require concentration to remove the serpentine.

That much at least of this material is an original constituent of the peridotite is shown by the relations of the bands to pyroxenite dykes. Where a chromite band encounters a little dyke it does not cut through it, even though the dyke is completely serpentinized. On the contrary, the dyke cuts the band. Examples of this were observed on the east flanks of Red Hills, and again on Nadeau Hill. It has been shown that the pyroxenite dykes represent, in all probability, a sort of pegmatitic residue, the last liquid parts of the consolidating magma. It is clear, therefore, that the chromite bands must have formed during the earlier stages of solidification.

The second type of chromite occurrence differs widely from the first. The chromite grains do not lie in a serpentine matrix, but are closely packed together, with little or no interstitial material. The chromite does not form long, parallel, straight or gently curving bands, but irregular nodules, and short, irregular vein-like bodies that project through the rock in various directions. The bodies are not parallel to the flow structures of the country rock, but may cut across it at any angle. In the chromite bands of the first type, the serpentine of the matrix is identical with that of the surrounding rock; but in the second type the serpentine around the edges of the chromite bodies is commonly altered. In the chromite bands of the flow type there is never the smallest trace of any original fissure through which chromite-bearing solutions might have entered. The chromite of the second type, on the contrary, is always found either in a fault or, more commonly, in the small tension cracks that run off from a fault. It is clear, therefore, that after the consolidation, serpentinization, and faulting of the peridotites a second generation of chromite was introduced and deposited in irregular, vein-like forms.

The following descriptions of occurrences will illustrate and amplify the above statements:

In the eastern end of the Hall chrome pit (northeastern end of Lot 16, Range A, Coleraine Township) the rock is the serpentinized pyroxene-rich peridotite, which is cut by a small fault striking east and dipping 55 to 60 degrees north. Little chromite occurs in the fault itself, but from the fissure numerous, short, vein-like bodies of massive chromite up to 2 inches wide project into the hanging-wall. One also was seen to project into the foot-wall. One of the projections into the hanging-wall tails into the central fissure (Figure 10). Each chromite vein has an edging of

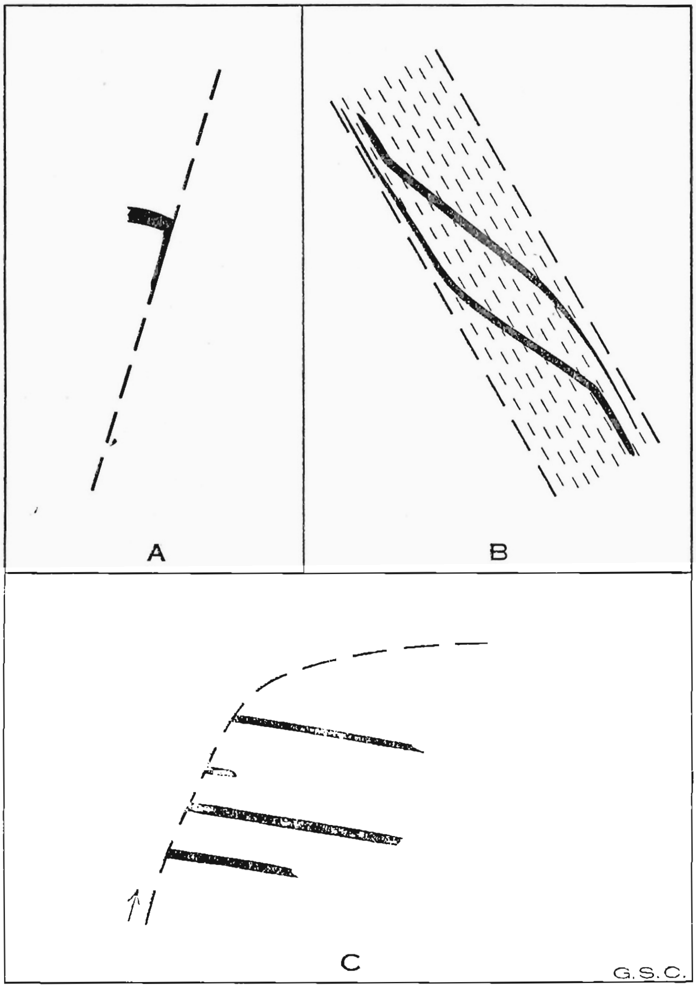


Figure 10. Chromite veins at: (A) Hall chrome pit; (B) Caribou chrome pit; (C) pits south of Breeches Lake. Chromite veins shown in solid black, faults by heavy broken lines.

very pure, light green serpentine, probably containing some talc, as the material is too soft for normal serpentine. The edgings vary from one-sixteenth to one-eighth of an inch in thickness, and grade outwards into the normal, dark, serpentinized peridotite of the wall-rock.

At the northeast end of Lot 17, Range A, Coleraine Township, there is a chromite pit belonging to Mr. E. T. Gray, of Thetford Mines. The rock of the neighbourhood is the serpentinized pyroxene-rich peridotite, and contains numerous chromite bands of the ordinary flow type, striking north 70 degrees east. A fault, containing irregular masses of supposedly granitic material now altered to vesuvianite, strikes north 10 degrees west and dips 70 degrees east. Much chromite is developed in and close to the fault. The chromite is massive; no other constituent could be detected with the lens; it has vein-like forms, with sharp, clean-cut walls, which cut the rock in various directions and tail off into thin stringers. The serpentine next the chromite is not visibly altered. Mr. Gray kindly supplied a specimen showing a slab of chromite about an inch thick entirely within the vesuvianite. The vesuvianite breaks through the chromite in a number of places, so that the chromite is clearly the older. Other specimens were found showing small veins of asbestos cutting through massive chromite, so that the chromite is also older than the period of asbestos formation.

In the Caribou chrome pit, near the northwest shore of Caribou Lake, the rock is normal olivine-rich peridotite, cut by parallel faults spaced 20 to 30 feet apart, which strike north 80 degrees west and dip northward at angles varying between 35 and 60 degrees. The shear zone of each fault contains thick, very irregularly shaped, vein-like masses of massive chromite. The northernmost of the faults visible in the pit has crushed the country rock, over a width of somewhat more than 2 feet, to a sandy gouge; and cutting through this gouge are two veins of chromite, each about 2 inches wide. The veins cut across the schistosity of the central part of the gouge at an angle of about 20 degrees; and toward the edges turn to parallel the schistosity or nearly so (Figure 10 B).

In the Beaver mine, at Thetford, a large body of chromite has been opened up, but is not at present being mined, and has been walled in, so that it cannot be directly observed. According to the manager, Mr. G. F. Jenkins, this body strikes north 70 degrees east. The writer's examination was confined to some of the ore already extracted and stored in a crib on the surface, and to material lying on the dump. The chromite is rather more coarsely crystalline than in the deposits already described, and much more friable, due probably to the presence of some interstitial talc. The edges, against the country rock, are sharp and clean-cut; and several specimens were obtained showing shorter or longer apophyses of massive chromite, commonly of very irregular shape but with clean-cut edges, running off from the main body into the country rock. More alteration of the surrounding serpentine was seen here than anywhere else. Most specimens from the contact show a development of about $\frac{1}{4}$ inch of talc, grading outward into the normal serpentine.

Slickensided faces on some of the chromite specimens show that faulting went on after deposition of the chromite.

About half-way between Breeches and Sunday Lakes, in the Disraeli quadrangle, the rock is a normal olivine-rich peridotite, with flow textures, as determined in several places from strings of chromite grains, striking north 10 degrees west and dipping about 60 degrees west. The rock is badly broken by faults, only the oldest of which have any connexion with chromite deposition. In a small pit at this place, such a fault strikes approximately east and dips south. The dip rolls from 65 degrees south, at the bottom of the pit, to horizontal, about 6 feet above. The fault is a thrust; and the rock of the elbow is much fractured by a number of joints more or less parallel to the horizontal part above (Figure 10 C). No chromite was found in the main fault, though possibly some might have been there and have been removed by the miners; but the joints mentioned, and little subordinate fault fissures, contain plates of chromite. The writer pried off a plate about 1½ square feet in area and ¼ inch thick from the face of one of the subordinate faults.

The chromite of these veins is hard and massive, with no other constituent visible under a lens; and the veins are flanked by bands of light green serpentine about one-twentieth of an inch wide.

Additional facts of the same sort were accumulated from the examination of other pits, but need not be detailed here. It may be said, however, that in every pit where massive chromite was found, except one, there was evidence that it is of the later, vein type. The exception is the pit of the Vanadium Company at the extreme west end of Caribou Lake, where there is both disseminated and massive chromite, all of which is clearly primary ore. Therefore, although it is difficult to understand how a mineral so insoluble as chromite could have been carried in solution, or why it should have been deposited in such irregular and discontinuous bodies, there seems no escape from the conclusion that it was so carried, and that deposition was controlled by the oldest faults cutting the peridotite.

Prospecting for chromite bodies should, therefore, be carried on in faulted areas, particularly in those faults that contain dykes of altered "granite," because these are likely to be among the oldest. Faults, particularly in the olivine-rich peridotites, are apt to occur in zones, within which several faults parallel one another at no great distance apart; they tend likewise to maintain a fairly uniform strike for a considerable distance. Thus, on the south side of Quarry Hill, where much chromite has been found, there is such a zone of faults striking approximately north 80 degrees west. Once a zone of this kind has been recognized, and the existence of chromite in it established, the zone may be projected beneath drift-covered areas with a good deal of accuracy. Thus prospecting operations may be undertaken with a minimum expenditure of time and money.

SULPHIDE DEPOSITS AT CAPE SMITH, EAST COAST OF HUDSON BAY

By H. C. Gunning

CONTENTS

Illustrations

INTRODUCTION

During the summer of 1933 about two weeks in August were spent examining the geology and mineral deposits of Smith Island, Northwest Territories, and the neighbouring mainland in the Province of Quebec. The opportunity to do this work arose when the writer was attached, as geologist, to the 1933 eastern Arctic expedition. This expedition was financed by the Department of Interior, Canada, and was in charge of Major D. L. McKeand of the Northwest Territories and Yukon Division of the Dominion Lands Administration. The Government party sailed from Montreal on July 8 aboard the Hudson's Bay Company steamer *Nascopie* and reached the company's trading post on Smith Island on July 29. The writer, assisted by Constable F. S. Spalding of the Royal Canadian Mounted Police, remained there until August 14 when a trip was made northward by native schooner to rejoin the expedition at Cape Wolstenholme.

The work at Cape Smith was greatly facilitated by help from officers of the Hudson's Bay Company. Fortunately, also, a party of four were engaged in testing sulphide deposits on the mainland at the time of the writer's visit. This work, in charge of Mr. C. W. Workman, was financed jointly by Cyril Knight Prospecting Company, Limited, Huronian Mining and Finance Company, Newmont Exploration, Limited, and Quebec Prospectors, Limited. Mr. Workman and his associates were thoroughly familiar with the mineral deposits and the main geological features of the region. This information was freely given to the writer and in addition these men assisted in many other ways. Without their aid much of the work accomplished could not have been done.

PREVIOUS WORK

In 1898 A. P. Low explored and mapped the geology of the east coast of Hudson Bay. His " Report on an Exploration of the East Coast of Hudson Bay from Cape Wolstenholme to the South End of James Bay " was published in 1902 as part D of the Annual Report, volume XIII, Geological Survey, Canada. Low mapped a large area of " diabase trap " that outcrops on the coast from Kettlestone Knob to Mosquito Bay and described the nature of these rocks and the bordering granites. Farther south he encountered iron sulphide mineralization in similar basic rocks, and assays showed small quantities of nickel and copper. The conclusion was drawn that the area northward from Portland Promontory to the vicinity of Mosquito Bay offered most promise for the discovery of sulphide deposits in the " diabases."

During 1931 and 1932 the greenstone belt running inland from Cape Smith was prospected for the companies already mentioned. The work was in charge of W. B. Airth and he was assisted by Messrs. M. J. McCart, W. H. Whorley, and M. E. Watts. These men explored the belt for over 150 miles eastward from the coast and located mineral showings on Smith Island and the mainland. Mr. M. E. Watts constructed a geological sketch map of their explorations on a scale of 8 miles to 1 inch and covering an area of over 5,000 square miles. Through the courtesy of Mr. Cyril W. Knight the writer obtained a copy of the map for use in preparing this report. Much credit is due the four men for the work that they accomplished. The area is entirely within the Arctic barren lands, was previously practically unknown, and is not at all well supplied with water routes. Most of their travelling had to be done on foot.

In 1933 the writer, in addition to examining the sulphide deposits at Cape Smith, endeavoured to obtain a working knowledge of the greenstone belt and adjoining granites as exposed along the coast from Kettlestone Bay to Korak River on the south side of Mosquito Bay. Through the personal knowledge of Messrs. M. J. McCart and W. H. Whorley, who were again at Cape Smith, he was enabled to proceed directly to points of particular geological interest. The short time available was, therefore, more productive than it would otherwise have been. W. B. Airth has described the principal sulphide showings in an article entitled " Cape Smith Sulphide Deposits," published in the Canadian Mining Journal in February, 1933.

LOCATION AND NATURE OF DISTRICT

Smith Island lies just off the east coast of Hudson Bay in latitude 61 degrees north and longitude 79 degrees west. It is 675 miles almost due north of Moose Factory on James Bay, 550 miles northeast of Churchill, and 125 miles south of the west end of Hudson Strait. By steamer, Cape

Smith is about 2,500 miles from Liverpool and 2,400 miles from Montreal. At present the only regular service is by the annual Hudson's Bay Company supply ship from Montreal. This boat calls there once each year to drop supplies and take on products of the fur trade. The trip to Cape Smith has been made by small schooner and by canoe from Moose Factory and during 1933 prospectors and supplies were successfully transported from and returned to Moose Factory by plane.

The climate is arctic and the northern tree limit lies some 200 miles to the south. The summers are short and cool, the winters long and cold. In 1933 the water about Smith Island was not entirely free of ice until the third week in July, but that was an exceptionally late season. Nevertheless, natives report that in at least one year they were able to indulge in ice sealing all summer. This means that sea ice never entirely left the district that year. Deep snow may be expected to lie in sheltered places on land well into June. The freeze-up has been known to arrive late in September, but is generally several weeks to over a month later. Although there are usually a few pleasantly warm days during the summer, rain or fog, and strong winds are very common. On calm, warm days the mosquitoes are abundant and voracious.

Smith Island is a rugged mass of dark green to black rock rising abruptly from the sea. The monotony of bare rock is broken only by a few, narrow, low valleys trending approximately north 60 degrees east, parallel to the long axis of the island. In these sheltered places the clay and sand bottoms support an abundant growth of grasses, heather, arctic flowering plants, and some stunted arctic willows. There are many small lakes. The dark rock ridges rise abruptly between the valleys to heights of several hundred feet.

The same type of country continues eastward on the mainland and, a few miles inland, broadens to form a belt some 40 miles wide from north to south. Within this belt the highest ridges form a central axis and are separated by broad, low, drift-filled valleys occupied by shallow rivers and many small lakes. The central ridges, trending about north 60 degrees east, attain heights of 500 to about 700 feet within a few miles of the coast and are reported to rise several hundred feet higher farther inland. To the north and south the ground is lower and gradually, in places abruptly, falls away to a flat or rolling plain to the north of Kettlestone Bay and south of Mosquito Bay. All the low-lying tracts are surfaced with a heavy cover of moss, heather, grasses, and flowering plants and abound in swamps, ponds, and small lakes; walking over them is a slow and arduous task.

None of the rivers draining the belt affords a good water route. Chukotat River, flowing into Mosquito Bay, is the largest and it abounds in shallows and rapids. Towards the east the belt is drained by Povungnituk River and a series of fair-sized lakes, and conditions there are more favourable for canoes. The waters of the coast are generally shallow for some distance from shore. This is particularly true in Mosquito Bay where the shallowness and numerous small islands and rocks make navigation, even in a small boat, rather hazardous. Northward from Cape Smith there are few islands, but the water is shallow for several miles offshore and sheltered harbours are few and far between. Fortunately some fairly good anchorages are available on the south side of Smith Island, although there is little or no protection for large ships from southerly winds.

Game is not plentiful. Caribou have almost entirely disappeared from the mainland within recent years. The white or arctic fox is abundant and is trapped extensively by natives during the winter. Skins of this animal are the principal commercial product of the region. Geese and ducks are fairly abundant during the summer months and ptarmigan are quite plentiful in certain places. Some of the streams and lakes and certain parts of the coast waters are well stocked with trout, up to about 4 or 5 pounds in weight. The small jar seal is one of the chief items in the native diet and the large bearded seal, or square flipper, is quite abundant. The dressed hides of this animal are extensively used for clothing, dog harness, and covers for kyaks. The walrus is not common about Cape Smith, but large numbers are caught annually near the islands about the west end of Hudson Strait. The flesh is particularly important as dog food.

The Hudson's Bay Company trading post, in a small cove on the southeast side of Smith Island, is the social and commercial centre of the district. Mr. A. T. Swaffield is post manager. Eskimos leading a nomadic life but somewhat centred about the east and west ends of Mosquito Bay, Kettlestone Bay, and Kovik Bay, trade there. The only other permanent residence is the cabin constructed at Knight Harbour in 1931 by W. B. Airth and his companions. It is in a sheltered cove about 13 miles east of the trading post. Although no soundings have been made it seemed that a channel with sufficient depth of water for small ships might be found to lead into the harbour. The only permanent white residents of the district are the two company men at the trading post.

GENERAL GEOLOGY

Low's original map, published in 1902 on a scale of 8 miles to 1 inch, shows a belt of "diabase trap" extending from just north of Kettlestone Bay to the north shore of Mosquito Bay and thence eastward. Smith Island is mapped as the same rock. To the north and south, and in a narrow strip along the coast south of Kettlestone Bay, "Archæan and granite" is shown. The trap Low believed to be ancient lava flows and he found evidence that it was cut by, and, therefore, was older than, the bordering granite.

Recent work has shown that the limits of Low's trap must be extended, at least along the coast, and the belt of these rocks is now known to be some 7 or 8 miles wider than he showed it. Figure 11 indicates the approximate limits, as now known, of this greenstone belt as it may be termed for general reference. The belt consists of altered lavas and some sediments, all cut by diorite dykes. It is about 40 miles wide, over 150 miles long, and is bordered to the north and south and along the coast for a few miles south of Kettlestone Bay, by granitic rocks, in part gneiss.

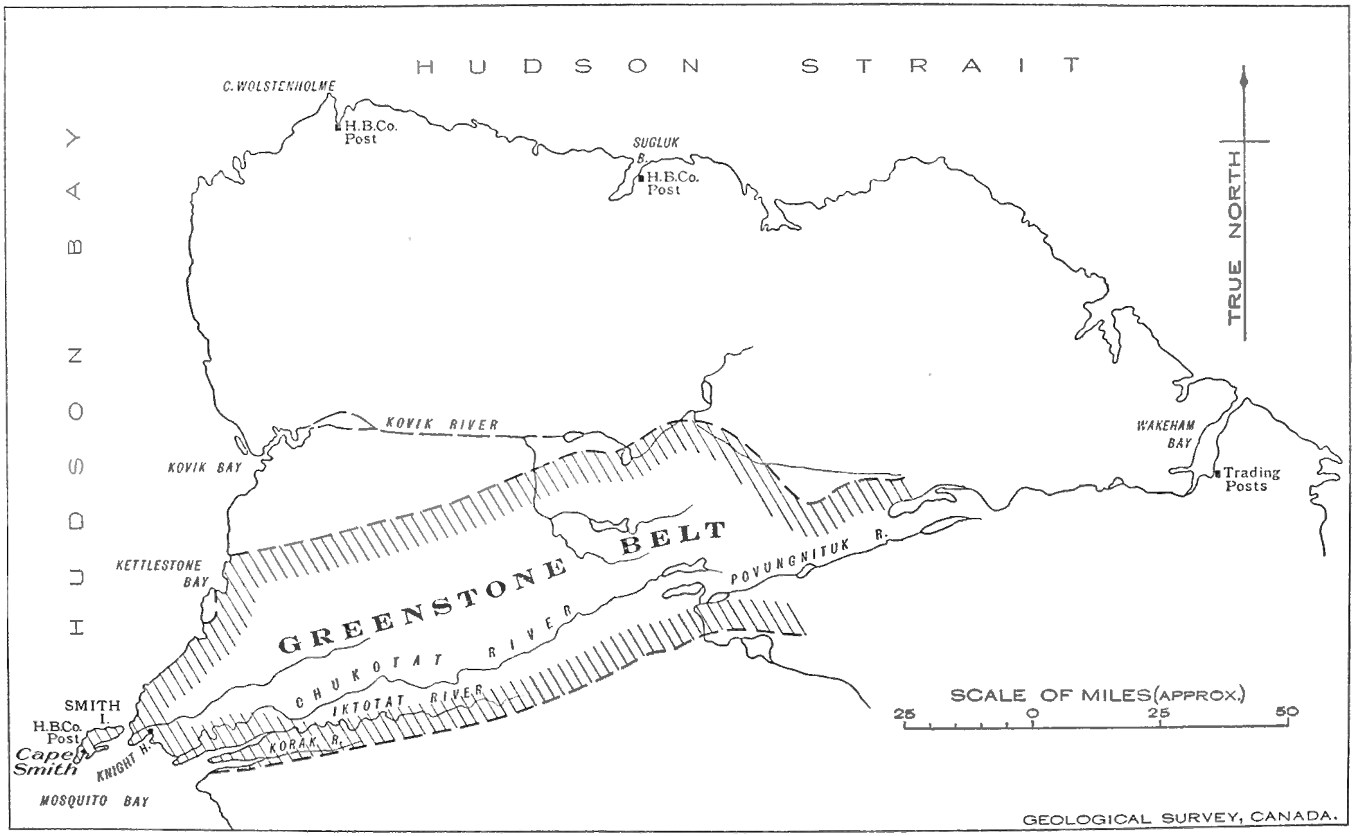


Figure 11. Approximate boundaries of greenstone belt, Cape Smith, east coast of Hudson Bay (after M. E. Watts).

LAVAS

Large areas within the belt are underlain by altered lava flows. Pillow lavas are beautifully exposed over the greater part of Smith Island and over large areas on the mainland. The pillows are generally between 2 and 4 feet in length, but many are smaller and some are several feet longer. The shapes are very irregular but there is a distinct tendency for elongation along the strike of the flow. Each pillow is partly or completely surrounded by a dark green, very fine-grained rim, darker in colour than the interior of the pillow. Many of the irregular interstices between the pillows are filled with a coarsely crystalline mass of quartz, calcite, epidote, chlorite, and other minerals. The colour of the flows varies from pale greyish green to dark green and almost black. Some flows show no pillow structure and are dense to fine-grained and structureless. Amygdules are lacking or very scarce. Not many flow tops or bottoms were observed, but the data obtained indicate that the flows are thick, of the order of 100 feet and more. In some flows there is developed a distinct columnar jointing that produces roughly hexagonal columns lying approximately at right angles to the top or bottom of the flow.

On weathered surfaces the lavas are light to dark green or rusty brown. Clean outcrops of the pillowed varieties are too dense and altered to give any clue to their original composition. Some of the even-grained, holocrystalline varieties evidently consisted originally of minute to moderately coarse crystals of feldspar and a ferromagnesian mineral and resemble fine-grained diorite or diabase. Very few show small phenocrysts of feldspar. Under the microscope these rocks are seen to be severely altered to chlorite, calcite, epidote, and zoisite, and, less commonly, actinolite. There is also a small amount of original magnetite or ilmenite, in tiny grains. In several sections there remains a considerable amount of partly chloritized augite intergrown with and surrounding partly or completely altered crystals of plagioclase feldspar. The texture is then diabasic. The feldspar is so greatly altered that it is very difficult to determine accurately, but most of it seems to be oligoclase or oligoclase-andesine. No labradorite was observed. A small percentage of original quartz was noted in one section. The microscopic evidence, so far as it goes, would indicate that the altered flow rocks were originally andesite or augite andesite. In the field, judging by colour and texture, one would be inclined to suppose both basalt and andesite to be present.

Similar flow rocks continue from Smith Island to the mainland and extend for many miles eastward in a zone from 10 to 20 miles wide forming the middle of the greenstone belt.

SEDIMENTS

Along the south side of Smith Island, on the shore of the peninsula east of the post, sedimentary rocks underlie pillow lava. In one place a narrow, lenticular band of sediments is interbedded with lava. To the east the sediments beneath the lavas pass under the waters of Mosquito Bay and reappear 13 miles east, at Knight Harbour. They are known to continue eastward for at least 6 miles within a narrow belt a few miles north of Chukotat River. They include soft, black to dark grey slate, impure dark grey limestone, and a wide variety of thin-bedded, hard, dark grey to almost white rocks. In many of the latter the lamination is apparent only on the weathered surface, the freshly broken rock being uniformly dense and grey to greenish grey.

Field and microscopic study indicates that all are waterlaid strata. The soft, dark grey, slaty members are altered argillaceous to carbonaceous, siliceous sediments. The harder grey members are evidently siliceous and feldspathic tuffs that in some cases grade to normal, fine-grained quartzite. The tuffs consist of microscopic fragments of quartz and feldspar with a considerable proportion of chlorite and pale green mica. Epidote, actinolite, and pyrite are sparingly present. Only very occasionally are light grey fragments visible to the naked eye.

A few feet of volcanic breccia was noted on the south shore of Smith Island at the base of a flow of pillow lava. Moderately coarse andesitic breccia was noted in one place and in another a few feet of a breccia consisting of black sedimentary fragments in a green chloritic base. The fragments are irregular in outline and vary from ½ inch or less to several inches in length. The rock is mineralized with pyrite and may represent a mineralized fault breccia. "Ore" of a similar nature was noted at one place on the mainland.

Across widths up to at least 8 or 10 miles against the bordering granites the rocks of the greenstone belt are altered to chloritic phyllite and schist, amphibolite, or soapstone. Samples from near the mouth of Korak River consist largely of pale green to colourless amphibole and chlorite. Low describes steatite schist and slaty rocks veined by calcite north of Kettlestone Knob. Quartz-calcite lenses and veins are fairly abundant in Mosquito and Kettlestone Bays. On the coast about 5 miles north of Smith Island the writer found a gradation from chlorite schist to relatively fresh pillow lava, quartz veins being abundant in the schist and rare in the lava. Where observed, the schistosity dips at a steep angle and in a general way parallels the granite contact.

DIORITE INTRUSIVES

The lavas and sediments of Smith Island and the adjoining mainland are intruded by dykes of augite diorite. Similar dykes are reported to occur for many miles to the east. The intrusions are largely concordant with the stratification of the rocks they cut and form long, generally narrow bodies, with rounded or gradually tapering ends. In some places, however, they cut across the bedding of the sediments and, particularly around the ends of some bodies, their intrusive nature is clearly evident. Widths of 300 to 1,000 feet are not uncommon and one body, north of Chukotat River and south of the mineral showings to be described, is over 1,500 feet wide and at least several miles long. Where fairly coarse-grained and relatively fresh these rocks present a greenish grey to dark green mottled appearance with dark crystals of augite set in a grey or green feldspathic base. The augite crystals are seldom as much as ¼ inch in diameter. The finer grained varieties show almost no crystallinity and closely resemble some of the light green lavas. Weathered surfaces are generally brown. In the field their most distinct characteristic, apart from the appearance of the coarser grained varieties, is a rough to almost perfect columnar jointing. The columns are 2 or 3 to about 5 feet across and lie at right angles to the edge of the intrusive body. Even where no contacts are visible it is often possible, by observing the attitude of the columns, to obtain a fair approximation of the attitude of the intrusive.

Under the microscope the coarser grained varieties are seen to consist largely of augite and plagioclase feldspar. The augite is in large phenocrysts that are partly uralitized and chloritized, but on the whole are remarkably fresh. The plagioclase is in smaller crystals in and about the augite and is much altered. The few identifications that were made indicate a sodic andesine, about $Ab_{70}An_{30}$ to $Ab_{65}An_{35}$ in composition. A very small percentage of quartz is present in most thin sections. The feldspar and groundmass are largely altered to chlorite, finely divided pale green to colourless mica, epidote, and other minerals. There are a few, tiny, scattered grains of pyrrhotite.

On the basis of microscopic examination the rock should be termed augite diorite. In the field the term gabbro seemed more appropriate.

GRANITES

The granites bordering the greenstone belt were observed by the writer only on the south side of Korak River and a few miles south of Kettle-Stone Bay. They are grey to pink, medium-grained to coarse, porphyritic rocks. In some places they are distinctly gneissic, in others quite massive. The composition varies considerably from coarse quartzose and feldspathic phases resembling pegmatite and usually dyke-like, through normal grey to pink biotite or hornblende granite to finer grained, darker phases resembling diorite. These basic phases become more abundant towards the greenstone contact and in places contain many altered, dark-coloured inclusions, and are cut by barren quartz stringers. Some outcrops of rather fine-grained feldspar porphyry were observed south of Korak River.

A thin section of rather typical, coarse-grained, pinkish "granite" contains about equal amounts of microcline and oligoclase-andesine ($Ab_{70}An_{30}$), about 20 per cent quartz, and roughly 15 per cent of biotite, epidote, sericite, apatite, and pyrite.

The contact between granite and greenstone was not observed. The increase in shearing and alteration of the greenstones in proximity to the granite and the presence of many altered dark inclusions in the granite near the contact, however, suggest that the granites are later than and intrude the greenstone. This conclusion is supported by the fact that Low considered the granites to be later, and, south of Kettlestone Bay, found "granites which enclose broken bands of the dark schists." In addition Mr. Airth and his associates have reported finding "porphyries" cutting the greenstone.

STRUCTURE

The rocks of the greenstone belt are intensely folded. The strata now dip, in most places, at very steep angles and strike within a few degrees of north 60 degrees east astronomic. The major structure across the belt is not known. Detailed studies at Cape Smith, to be discussed more fully under mineral deposits, indicate that the strata there are folded into a series of tightly compressed, in places overturned, plunging anticlines and synclines and it seems probable that a major anticlinal axis may trend about north 60 degrees east past the south shore of Smith Island and thence eastward past Knight Harbour; that is, in the vicinity of the principal sulphide mineralization. Also, in this zone, the augite diorite intrusives are particularly abundant. The predominant plunge of the folds is towards the northeast, at moderate angles, generally not over 40 degrees. To the north of this probable anticlinal axis for several miles the predominant dip is vertical or 60 degrees or more to the north. Along Korak River the schistosity of the chloritic rocks strikes north of east and dips north at about 65 degrees and at Kettlestone Bay the dip is vertical or nearly so.

In many places the massive pillow lavas are sheared, and possibly faulted, along or parallel to flow contacts. On Smith Island less intense shearing, accompanied by some minor faulting, trends about at right angles to the above, that is, close to north 30 degrees west.

GLACIATION AND POST-GLACIAL CHANGES

The whole country has been intensely glaciated by ice moving in a westerly direction from the interior of Ungava Peninsula. Grooves and striations upon roches moutonnées on Smith Island, near the post, indicate that the ice passed over the island on a course of about north 30 degrees west. Some 15 miles east, on the mainland, readings varied from northwest to north 70 degrees west and near the mouth of Korak River the striations point about due west. Low has given his observations on glaciation at some length.

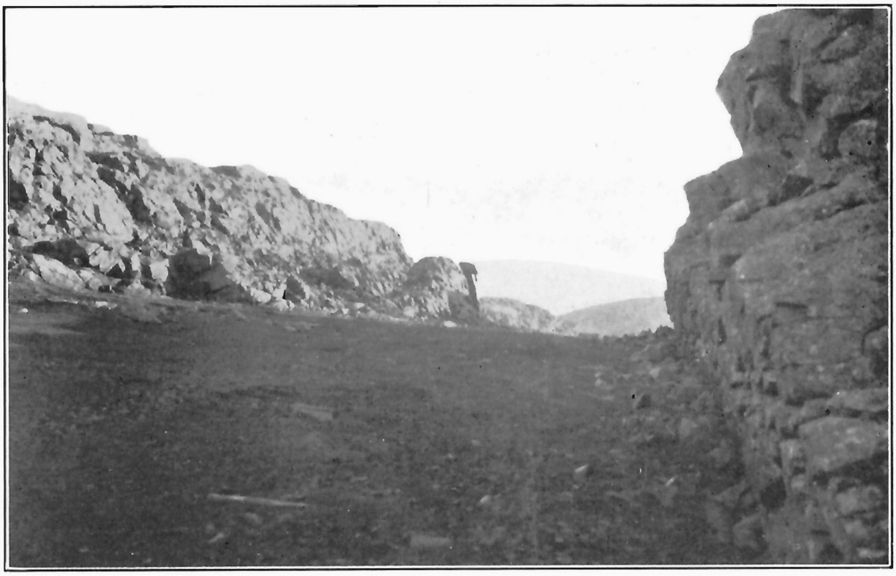
As the ice withdrew, boulders, gravel, sand, and clay were deposited on the bare rock surfaces. Since the glacial period the land has been uplifted, relative to sea-level, several hundred feet. On the mainland east of Knight Harbour well-preserved marine beaches were found up to 435 feet above sea-level. The determination of elevation was made by aneroid barometer under favourable conditions and should be quite accurate. Above the 435-foot level, erratic boulders, mostly granite, are spread thickly over the rough surface of volcanic rocks, not only in depressions and on hillsides but perched precariously on sharp ridges and prominent knobs. Below this level there is a sudden change and all the erratics are either collected in old marine beaches or are in sheltered depressions. The only apparent explanation is that the sea once stood 435 feet higher than now and that, as it receded, the waves swept erratics from ridges and knobs and collected them in beaches. The topmost of these beaches now coincide, approximately, with the lowest level at which erratics are precariously perched on exposed and prominent ground. This level, the highest attained by the sea since glaciation, is 435 feet above present high tide.

MINERAL DEPOSITS

Large bodies of sulphides were discovered on Smith Island and the neighbouring mainland in 1931, and in 1932 exploration revealed similar mineralization at intervals for over 100 miles eastward along the greenstone belt. In addition, quartz veins were encountered at several places, but none of these has as yet been found to carry more than a very small amount of gold or other valuable metals. In 1933 the sulphide bodies on Smith Island and in the vicinity of Knight Harbour on the mainland were prospected and systematically sampled by Mr. Workman and his associates. Mr. C. W. Knight informs the writer that assays of their samples indicate that the gold content is either nil or so low as to be of no commercial value whatever and that only traces of copper and nickel were found. It, therefore, appears that the bodies that have so far been tested must be considered as of no commercial value.

The geological setting of the deposits as a whole is well illustrated in the vicinity of Knight Harbour, on the mainland. There (*See* Figure 12) lavas are underlain by a relatively thin band of sediments and tuffs and the whole is intruded by sheet-like masses of augite diorite that are essentially concordant with the bedding of the older rocks. The entire assemblage is tightly folded into a narrow syncline and anticline and these structures plunge eastward at 40 degrees or less. The intrusives have entered the older rocks within, above, and below the sedimentary horizon and as a result narrow bands of sediments are overlain, underlain, and separated by tabular masses of augite diorite. The lavas and the diorite are hard, massive rocks that are resistant to erosion, whereas the sediments, though commonly hard, are thinly laminated and have yielded readily to disintegration by frost and normal weathering. As a result the sediments have worn away more quickly and now lie under low-lying, drift-filled, or debris-covered and steep-walled, narrow depressions between the more resistant igneous rocks (*See* Plate IV A). Along these depressions which, on the whole, faithfully outline the structure of the whole assemblage, the sediments generally outcrop only in isolated, narrow areas at intervals along the walls. Only in a few places is a thickness of more than 10 or 15 feet of sediments thus exposed and the remainder of the width of the depression is surfaced with a mass of rusty, decomposed, sedimentary material or a deep cover of boulders and gravels with, near sea-level, marine shells. The augite diorite, though generally concordant, in some places cuts across the bedding of the sediments at a low angle, less commonly at a large angle, and is invariably fine grained for a few feet next to them, due to chilling.

The " ore " consists, most commonly, of massive, fine-grained pyrrhotite cut by veinlets of later, coarser pyrrhotite, some of which carry small amounts of chalcopyrite. In some places, instead of, or as well as, the fine-grained pyrrhotite, there is an abundance of equally fine-grained pyrite. The " ore " varies considerably in appearance. The most conspicuous characteristics are its excessive fine grain and a pronounced and generally very thin banding due to preservation of the original banding of the sediments which the sulphides have replaced. The finest grained varieties are



A. Looking west near the west end of "H" lead. Walls are augite diorite. (Negative No. 77189.)

B. Fourteen feet of sulphides (below white line) beneath augite diorite. Looking east at showing at west end of Rusty Lake. (Negative No. 77206.)

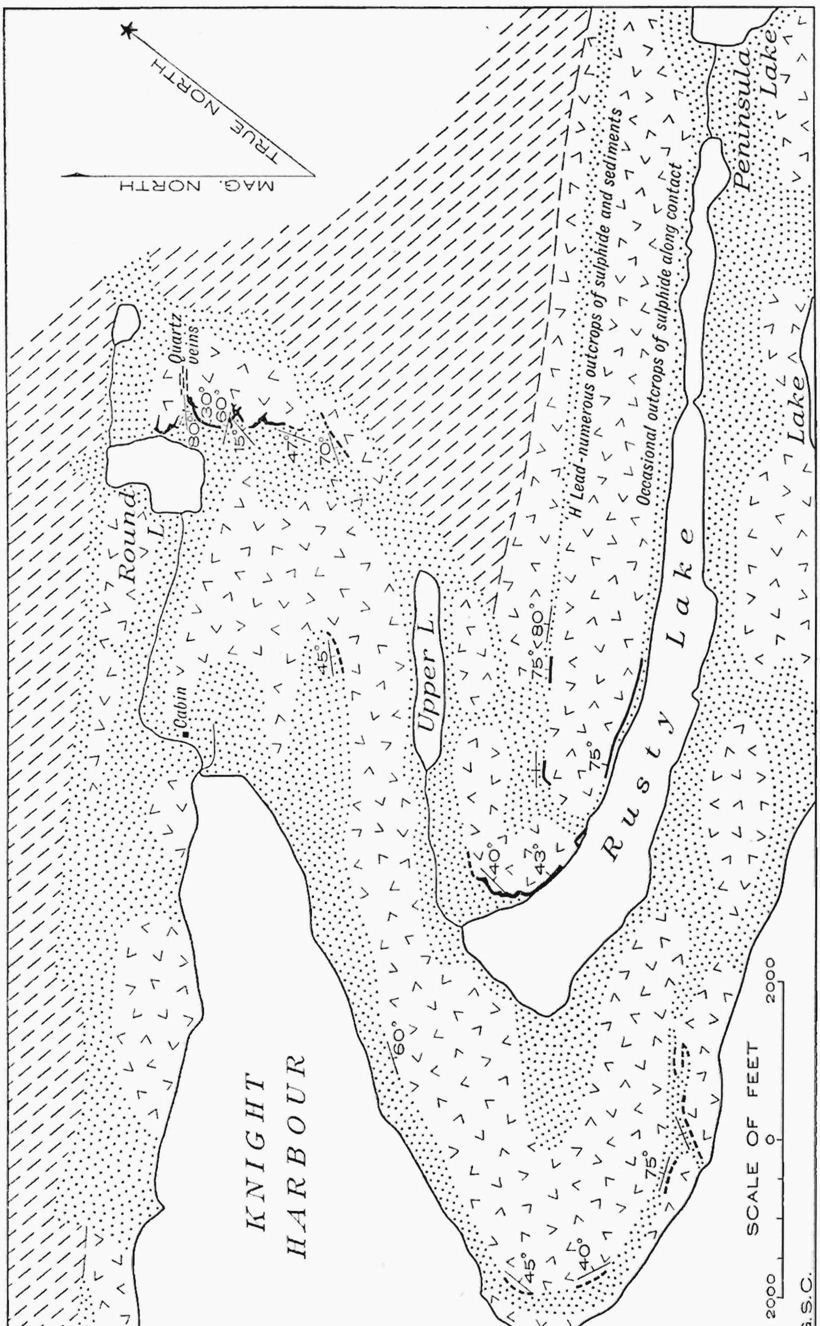


Figure 12. Sketch map of vicinity of Knight Harbour, Mosquito Bay. Altered lava flows shown by pattern of broken diagonal ruling; intrusive augite diorite by pattern of angles; outcrops of sediments by heavy broken line; outcrops of "ore" by heavy solid line; and drift-covered areas by pattern of stipple.

dense black and closely resemble a hard slate. These consist of minute grains of pyrrhotite mixed with equally minute grains of quartz, carbonaceous matter, chlorite, and epidote, the sulphide forming from about 25 per cent to 80 or 90 per cent of the whole. Only by its heaviness and a metallic lustre when scratched can such material be distinguished from dense, black slate. The diameter of the sulphide particles in this type of material is considerably under $\frac{1}{100}$ of a millimetre. Of somewhat coarser grain, but still exceedingly fine, are varieties in which pyrite predominates. The colour is then a dull grey to greyish brass or whitish grey. In both varieties there are, not uncommonly, small, irregular to lenticular remnants of unreplaced sedimentary material.

In most showings the fine-grained material is veined by, or shot through with, variable amounts of later, quite coarse-grained pyrrhotite. In some places the veins consist entirely of pyrrhotite, in others of a mixture of pyrrhotite, quartz, calcite, chlorite, and some pyrite. Not uncommonly the earlier, dense sulphidic mass has been extensively replaced by later pyrrhotite, the replacement spreading out irregularly from minute veins. The proportion of this later pyrrhotite in the " ore " varies, in different showings, from almost nil to well over 50 per cent. In some places the " ore " resembles a breccia and the original dense, black or dark grey sulphide has been extensively crushed and sheared, and the fragments polished and slickensided before the later pyrrhotite entered to re-cement the broken mass.

No free gold, nor any nickel mineral, has as yet been identified in the " ore ". Chalcopyrite was observed in a few showings, but it is nowhere abundant. The field evidence and a study of polished surfaces indicate that it is always associated with the later pyrrhotite which it either replaces or is intimately intergrown with.

The sulphides occur as lenticular replacement bodies in the sediments and occasionally along contacts between lava and diorite. The bodies vary greatly in size, but widths of 5 to 25 feet for lengths of several hundred feet are not uncommon. So far as is known the " ore " is always closely associated with augite diorite. Commonly this rock forms the hanging-wall and it is then considerably altered to chlorite, calcite, sericite, and other minerals; augite is generally completely altered to these minerals. The fine-grained plagioclase, however, remains relatively fresh and unaltered. Disseminated pyrrhotite forms a small percentage of the rock. In other places augite diorite forms the foot-wall of the sulphide bodies and the hanging-wall is sediments overlain by lava or by diorite. Elsewhere the sulphides are directly overlain by lava and the diorite either forms the foot-wall or is present as irregular, sheet-like bodies in the sediments a short distance below the " ore ". In some places irregular, tongue-like bodies of sulphides extend a few feet into the hanging-wall or foot-wall, either diorite or lava, where these rocks are considerably crushed or sheared.

As a general rule there is little or no vein quartz or calcite in the sulphide bodies. In one or two places, however, there is a small amount of white quartz across 2 or 3 feet on the hanging-wall side and a few inches of quartz and calcite along the hanging-wall of the sulphides. In addition, Airth mentions one deposit that was not seen by the writer in which pyrrhotite and pyrite are disseminated in a quartz gangue for a width of 30 feet and over an exposed length of 40 feet. Nevertheless, when the deposits are considered as a whole, vein quartz and calcite are conspicuously absent from the sulphide bodies. It is rather surprising, therefore, that irregular quartz-calcite veins are very abundant in fracture zones in the hanging-wall diorite or lava in several places. These veins, or swarms of veins, are found above the ore along the crests of tightly folded, anticlinal structures and, as will be shown later, they serve as a guide to sulphide bodies below. The veins themselves are quite barren of sulphides. The writer is inclined to believe that these veins were formed at about the same time as the sulphide bodies, or at least during the same period of mineralization, but this point was not proved beyond question.

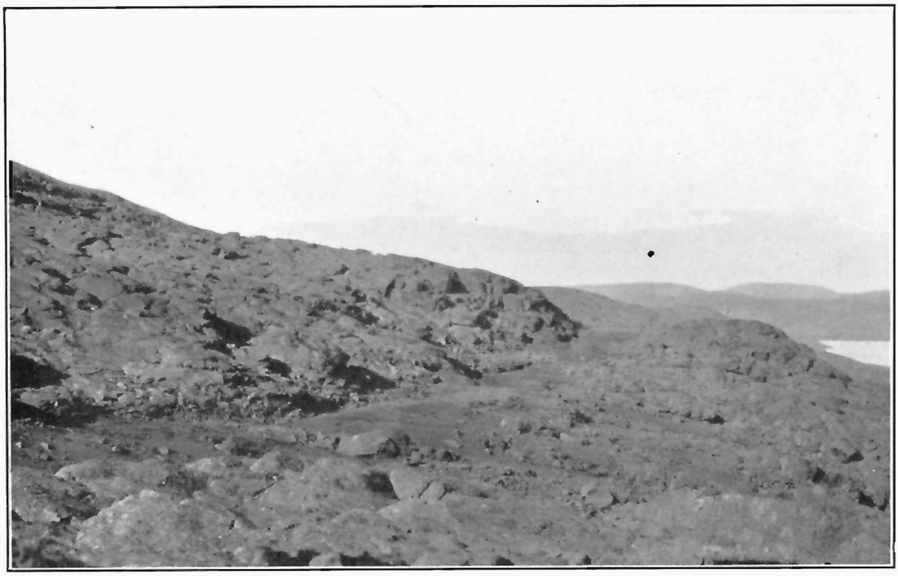
There are four principal showings on the mainland. Three of these are shown on Figure 12: at Round Lake; along the northwest shore of Rusty Lake; and the "H" lead, beginning $\frac{1}{4}$ mile north of Rusty Lake and continuing north of east for several miles. The fourth, known as the Glory Hole showings, is $3\frac{1}{2}$ miles north 75 degrees east from the head of Knight Harbour and $\frac{1}{2}$ mile north of Peninsula Lake.

At Round Lake dark grey slates and fine-grained grey tuffs are exposed around the nose of a broad anticline that plunges down to the northeast. The sediments are overlain by intrusive augite diorite that in some places cuts across the stratification of the sediments but is generally conformable. In addition there are a few narrow sheets of diorite in the sediments. The diorite forms an abrupt hill about 100 feet high and the sediments, and the "ore" in them, are exposed along the west face of the hill, with lower, drift-covered ground to the west. The major anticlinal structure is complicated by a series of generally tightly compressed anticlines and synclines that also plunge northeast at angles of from 15 to 30 degrees. For about 1,700 feet along the base of the hill there are many good exposures of massive sulphide against the overlying diorite. To the south the "ore" gradually dies out, passing into barren or poorly mineralized tuffs, but to the north it continues to the edge of drift-covered ground. If, as seems probable from the showings, "ore" is continuous for the distance given, the actual length of mineralized material would more nearly approach 3,000 feet than 1,700 feet, because of the numerous minor folds in the mineralized horizon. The exposed widths of sulphides vary from 18 inches to about 20 feet, but the foot-wall is drift-covered in most places. Pyrite is quite abundant, much more so than in other showings. The greatest widths of ore are exposed along the tight, minor anticlines. Along the crests of these folds the overlying diorite is fractured and in places sheared. But no sulphide occurs in these fracture zones for more than a few feet from the sediments. Instead, the zones are marked by irregular and generally discontinuous, barren quartz veins. Above the most important minor anticline there are swarms of these veins in the diorite. The attitude of the veins roughly parallels that of the axial plane of the anticline along which they lie. It was concluded, in the field, that these veins in diorite were an indication of ore beneath. This conclusion was supported by the result of dip-needle work performed later by Mr. C. W. Workman. Strong magnetic attraction was shown beneath the vein zone.

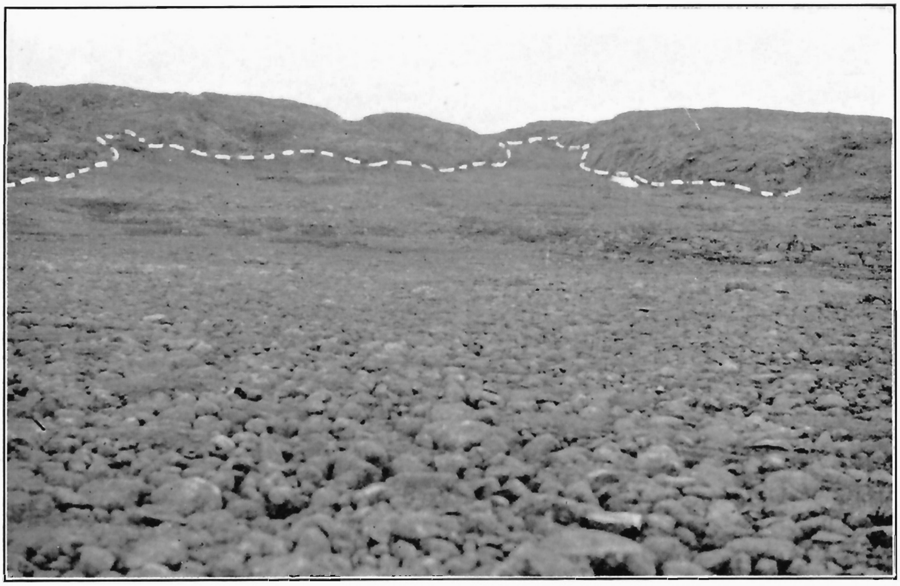
The showings at Rusty Lake lie in sediments beneath diorite on the nose and east limb of a syncline plunging towards the east. The maximum width of heavy sulphide mineralization is about 15 feet, but a rich mixture of sulphide and slate is exposed across 25 feet in one place. On the north limb of the syncline the mineralization dies out in unmineralized sediment. On the south limb the diorite-sediment contact is offset in at least three places, once by a sharp turn in the base of the intrusive and twice probably along minor northeast trending faults. If one assumes, as seems reasonable, continuity of mineralization along two stretches of 250 feet and 700 feet of drift-covered ground, heavy sulphide mineralization extends around the nose and along the south limb of the fold for a total distance of at least 4,500 feet. One or two rusty outcrops indicate that similar mineralization may persist, at least at intervals, for nearly 2 miles to the east under a drift cover along the south contact of the diorite, along the north shores of Rusty and Peninsula Lakes. Around the nose of the fold there is a fair proportion of pyrite in the " ore," much of which is massive, coarse-grained pyrrhotite of the later generation (*See* Plate IV B). There is very little chalcopyrite visible.

The " H " lead is a long, narrow depression between low but steep walls of augite-diorite. Towards the east end lava forms the north wall. The depression varies in width from a foot or less in one place to a maximum of about 200 feet and can be followed readily on the surface for $2\frac{1}{2}$ miles (*See* Plate V A). For most of this distance the surface is covered with boulders and gravel, or with rusty, finely divided debris from the weathering of underlying sediments. At many places along either wall, however, there are outcrops of sediments or sulphide. No development work has been done, but the surface showings indicate that, along this $2\frac{1}{2}$ mile depression, there may be expected a series of lenticular sulphide deposits, largely of pyrrhotite, that vary in length up to at least 500 to 600 feet and in width from 2 or 3 feet to at least 25 feet. The rest of the " lead " evidently consists of sparsely mineralized or barren sediments with, possibly, a few concordant sheets of diorite. The dip of the sediments and ore, where observed, varies from vertical to 70 degrees north. In a few places irregular, wedge-shaped bodies of mineralized material extend a few feet or tens of feet into either wall.

The Glory Hole showings include a group of deposits around the north, east, and south sides of a broad, boulder-floored basin (*See* Plate V B). Black, slaty sediments and sulphides are exposed, dipping at steep angles, against sharply rising walls of lava and diorite. Dense, black sulphide veined by late coarse pyrrhotite is exposed across widths of a few feet to 30 feet. In one place a trench has exposed a width of 35 feet of slightly mineralized sediment extensively veined by later pyrrhotite. Chalcopyrite is sparingly present in a few croppings. A few outcrops within the drift-filled basin suggest that the sediments are underlain to the west by intrusive diorite. The attitude of the sediments and ore indicates an anticlinal structure pitching steeply down to the northeast, with steep dips on the flanks of the fold. Around the nose, where most of the showings occur, there are tight minor folds, similar to those at Round Lake, and generally overturned to the south so that the prevailing dip is steep to the north. These minor folds are responsible for tongue-like extensions of sediments and ore that



A. Showing the "H" lead running east between diorite walls, north of Rusty Lake. Peninsula Lake on right. (Negative No. 77199.)



B. The "Glory Hole" from the west. Outcrops of sulphides and sediments occur approximately along the white line. (Negative No. 77197.)

project northeastward from the edge of the main basin. The outcrops indicate that mineralization might be expected to continue irregularly across widths up to 30 feet or more for a linear distance of at least 2,000 feet.

There are other showings, of smaller extent, in the vicinity of these four principal ones. They have not been developed, but the outcrops indicate that they are but smaller manifestations of the same kind of low-grade pyrrhotite and pyrite mineralization. In addition, croppings of similar mineralization are known to occur at intervals for many miles to the east.

The showings on Smith Island are on the south shore, 2 miles east of the Hudson's Bay Company post. The heaviest sulphide mineralization extends, at intervals, for about 1 mile along the shore and is all within about 30 feet above high tide. Much of this section is deeply covered with boulder and gravel beaches. Less intense mineralization has been found for 250 yards to the west and again over half a mile to the east. As on the mainland, much of the ore is dense, finely banded pyrrhotite with some pyrite. This material is veined and in part replaced by later pyrrhotite. Chalcopyrite is visible in only a few places and then in very small amount.

The largest showing is in a shallow cove backed by steep walls of pillow lava from 5 to about 60 feet high. The cove has been caused by erosion along the axis of an overturned anticline and the low ground between the steep walls is underlain by sediments that are extensively replaced by fine-grained sulphides. A small outcrop of diorite in the centre of the cove may indicate that the mineralized sediments are underlain by this rock. For a length of 250 feet across the nose of the anticline almost solid, banded sulphide is exposed across widths up to 25 feet with the foot-wall drift covered. The hanging-wall is altered pillow lava. On the northwest limb of the fold there is 5 to 6 feet of sulphide against pillow lava and then nearly 200 feet of less thoroughly replaced sediment. Mineralization is more intense across the same distance on the southeast limb.

About 200 feet west of this showing, across a ridge of pillow lava, a series of outcrops of sediments, lavas, sulphides, and diorite extend for nearly half a mile along a low beach. The strata stand nearly vertical. It seemed probable, after a brief examination, that the mineralization lies along the top of a sedimentary horizon of at least two, and possibly three, tightly compressed anticlines. From $\frac{1}{4}$ to $\frac{1}{2}$ mile east of the cove the sediments again outcrop on the shore around the nose of an easterly plunging open anticline and are capped by diorite. The mineralization is much less intense than farther west. The best "ore" lies along a tightly compressed subsidiary anticlinal structure on the northwest limb of the major fold.

CONCLUSIONS

All the rocks at Cape Smith are presumably Precambrian; they form part of the Canadian Shield. The lavas and sediments of the greenstone belt are intensely folded and greatly altered and are bordered, for many miles east of Hudson Bay, by younger intrusive granitic rocks that are themselves in part gneissic. It seems possible, therefore, that the lavas and sediments are of Early Precambrian age. The relation of the augite diorite intrusives in the greenstone belt to the bordering granites is not known. Until additional evidence is obtained they may be assumed to be older than the granites.

These presumably Early Precambrian lavas, sediments, and basic intrusives form a belt some 40 miles wide running eastward for at least 150 miles from Cape Smith. There is thus a large area that, on the basis of experience elsewhere in the Canadian Shield, may be considered as potentially favourable for prospecting.

Some 5,000 square miles of this belt have already been prospected in a rough exploratory way by four men. Sulphide mineralization and quartz veins were encountered at many places. As yet none of the quartz veins has been found to contain important amounts of gold. Extensive testing of sulphide bodies near the coast of Hudson Bay has revealed only traces of copper, nickel, and gold in these deposits.

The nature and occurrence of the sulphide deposits suggest that they are related in origin to the augite diorite, although they were formed after that rock had been intruded. The deposits examined by the writer, and sampled during 1933, represent but a small part of a long zone in which similar mineralization is known to occur. It is obvious, therefore, that the disappointing results obtained do not necessarily apply to the whole zone. Nevertheless, the work done shows that, within a length of some 20 miles along the mineralized zone, all the sulphide bodies examined are much too low grade to encourage development. Further, all the mineralization examined by the writer within this 20-mile stretch is remarkably uniform in grade, appearance, and occurrence. We have to do, therefore, not with a series of deposits that are, *on the average,* very low grade, with some minor encouraging enrichments, but that are *all* uniformly poor with no known enrichments of any importance whatever. Possibly these deposits are products of a magma that contained only very minute amounts of copper and nickel and was incapable of producing deposits that contained commercial quantities of these metals. At least such a possibility should be borne in mind in considering the likelihood of finding commercially valuable deposits elsewhere in the lengthy zone in which similar mineralization is known to occur.

The preceding statement applies only to sulphide deposits that occur within a relatively narrow zone trending about north 60 degrees east from the south side of Smith Island and should not be taken as constituting a condemnation of the mineral possibilities of the whole greenstone belt running east from Hudson Bay. The belt has been barely explored, not to say prospected, and it compares favourably in size with any of the larger areas of similar rocks that, throughout the Canadian Shield, are generally conceded to constitute favourable ground for prospecting.

BORINGS IN EASTERN CANADA

By W. A. Johnston

(Geologist-in-Charge, Division of Pleistocene Geology, Water Supply, and Borings)

Logs of wells drilled in Ontario in 1932 for oil and gas were received through the courtesy of Colonel R. B. Harkness, Gas Commissioner of Ontario. Mr. C. S. Evans of the Geological Survey has continued a study of these logs, and of the samples from the wells drilled in former years, for the purpose of aiding companies in the search for new oil and gas fields.

In the province of Quebec, drilling for natural gas was continued in 1933, but only two wells were completed. Well samples were received from the companies engaged in drilling, and reports on the samples were sent to the companies and to the Quebec Bureau of Mines.

The Canadian Seaboard Oil and Gas Company, Limited, which had put down the St. Gerard well in Yamaska County in 1932 to a depth of 6,160 feet, drilled the Ste. Angele No. 1 well in Nicolet County in 1933. The well is located on the south side of the St. Lawrence River a few miles southeast of Three Rivers.

Log of the Ste. Angele No. 1 Well

Name: Canadian Seaboard Oil and Gas Company, Limited, Ste. Angele No. 1.

Location: Lot 160, Petite Bois Range, Parish of Ste. Angele de Laval, Nicolet County, Que.

Drilling method: Standard.

Depth in feet	Lithology and stratigraphical interpretation
0–20	Surface deposits
20–210	Lower Richmond, greenish grey shale with limestone bands
210–1,250?	Lorraine, medium grey shale with thin limestone bands
1,250?–2,260	Lorraine, medium grey, sandy shale
2,260–3,400?	Lorraine, dark grey shale
3,400?–3,900	Utica, dark grey shale with brown limestone (Fossils determined by Miss A. E. Wilson suggest that the samples from 3,400 feet may be Utica rather than Lorraine)
3,900–4,290	Lower Utica, dark grey shale with limestone bands
4,290–4,930	Lower Utica or Upper Trenton, dark grey shale and limestone
4,930–5,100	Trenton limestone
5,100–5,120	Basal arkose?
5,120–5,200	Precambrian

In this well the shale between the base of the Lower Richmond beds and the top of the Trenton limestone is about 700 feet thicker than in the St. Gerard well. In some of the samples there is much slickensided material. Apparently there is duplication of some of the beds by faulting.

In the St. Gerard well the Trenton and Black River limestones were 440 feet thick, and the well showed that there is at least 180 feet of Palæozoic sandstone, limestone, and shale below the beds. In the Ste. Angele well the Trenton limestone is only 170 feet thick and rests almost directly on the Precambrian. Probably at this locality the Palæozoic sediments were deposited on a very uneven surface of the Precambrian, so that only a part of the Trenton limestone was laid down. A strong flow of gas was struck in the lower part of the well but did not prove to be of commercial importance. The company proposes to drill another well in this area at a locality where the seismograph tests have indicated more favourable structural conditions to exist.

On the north side of the St. Lawrence River, a well was drilled on lot 531, St. Philippe Range, L'Assomption County, to a depth of 322 feet. The well passed through a dark shale and limestone of the lower part of the Utica or upper part of the Trenton, and this indicates the occurrence of a considerable thickness of source rock for the " surface " gas in this area.

OTHER FIELD WORK

M. E. Wilson. Mr. Wilson continued the detailed investigation of a limited area that includes the Noranda, Amulet, and Waite-Ackerman-Montgomery mines in the vicinity of Noranda, Quebec.

A. H. Lang. Mr. Lang revised the geology of the Kinojevis map-area, northwestern Quebec.

L. J. Weeks. Mr. Weeks commenced the geological mapping and study of the Amos 1-mile quadrangle, northwestern Quebec (latitudes 48° 30′ to 48° 45′, longitudes 78° to 78° 30′).

Alice E. Wilson. Miss Wilson continued geological mapping of the Palæozoic strata of the Ottawa 1-mile map-area (latitudes 45° 15′ to 45° 30′, longitudes 75° 30′ to 76°).

D. C. Maddox. Mr. Maddox began a systematic survey of the underground water supply in and near Ottawa.

F. J. Alcock. Mr. Alcock commenced geological mapping of a 1-mile quadrangle including part of the basin of Serpentine River in northwestern New Brunswick (latitudes 47° to 47° 15′, longitudes 66° 30′ to 67°).

INDEX

The annual Summary Report of the Geological Survey is issued in parts, referring to particular subjects or districts. This year there are four parts, A, B, C, and D. A review of the work of the Geological Survey for the year forms part of the Annual Report of the Department of Mines.